West Yorkshire Combined Authority

Working in partnership with the

Leeds City Region Enterprise Partnership

Advanced Urban Transit Technologies – Worldwide Market Testing

Report summarising the feedback received through the Market Testing

March 2020

£69.6 Billion GVA

A region packed with ambition and untapped potential

In partnership with:

University of HUDDERSFIELD
Institute of Railway Research

UNIVERSITY OF LEEDS
Institute for Transport Studies

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- Appendix 1: Market Testing Prospectus issued in August 2019
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1. Purpose of this report

1.1. This report summarises the messages and opinions which the West Yorkshire Combined Authority has heard from Industry regarding the "*Advanced Urban Transit Technologies: Market Testing*".

1.2. The market testing has been targeted towards all promoters, manufacturers, suppliers, constructors, engineers, system developers and operators of urban transit systems from across the world. There was strong industry interest with around 120 organisations taking part in the market testing. Organisations from sectors including monorail, pod, bus, tram, train, metro manufacturers and operators and consultancies as well as interested stakeholder groups took part, with bases from across the UK, Europe, North America, Asia and Japan.

1.3. Based on the feedback received, this report highlights the areas where the mass transit sector is undertaking research and development to enable cities to come forward with innovative and advanced mass transit systems. It highlights the views from industry around how mass transit can contribute to addressing the climate emergency and how mass transit can help to stimulate inward investment.

1.4. The feedback received through this market testing will form an important part of the evidence base for the development of the business case for mass transit in West Yorkshire. It should be noted that:

1.4.1. As the report focuses on the key messages received, it does not specifically identify which organisations provided which feedback, or reflect all feedback provided. All the organisations which have participated in the market testing are listed in Appendix 3.

1.4.2. Whilst the report reflects the common messages, opinions and views of industry, it should not be taken as a West Yorkshire Combined Authority policy position.

1.4.3. The report solely focuses on the evidence submitted from respondents and whilst the market testing received a strong level of response from industry, it is not an exhaustive review of all mass transit technologies which could exist.

1.4.4. As can be expected with any engagement, there have been a wide range of views received with several conflicting opinions expressed for certain questions.

1.4.5. Finally, choices on future mass transit technologies for West Yorkshire will be informed by the conclusions of this report but will not be constrained by it.

1.5. The West Yorkshire Combined Authority project team are grateful to the time, effort and resource provided by all the respondents to this important market testing.

Who is undertaking the Market Testing?

1.6. This market testing was undertaken in partnership between the following organisations:

1.6.1. The **West Yorkshire Combined Authority**
1.6.2. The **University of Leeds**, Institute for Transport Studies
1.6.3. The **University of Huddersfield**, Institute for Railway Research

What Happens Next?

1.7. The Combined Authority are keen to continue to develop the conversations with respondents, as the work continues around mass transit.

1.8. The Combined Authority, in partnership with partner councils are currently progressing development of a Transit Strategic Outline Business Case (SOBC) which is expected to report during 2020. This business case will be informed by a range of sources including the evidence provided in this report.

1.9. Engagement would be anticipated to take place on the conclusions of the SOBC. Subject to funding from central government, the intention would be that a mass transit scheme could be delivered during the mid-2020s.

2. Background and Context

2.1. The West Yorkshire Combined Authority is at the early stages of developing new proposals for an Advanced Urban Transit System, which supports the Leeds City Region priorities of raising productivity, delivering inclusive growth and addressing the climate emergency through clean growth, all of which must be underpinned by a 21st Century Transport system.

2.2. It is the aspiration of the Leaders of the West Yorkshire Local Authorities that any new Urban Transit System for our region should be at the forefront of innovative 21st Century mass transit technologies. The market testing has been a key tool to establish the views of industry about how mass transit technologies are anticipated to change by the late 2020s/early 2030s.

2.3. Following consideration by West Yorkshire Transport Committee and the LEP Board, the 'Advanced Urban Transit Technologies Market Testing Prospectus ('The Prospectus') was published on 23 August 2019 on the Combined Authority website[1].

2.4. The Prospectus was targeted towards all promoters, manufacturers, suppliers, constructors, engineers, system developers and operators of urban transit systems from across the world.

2.5. The Prospectus is included in Appendix 1 to this report and it:

- Gave an overview of the market testing, including formation around the Leeds City Region
- Set out the ambition for the region
- Summarised the scope of the market testing
- Outlined the eight 'Discussion Questions', which respondents were asked to respond to
- Identified the types of organisations which the market testing was aimed towards
- Set out the timescales for responding and how to respond
- Provided context around the three organisations which were undertaking the market testing
- Set out the terms and conditions of the market testing.

2.6. To ensure a level playing field for all industry suppliers, this market testing assessment is being carried out in accordance with the fundamental EU principles of equal treatment, transparency and non-discrimination and in line with EU interpretative communication on public procurement (2006/C 179/02). The Market Testing was also published of the Office of European Journal (OJEU) formal procurement process called a 'Prior Information Notice' ('PIN'). The PIN was also published on 23 August 2019 and is included in Appendix 2.

2.7. The market testing should not be viewed as a procurement; it is an opportunity for the Combined Authority and its partners to develop a dialogue with industry to

[1] https://www.westyorks-ca.gov.uk/urban-transit/

develop and design an advanced urban transit system in an open, fair and transparent process.

2.8. Following publication of the prospectus on the website and the PIN, the market testing was raised in the local, national and international press. Through contacts held by the organisations leading the market testing, coupled with contacts at the Department for International Trade, key stakeholders were encouraged to take part.

This report

2.9. Chapter 3 provides a summary of the key messages received through the market testing.

2.10. Chapter 4 onwards provides further in-depth analysis of the feedback received through the market testing. Each discussion question chapter has been structured consistently with sections on:

- Illustrative quotes from respondents, and
- Detailed feedback, which expands on the key points Responses to 'Discussion Question 1' have been split into three separate chapters below (1a, 1b, 1c).

2.11. The terms 'respondents' and 'contributors' are used interchangeably throughout this report.

3. Summary of Key Messages

This report solely focuses on the evidence submitted from respondents. This report focuses on the key messages received, it does not specifically identify which organisations provided which feedback, or reflect all feedback provided. The key messages are set out here with further detail in the following chapters.

3.1 Propulsion Technologies

- In the short to medium term, respondents suggest battery technologies are likely to be the most viable option, and it is increasingly realistic to plan for end-to-end systems which do not require overhead wires for many routes. However, care needs to be taken in the planning stages to ensure detailed consideration is given regarding provision of overhead wires as they still provide an effective, proven technology and contributors suggest that they may have other advantages such as reducing carbon and reducing cost.
- Respondents suggested that Hydrogen is at the early stages of being utilised in mass transit systems and it is a possible solution, if (a) it is readily available as a by-product of industry; (b) Hydrogen does not need transporting to the mass transit vehicle depot; (c) if costs of producing/using Hydrogen can be addressed. Unless there is a significant change in Central Government policy, the challenges associated with hydrogen will continue to present a significant barrier to it becoming a realistic solution over the next decade.

3.2 Autonomously Operated Mass Transit Systems

- Transit technologies already exist for autonomous operations, but only in a fully segregated environment (for example, Docklands Light Railway)
- 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.
- It was also suggested that autonomous cars are not a solution to relieving congestion – indeed, they are likely to make congestion worse. It is important to plan for these possible eventualities and put in place management systems which address any possible negative impacts on mass transit's ability to alleviate congestion.
- 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.

3.3 Mass Transit and addressing the Climate Emergency

- Almost all respondents highlighted that Mass Transit is a small part of the overall solution to addressing the climate emergency. Regardless of the scale of mass transit provision, respondents strongly suggested that meaningfully managing down car demand is essential to achieving a meaningful impact on reducing congestion, cutting carbon and improving air quality.

- Industry was keen to highlight that regardless of whether a tram, bus or other type of vehicle solution is provided, many responses said it is essential that the transit solution is separated (or 'segregated') from general car traffic. It is separation from general car traffic which will deliver the journey reliability and faster journey times which is required for the system to provide a realistic alternative to the car.
- As part of an integrated transport strategy, respondents suggested that bus, light rail and heavy rail all have an important role. The choice between modes is dependent on the level of capacity required and the ambitions of the region. Many of the respondents highlighted that almost all major cities with comparable populations are said to be investing in a combination of bus, bus rapid transit and light rail to help address climate change.

3.4 Research and Development Technologies

- Passenger tastes and demand will continue to change faster than assets are renewed, so respondents suggest it is essential to build in flexibility and redundancy (e.g. to extreme weather, which in future may be normal).
- Technology will most likely have an impact on the way asset maintenance is carried out (i.e. smarter and data driven). Contributors identify asset monitoring and management solutions as key areas for innovation and delivery of 21st Century mass transit technologies. For example, moving from a cyclical maintenance regime to an on-demand monitoring system to enable component replacement prior to it failing.
- Digital platforms are developing quickly, and any mass transit system should investigate the possibility to define and 'host' a single digital platform, with standardised application programming interface (APIs) to ensure open data and interoperability of data from all modes of transport across all technology platforms
- Responses suggested careful consideration should be given to dual mode systems such as tram train. There are advantages to creating a tram-train network that can partly utilise the existing heavy rail mainline infrastructure (potential capital cost savings), but careful consideration will need to be given to avoiding existing bottle necks on the heavy rail infrastructure such as around Leeds station. Mixed systems can also import the minimum requirements of both systems, reducing flexibility and potentially increased costs of new lines and vehicles.

3.5 Inward Investment

- Whilst a number of new manufacturing bases have been set up in recent years respondents suggested that due to the small scale nature of the mass transit industry in the UK, it is unlikely that a new manufacturing base would be set up in the UK as a result of orders placed from a West Yorkshire mass transit system. It was highlighted that several new manufacturing bases have already been set up in recent years in the UK. However, respondents did suggest that they would focus on using local supply chains and social value commitments through an existing manufacturing base, with assembly possibly taking place locally at the proposed depot location.
- Bearing in mind the previous history around mass transit in West Yorkshire, respondents highlighted the need to make contracts attractive to both the

public and private sectors, as all mass transit projects are complex and have a reputation for being high risk to all parties.

- Contributors suggested mass transit business case development should carefully consider how the routing of the system could unlock potential sites identified in Local Plans and contribute to the City Region's Inclusive Growth ambitions.

3.6 Balancing new technologies verse proven technologies

- Respondents advised that it is possible to deliver a state-of-the-art mass transit system without taking unnecessary risks on unproven technology. However, it is essential that the promoter properly understands and balances where risks should best sit to determine those which the Authority is willing to take to deliver innovation.
- Contributors suggested that incorporating unproven technology can have significant impacts on the project in terms of cost and delay. Due to the 'systems' approach which Mass Transit requires promoters to take, there is considerable benefit to keeping the core system technology as simple as possible
- Respondents advised to avoid the temptation to innovate for innovations sake – don't reinvent the wheel. It was suggested to look to purchase an existing chassis which can be 'customised' to meet local needs (for example the design of the front end, colours, seat layout).
- Respondents highlighted that not all passengers will be connected (e.g. access to a smartphone) and that they may continue to be reliant on cash. The share will continue to decline, but contributors advised that to deliver social inclusivity, accommodating these requirements and considerations (while not limiting technical ambition) will be essential.
- Contributors advised to ensure interoperability, and not to constrain the system to a single specific supplier's technology for the totality of the system, or it will become very expensive in the future.

3.7 Mass Transit Vehicle Types

- Many respondents provided feedback regarding technology solutions. With many providing setting out the pros and cons of the various types of mass transit vehicles or modes which were identified as having potential for use in West Yorkshire. It is important to emphasise that responses relating to wheel type attracted several diverging views. This was largely dependent on the sector the respondent represents and was useful to gain insight into the full spectrum of industry opinion relating to wheel choice.
- A selection of the images provided by respondents of various mass transit technologies is provided in Appendix 4. This is not an exhaustive list of all mass transit technologies available. It is also important to emphasise that a blend of transit vehicle types may be considered for West Yorkshire and therefore it has been helpful to understand different perspectives from industry. This will be dependent on a number of suitability factors and dictated by further business case work. A brief summary of the highlights of the various points raised by respondents on modes included:

- Some respondents suggested buses and rubber wheeled systems offered lower costs than steel wheel / tracked systems in terms of up-front capital expenditure and provide more flexibility in terms of service operation.
- Some respondents suggested that steel wheel / tracked systems offered advantages in terms of energy consumption due to low rolling resistance, are less polluting in terms of particulate matter emissions and avoid many of the non-tailpipe emissions seen with rubber wheel based vehicles.
- Some respondents suggested that steel wheel / tracked systems attract inward investment by appearing more permanent to developers than rubber wheel-based systems which are temporary and prone to change.
- Some respondents suggested that steel wheel / tracked systems are said to be proven attractors of mode shift from car drivers where rubber wheeled systems do not have the same effect.
- Some respondents highlighted the benefits of elevated autonomous pod-based (personal rapid transit 'PRT') systems and set out that a lot of research has gone into PRT and these offered the best potential for a whole system approach due to their relatively low costs and rapid construction potential and their ability to avoid traffic congestion by operating above roads. Other respondents suggested that pod/PRT based systems are more akin to car/taxi services and as such are not mass transit, but that they are an interesting prospect to complement mass transit as feeder services or for inner city logistics.

4. Feedback on Discussion Area 1a

What are the significant innovations and research & development in the industry, which we should be considering when planning an advanced Urban Transit system?

4.1. Responses to this question focused around the research and development of fuel propulsion systems. Chapters 5 & 6 cover other aspects of research and development.

Illustrative Quotes from Respondents

"Work already underway is expected to come to fruition in future years which should drastically lower the costs of operating hydrogen fuelled vehicles."

"Hydrogen Fuel Cell (HFC) has some inherent disadvantages in that the required equipment occupies a lot of space on a vehicle (requires fuel cell, gas storage tanks, batteries, and a cooling system) and space is at a premium on vehicles for Urban Transit. For a given amount of output power, an HFC vehicle requires significantly more space than a diesel or battery solution Accordingly, we do not expect HFC to see widespread application for urban transit vehicles."

"Battery technology is constantly evolving, and recent developments have meant that battery capacity has grown 10% every 2 years for a given size of battery. Supercapacitors (rapid charging but low capacity storage) also continue to be similarly developed to improve their capacity."

"Existing technology (e.g. battery life) is developing so quickly, radical options may not be needed".

"Overhead wired system is seen as the proven, efficient and lowest cost technology, as it is so well known in cities across the world"

"Technology within Urban transit over the next decade needs to transform alongside the needs of the customer. The technology will need to ensure that the journey can be planned and executed at the touch of a button with minimal friction."

"Ultimately, propulsion and energy storage mix should be decided once capacity and duty cycle characteristics are modelled and defined."

Points raised by respondents

Hydrogen

4.2. Hydrogen fuel cells are not yet a proven technology in mass transit vehicles in Europe, but respondents outlined that several cities in China are using hydrogen to power mass transit vehicles. Most of the research and development in hydrogen mass transit vehicles is being led by Chinese manufacturers, with some European manufacturers highlighting that very little research and development is taking place.

4.3. Several respondents outlined that it would be possible for hydrogen to be used in the UK for a mass transit system, if there is a readily available source of Hydrogen at the mass transit depot. However, they noted that:

4.3.1. Significant energy is typically required to produce hydrogen, which can mean it is not an efficient or a carbon neutral fuel to produce. Hydrogen is in some industries produced as a by-product, as seen in Teesside for example.

4.3.2. It is difficult to transfer/move the levels of hydrogen required for mass transit without installation of a major pipework network infrastructure to the depot.

4.4. Hydrogen is therefore a possible solution, if (a) it is readily available as a by-product (b) It doesn't need transporting (c) if costs of using it can be addressed. It was suggested that the opportunity be taken to future proof any mass transit system and make passive provision for use of hydrogen technology in any future upgrade.

4.5. The long-term reliability and lifecycle costs of hydrogen fuel-cells in a public service vehicle has yet to be proven. There are significant risks associated with: vehicle space, additional expense, range and reliability. The vehicle must accommodate bulky items of expensive equipment (fuel cell, battery, hydrogen storage tanks, cooling system) and this poses a significant problem in terms of the space available, which currently may result in reduced passenger space in comparison with either a battery, or a non-self-powered vehicle.

Battery

4.6. Contributors said that the pace of technology development both for batteries and fuel cells is very much driven by road vehicle market, rather than the mass transit industry.

4.7. Almost all respondents outlined the advantages of electrically powered mass transit vehicles over the next decade. Some manufacturers outlined the benefits of the proven catenary (Overhead Line Equipment) systems used across much of Europe and in Manchester Metrolink, for example.

4.8. Almost all respondents highlighted the scale of research and development taking place with battery technologies and that battery-based energy storage solutions are the most realistic future propulsion technology. For example:

4.8.1. Battery technology is constantly evolving, and recent developments have meant that battery capacity has grown 10% every 2 years for a given size of battery.

4.8.2. It is anticipated that solid state batteries, which are currently in the lab development stage, will be available in the UK / Europe by 2025 after trials in China. Current water-cooled batteries are expected to remain unchanged for at least next 2-3 years.

4.9. A number of respondents highlighted the future innovations in battery technologies, which would allow mass transit vehicles to operate 'without wires' by the 2020s. This would have wider benefits, particularly around the townscape/visual amenities as well as reduced operating/maintenance cost of not having to maintain the overhead wire catenary.

4.10. Respondents highlighted that over the next five years it should be possible to operate a mass transit system, entirely powered by batteries and charged only at key termini / stop locations.

4.11. Some respondents highlighted that there were risks with moving to a fully battery-based system and instead suggested a mixed technology system where vehicles operated on batteries in urban areas, with the batteries charged either at terminating locations or small sections of the route. This approach could preserve visual amenity where this is an issue and avoid potentially costly catenary installation in difficult city centre areas.

4.12. The reductions in construction cost, land take and ongoing maintenance are significant once the overhead wires are removed from a city centre system. Outside the city centre, where there is more available land and potentially reserved space running, the cost benefit savings are not so significant.

4.13. Respondents pointed out that battery sets have a limited lifetime depending on their duty cycle. In a tram type vehicle, which may be in use for up to 30 years, the batteries may need to be changed several times (which was consistent with the life cycle refurbishment of a diesel engine vehicle). Batteries are heavy, which reduces the efficiency of the vehicle and adds to wear on trackways and roadways for vehicles with rubber tyres. The capacity of local electricity distribution networks is limited and could constrain battery charging unless a dedicated supply exists as part of an integrated infrastructure solution.

4.14. Concerns were raised regarding the environmental impact of batteries regarding the costly and wasteful production process and limited lifetime. Several respondents suggested that there would still be significant life within the batteries after they had reached the end of their ‘in-vehicle life’. This could enable these batteries to be repurposed as static ‘battery farms’, which, used in partnership with solar power or wind energy could create a fully green powered transit system.

4.15. Electrically powered transit systems around the world are already looking to reduce their carbon footprint even further by adopting renewable sources for their electricity. Respondents highlighted that it is possible to procure electricity supplies from 100% renewable sources.

Electrically wired systems

4.16. Some respondents said that the traditional light rail overhead wired systems are the proven, efficient and lowest cost technology, as it is so well known in cities across the world. However, others argued that this was no longer the case. Respondents also mentioned that no further research and development with overhead wired systems is being undertaken.

4.17. Overhead wire catenary free mass transit systems exist in several French cities, but most use an ‘in-road conductor system’ that which operate like induction power in that the electricity is switched on only as the tram passes over it. Some respondents highlighted reliability issues with these systems, inherent in the designs and that due to the bespoke/unique nature of the infrastructure required, the promoter would always be constrained to a single manufacturer.

4.18. A number of respondents highlighted the opportunities around induction powered systems, however, many others highlighted the disbenefits which these types of propulsion systems bring, for example the system being constrained to a particular supplier and the additional maintenance costs of additional infrastructure in the

highway, especially when battery technologies have moved forwards so rapidly in recent years.

4.19. The general message was that on-board energy storage solution with batteries would be a more flexible system and offer greater market interest than an 'in-road conductor system'.

Other Power Storage Technology

4.20. A small number of respondents highlighted flywheel technology as still being developed despite its basic mechanical principals being explored decades ago. Work is focused on combining a motor generator with the flywheel to allow electrical energy to be stored and recovered without short, or long-term loss. Whilst it is unlikely that this technology will be the prime mover, it could potentially be combined with batteries and fuel-cells to improve the efficiency of these systems in the future.

4.21. Some respondents mentioned that supercapacitors are being further developed, which might offer potential, particularly when used in tandem with batteries.

Modularity and Flexibility

4.22. There are growing levels of modularity between propulsion systems and energy storage, and hybrid combinations of both. This reflects the difference in the length and 'shape' of 'duty cycles' associated with urban mass transit, which often demand high acceleration and deceleration to meet capacity and efficiency targets. Ultimately, propulsion and energy storage mix should be decided once capacity and duty cycle characteristics are modelled and defined.

5. Feedback on Discussion Area 1b

Do you think new Urban Transit systems should be designed for autonomous vehicle operation?

Illustrative Quotes from respondents

"Technology to enable Autonomous/self-driving trams is a reality, but the current systems struggle to cope safely with a mixed city traffic environment"

"A wider roll out of autonomous vehicles would mean significant safety and certification challenges would have to be overcome. There is no precedent for this, so the timescale for achieving it cannot be accurately forecast, therefore the issue might take decades to resolve."

"A particularly impressive development is the automation of track inspection by plain line pattern recognition which can replace or reduce manual inspection of track components by utilising high resolution images to identify defects and missing or displaced components"

"…….there is the opportunity for greater use of 'driver aids' to improve safety, increase reliability and, but not remove the need for a driver. Therefore, the introduction of autonomous vehicles may turn out to be a process of incremental change rather than a revolution"

"There will be more automation. But automation is a continuum, so the real question won't be whether to automate, but how much will be automated when. Automation will probably come whether it is planned for long in advance. However, planning for automation will increase the advantages it brings, as well as hastening it."

"All new & segregated systems will be autonomous. However, passengers' value human interaction, so consider retaining on-board staff to some extent (in a customer-facing / non-safety critical role)".

"…we believe that it is vital that an Urban Transit scheme is planned for autonomous operation and importantly a wider connected transport network"

"Autonomous vehicle operation is unlikely to have any major impact on tramway systems, except possibly for depot movements"

Points raised by respondents

Feasibility of Autonomous Operation

5.1. Although automation on segregated systems is already present in systems like the Docklands Light Rail (DLR), contributors said that full automation of on-road systems where urban transit is mixed with general traffic is unlikely in the next decade.

5.2. Significant numbers of autonomous metro systems already operate around the world. The technology is well proven, but currently used in a segregated environment (for example, at airports).

5.3. A wider roll out of autonomous vehicles would mean significant safety and certification challenges would have to be overcome. Contributors highlighted that there is no precedent for this, so the timescale for achieving it cannot be accurately forecast, therefore the issue might take decades to resolve.

5.4. Current segregated autonomous system technology struggles to operate safely in a mixed traffic environment and contributors pointed out that the timescale required to develop systems and technology to overcome this issue is currently unclear.

5.5. There is potential for greater use of 'driver aids' to improve safety, increase reliability, but not to remove the need for a driver. Respondents said that the introduction of autonomous vehicles may turn out to be a process of incremental change rather than a revolution.

5.6. Autonomous Depot Operation – self-driving trams or tram-trains can be configured to assist with maintenance such as automatic running through the wash plant and then berthing in the stabling yard or depot shed ready for planned maintenance.

5.7. Contributors say that maintenance processes are an area of mass transit operation which may have good potential for automation. This would involve components or infrastructure being replaced on a predictive basis utilising sensors and data capture and analysis rather than on a cyclic basis.

5.8. With 5G technology there is the opportunity for the vehicle to be driven or controlled by a driver located in a control centre, rather than in the vehicle cab, but again the safety sign off route for this type of solution is unknown and the commercial benefits of implementing such as system have not been justified. This might be an area which the market could deliver innovation during the procurement process.

5.9. Promoters of elevated pod-based systems argue that these offer an ideal mass transit solution as they are autonomously operated and completely segregated and there has been significant research and development around personal rapid transit (PRT) pods since the 1950s.

Desirability of Autonomous Operation

5.10. Using autonomous vehicles avoids the significant cost of drivers, which, contributors said, is usually the largest operational cost. Mass transit system operators said that passenger's value human interaction, so retaining on-board staff to some extent (in a customer-facing / non-safety critical role) in any autonomous system would be advisable.

5.11. While there are experiments to test autonomous vehicles in public areas, their lack of a driver can be a hindrance rather than a benefit. As they operate on a fixed track, they are unable to move around an obstacle in their path and either must move forward slowly to try and dislodge the object or will wait until a third party removes the obstacle. This may cause unacceptable delay. A driving assistant may be required to override the system when safe to do so.

5.12. Contributors highlighted that there are several currently unresolved issues which would need to be addressed in an autonomous system such as: how could emergency situations be managed? Would there be a requirement to have a

guard? Could passenger safety and vandalism be managed remotely? Who is responsible in the event of a collision?

Digital and Cyber Security Issues

5.13. 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.

5.14. 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

5.15. The potential for connecting vehicles is progressing at a pace and importantly the need to implement a uniform approach that will include all vehicles (not just urban transit) and deliver seamless travel across geographic boundaries.

6. Feedback on Discussion Area 1c

6.1. This chapter provides a summary of any other points raised regarding future technologies as part of responses to Discussion Question 1. This included topics such as:

- What types of system technology and infrastructure we should consider?
- How could we best incorporate digital innovation in a new urban transit system?

Illustrative Quotes from respondents

"Even the highest quality bus-based solution will not lead to a substantial change in mode share"

"Steel rail/wheels sends a strong message being a very permanent infrastructure to support growth and development. Rubber tyre presents itself to businesses and the public as a less permanent solution and may not attract the same levels of investments and growth".

"Rubber tyred systems should not be considered because of the growing importance of non-tailpipe emissions (tyres, brakes and road dust). These pollutants are very low or zero for steel rail-based systems. It should be noted that some cities which chose rubber tyred systems have subsequently had to replace them with steel wheeled systems e.g. Caen and Nancy"

"Control systems are changing and integrating to deliver end to end travel systems – MaaS linking with operational and logistics management systems."

"Infrastructure investment is vitally important but works best when accompanied with educational and communication programmes to help people make more sustainable choices"

"… track forms are generally designed with the cost and ease/speed of construction in mind. Little thought is generally given to maintenance…"

"Digital Innovation will be applicable across many elements of an urban transit system such as:– Design: use of BIM, Digital Twins; Design Anomaly Detector, Construction Optimisation Tool – Construction: Digital Surveying, 3D Printing of transit infrastructure, Modular Construction – Operation: Asset Management Predictive Failure, Digital Connectivity, AI and machine learning asset monitoring".

"High quality BRT can compete directly with LRT in terms of capacity and frequency, but at lower cost per km and with greater flexibility, integration opportunities, quicker development time and less construction disturbance. In Nantes, France, both BRT and LRT sit together as part of an integrated public transport system. User perception surveys show that for both LRT and BRT users there is very little difference in mode preference. Existing and traditional solutions, including bus-based solutions, should not be dismissed if they are the most appropriate,

affordable and deliverable option for the Leeds City Region. Example – Belfast Glider".

Points raised by respondents

Vehicle Types and Efficiency

6.2. Use of lighter weight materials and design – the desire to make trains lighter in order to reduce their energy consumption and impact upon the track is leading to the use of lighter weight materials such as: super strength steel, carbon fibre and Kevlar. Respondents expect that these developments will flow down into tram or tram-train design.

6.3. More efficient traction systems are now available, which are also smaller than the equivalent standard type.

6.4. Smaller tram style units each with a capacity of 50-70 people but with the potential for combining two to three units into a single vehicle. Respondents highlighted that this technology is the subject of major investment in Coventry and there is a plan for development of a Very Light Rail (VLR) Innovation Centre in Dudley – test track planned for 2020 construction.

6.5. Very/Ultra-Light Rail is an evolving technology that contributors feel will reduce delivery & maintenance costs.

6.6. Advanced Very Rapid Transit (AVRT) offers the advantages of a conventional metro, tailored for demand levels below 1500 passengers per hour per direction (pphpd). Sometimes known as Micro-Metro, this system involves compact (40-50 passengers) battery powered rubber tyred vehicles on 100% segregated trackway at a frequency of every 2/3 minutes at peaks. The promoter felt that costs could be around half those of conventional LRT (£10-15m per two-way km).

6.7. Some respondents of elevated autonomous pod-based systems felt that this offered many advantages. They believe it to be a more sustainable solution, as it could be implemented rapidly over a wide area utilising existing mass-produced components and utilises comparatively small amounts of concrete. They also believe the system would have relatively low power requirements. However, such systems are currently under development, and may not offer a viable option for short to medium term implementation.

6.8. High-speed rail and maglev systems that are being used in Japan were felt by respondents to be worth of further investigation regarding how they can be used in an urban transit setting, although it is was pointed out that this technology might not be appropriate for urban transit systems and is better suited to long distance implementation.

6.9. Contributors speculated that all new segregated transit systems will be autonomous.

6.10. A contributor envisioned that urban air mobility will be available as a on demand mode of transport in many cities around the world.

Customer Experience / Interface

6.11. Contributors feel that passenger taste and demand will continue to change faster than assets are renewed, so it is essential to build in flexibility and redundancy (e.g. to extreme weather, which in future may be normal). The technology will

change both in time prior to construction, but also over the coming 30-40 years of operation.

6.12. The use of technology to improve the customer experience was felt by contributors to be a key factor in influencing passenger choices. These need to provide the customer with the right information to plan frictionless end to end journeys and pay for them in a safe and easy way.

6.13. Respondents say it will be vital to incorporate improved ticketing solutions including virtual ticketing, smartcards and customer response management (CRM) systems. This includes the ability to process "big data" within reasonably cost-effective systems.

6.14. Respondents speculated that with widespread access to smart devices and app-based mobility, customer expectations of transit will continue to change. They felt we are likely to see urban transit behaving more like Uber/Lyft or incorporating on demand/app-based access that combines multiple modes/service providers

6.15. Ticketing and fares collection have also seen major changes with the adoption of new personalised technology the biggest influencer. Respondents feel we can expect to see more personalisation of travel planning and payment, and better information for when things go wrong or changes to journey planning are required. New ideas coming to the fore are now focussing on automation and ensuring that the journey can be planned from door to door.

6.16. Smart ticketing is integral to the future of urban and rail transit systems, with increasing passenger numbers, the solutions need to be flexible and efficient to cope with increasing demand. Contributors say it is essential when providing a sustainable transport network that smart ticketing is a consideration and that the system places a value on the ability to tailor smart ticket products to individual needs, with data management and safety always prioritised. Passengers are clear that the introduction of smart ticketing is a shift into a more technology focused way of ticketing and the systems introduced need to be leading edge and long-lasting.

6.17. Respondents say that in future this could include Bluetooth or 'virtual tap' capability (currently in test in Italy) removing the dependency on physical barriers and validators. This system has numerous benefits to the passenger and operator including: reduced queuing, improving safety, seamless intermodal changes without the need for additional purchasing (enabling Mobility as a Service (MaaS)), passenger self-managed account, plus it reveals useful information such as: time of travel, favoured routes, journey time that can be used by the operator to improve services.

6.18. Contributors advised that in recent times season ticket sales have reduced due to more people working from home; this will affect revenue streams from transit and thus investment profiling.

6.19. Within the next decade, respondents expect technologies used within the urban transit sector will change drastically, especially within the ticketing and payments sector. With the transit process becoming more and more customer centric we are seeing urban transit across the world adopting new and innovative technology.

6.20. Contributors say innovative technologies will start to replace older legacy systems to achieve several goals:

- Increase usage of public transport

- Improve the customer experience when using Urban Transit
- Reduce the environmental impact of transport within an Urban region

6.21. Respondents advise that unfortunately, a single decade is too short for a modification in the urban transit sector. It was felt that the most realistic change technology can bring about is the way information is provided to passengers, with greater detail and accuracy of information than currently available.

6.22. One contributor foresaw more data collection and artificial intelligence algorithms being used to optimize the various aspects of urban transit usage and operation.

6.23. Another contributor advised to design a system that acknowledges a single fixed link may not be enough. They questioned whether interchange is in fact such a penalty? If the service is good and frequent enough passengers may not be concerned (e.g. TransMilenio BRT in Colombia). This will allow greater flexibility to mix technologies and potentially incrementally expand and adapt.

Construction

6.24. Contributors highlighted modern methods of construction (MMC) and Platform for Design and Manufacture (PFDMA) - where infrastructure can flex, based on initial and forecast requirements; mass manufacturing of assets that is flexible enough to suit many environments and uses.

6.25. They also suggested application of whole-life cost modelling techniques and ISO 55000 (asset management standard). Achieving a 'line of sight' from policy to strategy to local plans and linking long term investment in technology to policy and strategic objectives.

6.26. Respondents say there could be opportunities to deliver other "connected infrastructure" along the route such as fibre, 5G or other network opportunities. This can help in overcoming digital exclusion.

Specific Areas of Innovation to Consider

6.27. Digital systems are an area where contributors contend that advanced technology is proving it's worth.

6.28. Potential areas where digital innovation was suggested to be employed include:

Design:

- Use of Business Information Modelling (BIM) -3D modelling to improve planning, design and construction,
- Digital Twins - creating a digital simulation model of physical infrastructure, people, systems and devices.
- Design Anomaly Detector
- Construction Optimisation Tool - aids decision making

Construction:

- Digital Surveying / mapping - locating buried utility plant
- 3D Printing of transit infrastructure

Operation:

- Digital connectivity (5G) - both to passengers and for the management of on-board and network systems.
- Full-service information to passengers – live information on systems status, travel times, advice on best modes, ticketing etc.
- Data collection, analysis and storage systems with the ability to accommodate exponential growth in data availability, AI and machine learning.
- Smart assets – assets that monitor and report their status to enable potential failures to be predicted and interventions planned e.g.: for catenary management; track monitoring; structures monitoring; traction and power systems.

Rubber tyre vs Steel Wheel

6.29. It is important to emphasise that responses relating to wheel type attracted several diverging views. This was largely dependent on the sector the respondent represents and was useful to gain insight into the full spectrum of industry opinion relating to wheel choice.

6.30. Contributors highlighted that segregation of the system from general traffic is the most important for journey reliability than choice around bus vs light rail, but both technologies have a role to play as part of an integrated transport strategy.

6.31. Many of the contributors set out in their responses to this question that steel wheel rail systems such as trams are the only mass transit mode proven to promote mode shift from car use. It was highlighted that the permanent tram infrastructure sends a strong message to businesses and developers who appear more inclined to invest in areas served by this type of mass transit system. Rubber wheels are more flexible but could be more damaging than steel environmentally once non-emissions pollution is considered as highlighted by the recent Defra report on non-exhaust emissions.

6.32. A smaller number of respondents highlighted that bus-based systems could deliver mode shift from car.

6.33. Some respondents highlighted the opportunity to create new monorail or pod autonomous systems which placed new infrastructure above roads to avoid car congestion.

6.34. Strong feedback that steel rail-based systems offer the best solution due to their ability to attract mode shift from car use, low or zero emissions and effects on business confidence and development patterns.

6.35. Respondents pointed out that the potential of conventional railways should not be ignored, particularly where the tracks already exist. Where there is steep terrain, or where there are many river crossings, monorail and seilbahn (cable car) systems should be considered and the overhead rail-based SkyWay system could be worth investigating further.

6.36. Several respondents highlighted that Very/Ultra-Light Rail is an evolving technology that has potential to reduce delivery and maintenance costs.

6.37. Some respondents highlighted that there are several new lighter tram type vehicles being developed in the UK, which have a capacity of 50-70 passengers. These might offer a potential alternative where there are lower levels of demand.

6.38. Respondents felt the costs of different modes varied dramatically, with heavy rail being largely unaffordable for new build as it requires complete grade separation from other modes in the modern environment. Contributors said that light rail has a cost per km typically ten times that of comprehensive bus based rapid transit, and conventional bus has very low implementation costs. Conversely the benefits are said to be largely the same for heavy rail, light rail and the highest quality bus rapid transit, and generally far greater than those for simple bus deployment.

6.39. Contributors advise that there is extensive evidence, both observed and academic, that the public perception of a bus is not the same as a tram regardless of the quality of the bus. People will make major investment and location decisions as a result of the availability of fixed-track systems, for example, moving to a new house to be close to a station or stop. This is partly due to the perceived permanence of such networks. However, people are reluctant to make such significant lifestyle choices when faced with a bus service, which are perceived as being far less permanent and liable to change.

6.40. A promoter of an autonomous pod-based system felt that this should be considered due to the potential offered by its simple low-cost construction and rapid, area wide deployment possibilities. However, these systems are currently at pre-prototype stage so cannot be considered a viable option in the short to medium term without accepting considerable risk.

6.41. Bus operators were keen to point out the potential of rubber tyred solutions to enable an incremental, developmental and upgradable approach. They were also keen to highlight negatives of light rail-based technologies, such as high cost of construction and inflexibility.

6.42. On some existing mass transit systems, several respondents highlighted that rubber tyred transit systems had been replaced with a steel wheel / rail solution as the technology market was limited and the technology had high levels of failure rates.

Systems & Technology

6.43. Respondents felt that technology will most likely have an impact on the way asset maintenance is carried out i.e. smarter and data driven. Asset monitoring and management solutions are key areas for innovation and delivery of 21st Century mass transit technologies. For example, by enabling a transition from traditional periodic maintenance cycles to allow predictive and AI (‘Artificial Intelligence’) sensor-based maintenance systems to reduce operating (OPEX) costs and improve reliability, as already been implemented in seen in the airline industry.

6.44. Improved ticketing solutions including virtual ticketing, smartcards and CRM systems should be utilised. This includes the ability to process "big data" within reasonably cost-effective systems.

6.45. With increasing use of digitisation and resultant creation of data, some respondents advised that there is likely to be a move towards the concept of knowledge management rather than simply information management. This implies both a learning process, and a process by which information which is relevant to improving knowledge is identified as having a “premium value”. Examples include the realisation of opportunities of more effective demand responsive management, asset management and maintenance and system integration.

6.46. New innovative track forms are being developed to reduce construction and maintenance costs. Track replacement can be frequent and is disruptive and expensive so must be considered in whole life costings. Contributors pointed out that diversion of utility plant in track construction is also a major capital cost in new systems, so this area of research should be closely monitored.

6.47. Train research to reduce their energy consumption and impact upon the track is leading to the use of lighter weight materials such as: super strength steel, carbon fibre and Kevlar. Contributors expected that these developments will flow down into tram or tram-train design but is an early stage and is unlikely to be commercially viable within the next decade. Contributors mentioned that lighter vehicles could impact on the infrastructure required, such as track beds and track forms.

6.48. Multiple respondents advised that there should be a strong focus on reducing the need to move buried utility plant during the track construction phase, which can result in considerable time and cost savings.

6.49. Modular, off site track fabrication can offer savings in cost and disruption.

6.50. Where repairs to track are taking place, contributors pointed out that tram systems in mainland Europe use temporary track to avoid the work sites. This is now being considered by the Light Rail Safety Standards Board (LRSSB) for use in the UK. The effect of this would be to make it less important to have moved all the utilities beforehand as trams could still run around the works.

6.51. Respondents highlighted that grass tracks (where grass is grown between and adjacent to rails in a tram system, see photographs in Appendix 4) have a dual benefit as they reduce carbon dioxide levels and can be used to delineate the edge of routes or show motorists where not to drive. However, their use in areas with high pedestrian flows should be avoided. It does come with an additional maintenance cost but can help with integrating the system within the urban environment. These systems are currently rare in the UK, but more common in other parts of Europe.

6.52. Contributors advise that understanding the interfaces with adjoining infrastructure (such as heavy rail systems) will be vital and can result in significant cost savings.

7. Feedback on Discussion Area 2

How will the Urban Transit industry innovate to help address climate change and support the Authority's ambitions to address air quality to become a zero-carbon region by 2038?

Illustrative Quotes from respondents

"The policy relationship between transport, planning and parking policy is key. For air quality issues and climate change to be addressed it is essential that the public transport network is effective enough to reduce people's dependency on the private car and ensure that sustainable transport choice becomes the best option for them, meaning that is it quicker, more reliable and affordable to bring the workforce to employment nodes in order to meet the transport requirements of inclusive growth in a sustainable way"

"Whatever form urban transit takes in the future it will need to be accorded considerable priority treatment to ensure that it is not disrupted by traffic".

"But, it is important to note that even with the highest quality transit system, such modal shift is unlikely at any meaningful scale without complementary measures to deter car use – whether by increasing parking charges, reducing parking capacity and duration of stay, introducing road pricing, congestion charging or workplace parking levies, or some combination of all of these. The improved rapid transit offer must be in place and working effectively at the time when any such punitive measures are introduced, in order to be effective."

"Unlike cars, Euro VI buses deliver ultra-low emissions on the road not just in the test lab."

"In the overall field of transport, trams are one of the greenest forms of transport on both carbon and other forms of emissions".

"It is not just the energy and transport sectors which are responsible for CO2 emissions. Cement manufacture is also a major emitter. Use of alternative materials, including more environmentally friendly kinds of cement, should be considered for all infrastructure projects."

"Alternative fuel sources such as battery or hydrogen will reduce the carbon footprint of buses. However, all rubber tyred vehicles will produce more environmentally damaging PM2.5 particles from brake and tyre wear than light rail vehicles".

"The low rolling resistance of steel wheel on steel rail is a great advantage for rail-based systems and electric transmission from efficient and sustainable generation is more efficient than small on-board generators used by hybrid buses such as the new 'Routemasters' in London. Electric trams also have the ability to recover the energy from regenerative braking to power other trams on the network".

"One constraint with batteries is that performance reduces at around 7 years requiring replacement at 11 years. Therefore, it may be necessary to change batteries three times in the 30-year life of a vehicle. Significant capital cost, but battery life will no doubt improve, and costs will reduce".

"Ideally build-in flexibility to change fuel source in 20 years ('plug & play'). Note also that unlike diesel/petrol there may not be a common standard for new power sources"

"Passengers will demand (are demanding) change, and this will accelerate as younger generations drive policy/politics. This will expand beyond emissions at point-of-use to entire life asset cycle (e.g. manufacture to decommission)"

"Systems should be scoped such that they are specified with sufficient resilience to recover quickly from current and anticipated future climate change related events"

"New or innovate technologies can be an excellent focal point to drive change and bring with them an opportunity for revolution of the transport network rather than a gradual evolution. However, it is more important to be outcome focused, rather than mode focused. No matter how innovative, or traditional a system, there will need to be a dramatic shift in how road space is allocated and prioritised"

"Road space is at a premium and there are bottle-necks, and so to achieve success in the Leeds City Region, there will have to be a significant change in how and for whom road space is prioritised. Coupled with this will be additional measures to suppress the demand and need for private car journeys"

"This process must start now – there are quick wins to be had and the considerable success of the initial tranche of bus-based Park & Ride services in Leeds illustrates that public negative attitudes are not as intractable as had been feared".

Points raised by respondents

Carbon Reduction, Air Quality, Mode Shift from Car and Demand Management

7.1. Public transport, in whatever form, will not be attractive if it sits in congestion along with the private car. Successful networks in the UK and internationally not only seek to offer a high degree of priority along links, but they actively seek segregation and have infrastructure that prioritises public transport as a key principle of the network in order to maintain journey times and reliability on a congested network.

7.2. There is recognition from contributors that the full carbon impact of any system should be considered in decisions on the system type to be utilised. This would include the carbon impacts of construction, with the use of lower carbon and recycled materials being mentioned as being highly desirable. The carbon impacts of the selected fuel source should also be considered.

7.3. In terms of air quality impacts, steel rail-based systems were highlighted by many as having a significant advantage in terms of non-tailpipe emissions, i.e. they do

not produce particulates, (which arise from vehicle clutches, brakes, tyres and tailpipe emissions). Rail based systems were also felt to offer advantages in terms of energy consumption and lower noise emissions

7.4. The latest diesel bus designs were said to offer excellent air quality performance - Euro VI buses emit up to 99.5% less NOx emissions and 98% less PM emissions compared to buses purchased 10 years ago. Unlike cars, Euro VI buses were said to deliver ultra-low emissions on the road not just in the test lab.

7.5. Road space is at a premium and there are bottlenecks, and so to achieve success in the Leeds City Region, contributors felt there will have to be a significant change in how and for whom road space is prioritised. Coupled with this will be additional measures to suppress the demand and need for private car journeys.

7.6. Contributors mentioned that for those that have access to a car, public transport is seen as being 'more expensive than the car'. Paying a bus or rail fare brings with it an immediate and noticeable cost to using public transport; something that is often unthought-of when travelling by car, leading to the perception that public transport is more expensive. This is exacerbated when parking charges (where there is an immediate cost) are relatively low compared to fares.

7.7. Mass Transit as a tram-based system provides an opportunity to encourage and maximize mode shift from car to public transport compared to a bus-based solution. However, respondents felt that addressing car demand through road user charging or demand management is likely to have a far greater impact on reducing carbon emissions that investment in mass transit alone. The imposition of demand management measures is felt to be vital to the success of any system. These would deter car use and could be in a variety of forms, such as, congestion charge, workplace parking levy, price and availability of parking etc.

7.8. Respondents felt that pricing strategies are significant motivators for driving behaviour change, especially when there is a direct cost penalty to using the car, but it still often requires a cultural shift and availability of a quality alternative to inspire residents to make that sustainable choice. For the Leeds City Region, policies to reduce the relative levels of parking in the city centres will need to be considered in tandem with the increased offer at Park and Ride/Rail sites.

7.9. Respondents expected shared mobility to play a more prominent role in bigger cities. MaaS has the potential to encourage greater use of public transport, active and sustainable travel choices.

7.10. Contributors advised that those cities both nationally and internationally which have achieved significant modal shift to sustainable travel modes, do core things well, including demand management; road space allocation to mass transit and walking and cycling; and, integration with social aspects of the transport network.

Measures to Promote Mode Shift

7.11. Respondents recommended keeping things simple for the passenger and keeping them informed, must be a key focus. An unduly complex system provides another excuse to keep using the private car. A consistent message and mutual support by all parties can yield substantial benefits through changing public attitudes. Respondents mentioned that in Bristol, a concerted programme of improved operational bus performance, bus priority measures, fleet investment and a major overhaul of the fare structure resulted in 50% increases in bus patronage and a more supportive local media. This in turn led to the implementation of a bus rapid

transit network, delivering new standards of public transport in partnership between public and private sectors.

7.12. Respondents highlighted the need for mass transit schemes to be accompanied by complimentary measures - combining multiple measures that are known to encourage sustainable travel increases their effectiveness. Positively influencing people's travel behaviours depends on providing choice, so, contributors say a range of 'push' and 'pull' measures towards desirable travel modes is required. Infrastructure investment is vitally important but works best when accompanied with educational and communication programmes to help people make more sustainable choices.

7.13. But, contributors felt it is important to note that even with the highest quality transit system, modal shift is unlikely at any meaningful scale without complementary measures to deter car use, whether by increasing parking charges, reducing parking capacity and duration of stay, introducing road pricing, congestion charging or workplace parking levies, or some combination of all of these. The improved rapid transit offer must be in place and working effectively at the time when any demand management measures are introduced, in order to be effective.

7.14. Respondents highlighted growth in personal mobility devices like e-scooters, bikes, etc integrated for first and last mile connectivity to high-capacity transit networks will mean that routing, interchange and onward connectivity will be vital in delivering a fully integrated transport network aligned to MaaS

Whole Lifecycle Costs

7.15. Contributors pointed out that passengers will demand (are demanding) change to address climate change. This will expand beyond emissions at point-of-use to entire life asset cycle (e.g. manufacture to decommission). But:

7.15.1. Is electricity generated by gas really that green?

7.15.2. Zero-emission on site or in the manufacture too?

7.15.3. Hydrogen's profile is growing, but outlook for a new fuel (especially one that requires significant energy/carbon to create it) is unclear.

7.16. Proponents of rubber tyre-based systems point to rail-based systems having much higher up-front costs, but proponents of rail-based systems point out that the infrastructure and vehicles can be expected to last longer than a bus. The point is made that lifecycle costs can be reduced somewhat by making full use of efficiency opportunities. The point is also well made that customers are becoming more environmentally aware and are interested in the whole lifecycle cost, not just the emissions generated.

Resilience to Climate change

7.17. Several respondents highlighted the need that the system should have built into its enough resilience capacity to recover quickly from any climate change events.

Construction Technologies

7.18. Contributors pointed out that there are several emerging construction techniques that can significantly reduce the impact of the construction phase (e.g.: low carbon concrete) compared to existing Mass Transit systems.

Carbon and Power Sources

7.19. Please also see Chapter 4 (Q1a) on propulsion sources.

7.20. There was consensus from respondents that tram systems powered by overhead lines are likely to have the lowest whole life carbon impact, verses battery technologies. However, both were said to be significantly better than hydrogen. Significant energy is typically required to produce Hydrogen, which can mean it is not an efficient or a carbon neutral fuel to produce. Hydrogen is a by-product of some industrial processes, as seen in Teesside for example.

7.21. Manufacturers of elevated tracked pod-based systems contend that their products could offer a lower carbon footprint due to its light construction methods which use less concrete. They also point to lower power distribution requirements and infrastructure needs because of the low power consumption of the lightweight vehicles, which aligns them well with renewable power sources.

7.22. Contributors mentioned that the wider debate about provision of primary energy source is currently driven by the desire to decarbonise transport and shift the energy demand to new sources, primarily electricity (based on current trajectories) but also hydrogen. Electricity is seeing rapid adoption as the means for transporting as the energy networks already exists as a proven technology while hydrogen networks do not exist, although a number of trials are being undertaken to test the feasibility of using existing gas networks for the transport of hydrogen or hydrogen mixtures.

7.23. One contributor felt that development of battery power as a primary power source was unsustainable as is predicated upon undeliverable resource demands. They felt that initiatives to increase walking and cycling should be encouraged and supported rather than making heavy investment in mass transit systems.

7.24. In terms of air quality impacts, steel rail-based systems are considered by respondents to have a significant advantage in terms of non-tailpipe emissions, i.e. they do not produce particulates, (which arise from vehicle clutches, brakes, tyres and tailpipe emissions). Rail based systems were also felt to offer advantages in terms of energy consumption and lower noise emissions.

7.25. The trend towards lighter vehicles and more efficient traction systems will improve environmental performance. Respondents pointed out that the latest diesel bus designs offer excellent air quality performance - Euro VI buses emit up to 99.5% less NOx emissions and 98% less PM emissions compared to buses purchased 10 years ago.

7.26. There is a recognition from contributors that battery technology is improving at pace, but, based on current projections, concerns were raised that the life cycle of batteries may be relatively short, resulting in a need to replace them multiple times during the lifetime of a tram vehicle. This would make them less viable as a realistic alternative to overhead wire systems. The point was made that there are not yet enough battery powered trams in operation to be able to come to any firm conclusion on this issue.

7.27. Contributors advise that the method of charging may also have a bearing on the life which can be expected from batteries, with frequent rapid charging being felt to potentially adversely affect the life of batteries. This method would probably need to be utilised if a completely catenary free system was required.

7.28. Some manufacturers also feel that supercapacitors can offer an alternative to batteries in certain vehicles or be used in combination with batteries in the right applications.

7.29. Marginal power savings can be made by utilising solar power for on-vehicle systems and trackside infrastructure such as information displays at stations / stops. However, contributors advised that the full lifecycle costs of providing this source of renewable energy would need to be evaluated against any potential savings. Vehicles can also generate power through regenerative braking.

7.30. Forms of power including battery, capacitor, or hydrogen may have a role to play in future systems and are already being used on parts of some systems e.g. West Midlands Metro. However, contributors feel they are likely to be supplementary to overhead power supply for some time to come and would increase costs substantially, and possibly introduce technical unreliability if applied to a whole network.

7.31. The costs of the energy distribution system around the rapid transit network were also raised. As discussed elsewhere, hydrogen fuel is expensive to produce and difficult to distribute and store. Therefore, it might only be viable as a power source if the refuelling depot can be placed adjacent to a source of hydrogen (some industrial processes produce hydrogen as a by-product).

7.32. Electricity distribution infrastructure is also expensive. Electricity supply infrastructure to support rapid charging is said to be very expensive, which must be considered when considering which power source to utilise. Whether the mains electricity supplies in the areas where chargers are needed can cope with the high current demands are another issue which contributors say would need to be addressed in the system design.

8. Feedback on Discussion Area 3

How should Advance Urban Transit systems be designed to meet UK safety and regulatory requirements and support existing public transport services, whilst also complementing Mobility as a Service and the moves towards the autonomous vehicle revolution?

Illustrative Quotes from respondents

"Passengers' view of safety across the UK's light/heavy rail sector is positive & must be protected".

"It is clearly simpler and less risky to adopt systems proven in a UK environment (or at least proven technology)".

"Non-traditional systems, such as monorail or Personal Rapid Transit (pod) currently sit outside of this regulatory framework. Given they are largely pre-prototype stage, it will take many years for them to gain regulatory approval."

"Currently no regulatory framework to deal with Autonomous/self-driving trams within a mixed city traffic environment."

"Early consideration of these regulations would be a necessary requirement, as precursor to developing any transportation scheme, to identify the role to be fulfilled by the Combined Authority and the duties to be fulfilled in order to achieve compliance with the regulations. In addition, liaison with UK Tram and the newly formed Light Rail Safety Standards Board (LRSSB), early in a scheme's development will provide a useful source of guidance.

"Beware of the unique safety and regulatory standard of various classes of mobility (Heavy Rail, Light Rail/ Metro, Tram, Other guided systems, Autonomous/ manual driving) because ambiguity around transport category or stepping in between of categories could lead to costly and complex handling of regulations set out in the ROGS. Previous failing cases indicate the ambiguity could lead to significant delay in delivery and substantial increase in compliance costs".

"Some of the combined authorities are working up proposals for integrated ticketing systems to support MaaS on integrated ticketing, but this requires the voluntary involvement of the private transport operators. Where it can be shown that there is a clear financial benefit from doing so, they are more likely to become involved"

Points raised by respondents

Regulatory Requirements

8.1. The discussions in this section confirmed that there is a tried and tested regulatory framework for traditional rubber tyred or steel rail vehicles in the UK.

8.2. Many contributors felt that a traditional mass transit system, such as bus or tram-based would present far fewer risks than non-traditional systems from a safety and standards perspective.

8.3. The point was made very strongly by a number of respondents that there is no current regulatory framework for the less traditional systems like personal rapid transit, which are generally currently at the pre-prototype stage of development, so would not be a system which could be delivered in the shorter term.

8.4. The same situation exists for autonomous trams which operate in a mixed-use environment, where they interact with pedestrians and general traffic. These systems are currently only certified for use in fully segregated environments. Respondents said that bringing these innovative systems to a point where they are certified for use in mixed traffic conditions will be a lengthy process, so these would not appear to be a viable primary option but could be allowed for in efforts to future-proof the selected system

8.5. The point was again raised that rubber tyre-based vehicles would need to be of a type which is larger than the ones currently utilised in the UK, which might raise certification issues. Double articulated single deck vehicles could be required. These are expensive and would require specific regulatory approval for operation in the UK where the current maximum length permitted for an articulated bus is 18.75m. A double articulated vehicle would be approximately 24m long. Applications for such large vehicles are much reduced due to the presence of obstructions in or near the carriageway as their progress can be impeded by the presence of two parked cars one on each side of the road.

8.6. The point was also strongly made that the vehicles to be procured must be clearly and accurately categorised at an early stage. Other projects appear to have suffered delays and difficulties because of ambiguity on this point, leading to debate on the exact regulations which apply.

8.7. It was also pointed out that early consideration and full understanding of the relevant regulations will be critical, as any oversights can be costly and have far reaching implications.

8.8. The difficulty of specifying and designing vehicles which are expected to run on the heavy rail network for part of the journey are highlighted by contributors. It is suggested that West Yorkshire could benefit from the work carried out on the tram-train trial in Sheffield which had to overcome the light rail / heavy rail interface issues.

8.9. Several also pointed out it will be important to consider the lessons learned from previous similar projects when planning a new mass transit system

Integration with other Public Transport

8.10. Contributors agreed that the degree to which the new mass transit system can be integrated with the wider public transport system will be a critical success factor.

8.11. It is pointed out that the Bus Services Act 2017 offers better potential for integration of services than had been the case since the deregulation of bus services in 1986. Integration of the mass transit system with the wider public transport system is seen as being critical.

8.12. Integrated ticketing is mentioned by contributors as being highly desirable, particularly from a Mobility as a Service (MaaS) viewpoint. A notable point was the

advice that integrated ticketing is more likely to succeed where all participants have a financial incentive to do so. This is exemplified by the recent experience of Transport for the North (TfN) whose ambitions to introduce a voluntary multi-modal smart ticketing system across the North, to concentrate on the heavy rail sector has led bus operators to have to deliver the integration of their own smart ticketing systems to achieve this objective."

8.13. Public transport priority was raised as an issue by many contributors and it is felt that this is essential for all modes if a truly integrated service is to be provided.

8.14. It is also highlighted that good passenger information is essential for inter modal travel. It is said that comprehensive information needs to be available to passengers on mobile devices, this being especially relevant at times when there are issues on the public transport network and delays occur. Passengers need to be kept informed and offered alternatives if another route or a mode change is the better / quicker option.

8.15. It is also suggested by respondents that most people prefer not to interchange to other modes, so utilising one mode for the whole journey is felt to be preferable.

8.16. The supply of timely, accurate information to passengers is seen as a key point which will provide a major influence in efforts to promote modal shift away from car use.

8.17. Competition between transport modes is seen as a negative factor and contributors feel that this needs to be avoided as much as possible. Nottingham is seen as a good example where services have been able to be co-ordinated better because of the influence of the key stakeholders involved in the project on the routing of differing modes of public transport.

9. Feedback on Discussion Area 4

What do you view as the operational and supply chain challenges and opportunities associated with developing and delivering Urban Transit systems in England?

Illustrative Quotes from respondents

"Studies have shown that each direct job at Hitachi's Newton Aycliffe manufacturing plant (up to 1100 employees at peak) generated 6.15 jobs (3.22 in indirect/supply chains and a further 1.93 supported in the wider economy through spending of the direct and indirect employees)"

"Give early thought to what the long-term future might look like e.g. Manchester high platform challenge"

"While the opportunity to introduce new technology is positive, it can introduce a level of risk into the project in terms of cost and time".

"For infrastructure, the procurement model must focus on long term social value. Collaborative long term contracts such as those on the Manchester Metro (Impact JV, circa 8 years) or the Network Rail Track Renewals Alliances (NR, AECOM, Colas Alliance, 15 years) enable the private sector to achieve long term forward workload certainty and creates the basis to invest in long terms skills development locally. These types of contract when carefully established, create a framework that supports a local supply chain and local SMEs."

"Main Contract must be attractive to the market in terms of value, conditions, risk transfer and relationships – Urban Transit schemes are renowned as being challenging and risky".

"If the system is procured in separate packages it is vital that the systems and vehicles contractor is engaged early in the process to agree interface specifications with the civils contractor. Systems integration carries the greatest risk, so the customer must own this process to ensure any arising conflicts are addressed".

"Overly detailed design specifications can inhibit innovation, but specifying unproven innovation carries risk for the system procurer".

"Joint procurements by cities would allow for larger orders of parts and help to drive down price. A new one-line tram system is considered to be a small procurement by international standards and if a manufacturing production line needs to be specifically re-tooled for the work, the costs end up being much higher as the cost of the tooling needs to be fully recovered within the cost of that single order".

"One of the most consistent messages from businesses developing and selling products and services associated with public sector investment and procurement is the need for clarity, consistency and a reasonable amount

of certainty around which business planning and risk taking can occur. We endorse this position"

"Agree jointly all stakeholder's approval responsibilities and consequences before contract starts so that nothing falls between the parties".

"Set expectations with LA's early on. Expect regular attempts at betterment which could impact negatively on budget and affordability. Maintain a position and clearly set out extent of works, urban realm standards and compliance with planning conditions. This will reduce cost escalation later in the project."

"Develop a robust communications plan covering all stakeholders and the way they will be best engaged. Ensure that all associated websites and information sources are coordinated and provide a similar message. Engage with local Business Improvement Districts to communicate and mitigate impacts of works e.g. coordination of temporary signage to public etc"

Points raised by respondents

Manufacturing Facilities

9.1. Contributors do not feel that the size of an order from a Leeds City Region mass transit project would be sufficiently large for a manufacturer of traditional mass transit vehicles to set up a manufacturing base in the region. It is far more likely that an existing plant would be utilised, with assembly possibly taking place locally at the proposed depot location. Joint procurement with other cities and city regions might be a way of building the necessary critical mass of orders.

9.2. It was suggested that if a non-traditional mass transit system were selected for this project, there might be more scope for setting up a regional manufacturing facility, but, as mentioned elsewhere in this report, innovative systems carry with them significant risks.

Supply Chain / Industry Wide Challenges

9.3. At any one time there are only a very few mass transit systems in development or being built in the UK. Respondents advise that this does not provide the critical mass of work necessary to sustain the industry and retain the knowledge base acquired in each project. It therefore appears to contributors that each new system does involve an element of "reinventing the wheel".

9.4. Skills shortages within the engineering industry (particularly for rail-based systems) are also highlighted, particularly when considering the demands which will be made by other very large projects such as High Speed 2 (HS2).

9.5. Contributors feel that Leeds City Region are well placed to build on experience gained in similar projects such as the South Yorkshire tram-train trial and incorporate it in a future mass transit system.

Procurement

9.6. It was strongly highlighted that great care should be taken when taking key decisions in the specification, as these have long-term impacts across the whole system. However, it was emphasised that the specification should allow scope for innovation, but not at the risk of excessive cost escalation or delay.

9.7. The advantages of utilising a mass transit system and vehicles which have already been implemented elsewhere were considered favourable, as this could shorten project timescales, reduce costs and avoid unforeseen risks.

9.8. The potential advantages of joint procurement with other similar authorities who have an interest in procuring mass transit systems are highlighted and it is suggested that this might possibly lead to a large enough order book being secured to justify a regional production facility being built by a supplier.

9.9. The importance of incorporating social value within any contract are highlighted and contractual arrangements which are well suited to this are suggested. This is a particularly important area if the city region's inclusive growth ambitions are to be realised. It is also suggested that it would be possible for contracts to specify a percentage of local content (defined by postcode) in terms of materials supplied and staff utilised. This was done in Nottingham and provided a boost for the local economy.

9.10. Many suggestions have been made on finding the right contractual arrangements which give suppliers certainty to make bold business decisions and scope to incorporate innovation. It is also highlighted by contributors that potential contracts need to be attractive to the market, as mass transit system contracts have a reputation of being challenging and risky for suppliers.

9.11. Numerous suggestions have also been made by respondents on putting in place robust project management arrangements which will be needed to ensure the success of the project.

9.12. The costs and risks associated with accepting cash payments for tickets are raised and it is strongly suggested by contributors that cashless options should be pursued. Whilst it is accepted that cashless payments are less costly to process, a complete lack of cash payment options could be a limiting factor for a sizeable minority of people, raising concerns regarding fairness and equity.

Project Delivery

9.13. Respondents feel that understanding stakeholder requirements, such as Local Authorities, will be a key factor in the project being delivered to the desired cost and timescales. It will be essential to ensure that the Local Authorities have enough resources to respond to the project's requirements in a timely manner in order to avoid costly delays.

9.14. Respondents felt that gaining all the necessary consents to enable the project to be delivered is a huge task which will require a dedicated team.

9.15. Contributors highlight the size of the challenge to integrate innovation into systems and suggest that a strong system integration team will be necessary.

9.16. There is huge political risk in the build phase, so the commitment of the Passenger Transport Authority and politicians is key, but trams are highlighted as being hugely popular once in operation.

9.17. Contributors advise to agree clear governance to avoid scope change not being approved or requests for changes not going through the ultimate client (e.g. change board).

9.18. It is also advised to gain the involvement of an operator as early as possible as a consulting 'shadow operator', or by combining infrastructure and operations expertise to develop the solution.

9.19. Respondents suggest early consideration be given to the maintenance regime, with specific reference to the materials being used.

9.20. Contributors felt there should be a consistent material palette for all future extensions through a standardised design guide. This process needs to start early before or during the business case submission.

9.21. Early agreement of the quality control regime is felt to be vital, as this should lead to approved inspection and test plans with associated quality documentation.

9.22. Responses suggested that a robust and comprehensive communications strategy will be needed, utilising all channels of communication including social media, covering all stakeholders and the way they will be best engaged. Contributors suggest this includes:

- Appropriate use of social media
- Branded hoardings with notice boards offering progress updates
- Mobile electronic displays, coordination of external messages
- They suggest that all associated websites and information sources are coordinated and provide a similar message

9.23. Contributors said that expectations will have to be managed as a mass transit project is a long term undertaking which may take ten years to plan and design and five or more years to deliver once construction starts. Consistent communications will be vital throughout the project lifecycle.

9.24. Engagement with local Business Improvement Districts is felt to be important, to communicate and mitigate impacts of works (e.g. coordination of temporary signage to public etc).

9.25. Interface with Network Rail is suggested by contributors to be highly likely. They advise to ensure this interface is managed via an effective Scheme Sponsor who is in place early on and able to commit to the needs of the project. It is suggested to maintain regular management and technical process meetings with NR throughout

10. Feedback on Discussion Area 5

How should the development, construction and operation of new advanced Urban Transit systems be funded and financed and how could phased introduction or expansion of Urban Transit systems be incorporated efficiently within funding structures?

Illustrative Quotes from respondents

"Whilst we acknowledge that the Authority may have already done so, we recommend that a review is undertaken of recent experience and any relevant lessons identified that can be gleaned from other funding and financing structures for light rail programmes in Nottingham, Edinburgh and Manchester"

"There are a number of different paths to raising finance at a local level. Most are forms of taxation for use of road space in order to obtain additional funds from private car drivers. The class one here is a congestion charge or road toll. Nottingham has successfully introduced its workplace parking levy which does not restrict road use but does tax where a car is parked".

"Alternative local taxes are available, such as a congestion charge. However, apart from London, this has been very unpopular and attempts to introduce it in cities such as Manchester and Edinburgh have seen the proposals heavily defeated. Whether issues such as climate change and a desire for polluters to pay will bring about a change in attitudes over charging for personal car use, only time will tell. It may be time for a local authority to test this concept again"

"Leeds City Region includes a range of transit assets that are not owned regionally but are under the control of national infrastructure organisations in the public sector. There is a significant opportunity to unlock the value of these assets and to improve how they deliver regeneration and revenue opportunities in the region".

"Heathrow Southern Railway Ltd (HSRL) might provide an example of a way of financing a mass transit project at no cost to the taxpayer. HSRL is a properly governed company which stakeholders can identify with and which can enter its own contracts with government, industry and suppliers. Because the company is not funded by infrastructure contractors it can control budgets through effective procurement and risk management processes at every stage of the project development cycle. It is a company able to own and profit from its intellectual capital and in future its assets".

"The Government's own National Infrastructure Plan states private capital should fund at least half of the cost of a £483 billion infrastructure pipeline to 2021. In addition, there is a great willingness on the part of fund managers and investment banks to invest in long term infrastructure projects. There may be an issue in terms of providing adequate scale to

make schemes attractive to investors, but I believe that this may be the best way forward for standalone schemes such as this. This approach is used extensively already with rolling stock and depots and an extension to this approach is not unreasonable".

"Community Infrastructure Levies were used in Crossrail and can be used by local authorities to compel developers to fund a wide range of infrastructure need as a result of a new development".

"Tax Increment Financing as used in Manchester. TIF is a financing mechanism created in the United States and employed for 40 years. It has been hugely popular with local authorities in raising funding for critical infrastructure and major urban regeneration schemes".

"Progressive expansion of network over time may suit public funding and DBOM better than public-private-partnership. This is because as the network is developed, the next part to be built is likely to require the same financiers to commit to providing funds, which may be difficult in practice to agree for the long-term. And, any new or different financiers may see additional risk if the network and associated assets are not owned by a single entity. The additional risk would be translated into less favourable finance rates thereby making the expansion of the network more expensive".

"Any phased approach to the expansion of urban transit should consider those with the most immediate economic, social and environmental benefits first, whilst not adversely affecting the long-term business plan or adversely affecting safe operations"

"Procuring a system via a turnkey approach could result in a 15% time saving versus procuring system elements via separate lots".

"We cannot over-estimate the importance of ensuring that the strongest possible economic case is created. This should have firm foundations in local and regional policies and strategies, for example, covering employment, accessibility and regeneration".

"Crowdsourcing is the best form of scrutiny, and should be applied wherever possible, including sufficient financial incentives to get engineers involved".

"Modular construction of trams allows for increasing size as the routes become more popular and ridership rises. Modular construction of buildings or line parts will keep costs down as components are produced in bulk. This also makes it easier to keep a stock of relevant spares in order to replace a failed or worn out part. A bespoke component may take much longer to produce and cause delay to a necessary repair"

"Whilst capital funding would almost certainly be from public sources, several options for delivery and operating models exist, involving different permutations of public and private sector activity. These include: Full public management of design, construction, operation; Public

management of design and construction; with operations delivered by private franchisee; Public specification of outcomes, with subsequent procurement of a private sector design, construction and operating partner (this is the TfW model); A D-B-F-O PPP model for construction and operation, to achieve public-specified outcomes.

Whichever model is selected, early operator involvement is considered beneficial, particularly for a new system"

"There is, in the UK, a chequered history with respect to build and franchise operation of tram systems. On the face of it many of the problems have their routes in an inability to define realistic operational performance metrics for the tram systems. Metrolink looks to be an example of best practice, which is being proactively evolved. Whilst the TfW model is at an early stage of implementation, this also conforms with good procurement and project management practice. Nexus having been taken back in house less so. The key here is to get the requirements right, back up with data capture and analysis system align to an agile operational management systems approach. This all needs to be aligned to the investment case. In addition, whole life costs and the need to fund capital renewal cannot be ignored. The Sheffield Supertram is currently struggling to renew both fixed and fleet assets."

Points raised by respondents

Potential for Local Funding Contributions

10.1. The traditional source of funding for UK mass transit projects has been central government. However, it was pointed out that substantial local contribution is required.

10.2. Numerous sources of local contributions were suggested by respondents:

- Congestion Charge – a tax on vehicles entering a city. This was proposed in Manchester and Edinburgh but rejected by their citizens. Contributors highlighted that this has only been successfully implemented in London.
- Clean Air Zones – cities are implementing clean air zones in response to statutory requirements to act on air quality. These will produce income, but contributors suggested this may diminish over time as more drivers and fleets swap to cleaner, compliant vehicles.
- Workplace Parking Levy – a tax on employers who provide parking spaces for employees. The employer may pass on the cost to the employee. Successfully implemented in Nottingham explicitly to provide local funding for their tram system, currently raising £10m per annum. Other cities are investigating it's potential.
- Community Infrastructure Levy (CIL) – contributions from developers for specified infrastructure provision, secured when giving planning approvals.
- Planning Obligations – Section 106 as used in Croydon. New development can place extra burdens on the existing infrastructure and Councils may require developers to make some reasonable financial or practical contribution to the

community to address these types of issues. Commonly known as ‘s106’ agreements.

- Tax Increment Financing (TIF) - as used in Manchester, allows the local authority to trade anticipated increases in tax revenue for a present benefit. Under these schemes, local authorities may borrow for infrastructure projects, against the future growth in business rate receipts which will result from the projects.
- Business rate supplement – this has been implemented in London and collects 2% of the value of non-domestic properties over a set rateable value.
- Value capture – evidence suggests that well planned transport schemes can increase property value by up to 50%. Respondents advised that various locations around the world have employed value capture strategies to contribute towards the capital cost of transport infrastructure
- Money might be raised by local bond issues or against future income from land value uplift or fare box revenues.
- Special opportunities, for example in London, developers pay to build over railways. In Hong Kong, the transit authority purchase land on future transit routes and benefit from land value uplift when the lines are built, and property is subsequently sold.
- Park and Ride – as part of the overall transport strategy for the city region, contributors suggested strategic park and ride sites at mass transit stations can be provided. Charges could be made for this facility which would contribute to covering costs. (Any surplus income can be utilised for public transport improvements as this is a lawful use of surplus parking income by local authorities.)

Potential Finance Sources

10.3. A wide range of potential finance sources were highlighted in responses:

- Central Government, via specific grants. Contributors suggested that this is normally the primary source of funding for UK mass transit systems. Manchester have recently utilised Transforming Cities Funding (TCF) to purchase new tram vehicles.
- Private Finance Initiative (PF2) - Successor to PFI, which provides more flexibility and reduced expense to address the criticisms of this type of financing arrangement but requires co-investment by public sector and long-term commitment between supplier, the financiers and the public sector.
- Public-Private-Partnership - Long-term joint venture between supplier and public sector (majority owned), with investment from both sides with shared profits. Several current UK examples, including the PPP with the DfT for the Intercity Express Project (Class 800/801/802 trains)
- Hybrid models - may include private finance of rolling stock for which the operator pays an annual lease charge to cover capital and finance charges.
- Turn-Key Project/Contract - Design, build and financed by suppler and then purchased/sold to the public authority, or other private operator when fully complete and proven ready to operate, but at an increased cost to cover the

financing. This option may present potential issues with expandability and interoperability when procuring from a single supplier.

- Design-Build-Operate-Maintain (DBOM) - Several successful designs, build, manage and maintain systems exist around the world such as Copenhagen Metro.

10.4. Respondents suggested progressive expansion of network over time may suit public funding and DBOM better than public-private-partnership. This is because as the network is developed, the next part to be built is likely to require the same financiers to commit to providing funds, which may be difficult in practice to agree for the long-term. And, any new or different financiers may see additional risk if the network and associated assets are not owned by a single entity. The additional risk would be translated into less favourable finance rates thereby making the expansion of the network more expensive.

Delivery Models

10.5. Several potential delivery models were suggested:

- Full public management of design, construction, operation.
- Public management of design and construction; with operations delivered by private franchisee.
- Public specification of outcomes, with subsequent procurement of a private sector design, construction and operating partner (this is the TfW model).
- A D-B-F-O PPP model for construction and operation, to achieve public-specified outcomes.

10.6. Respondents suggested that early operator involvement would be beneficial, whichever delivery model is selected.

Whole Life Costs / Funding

10.7. Respondents suggested that whole life costs and the need to fund capital renewal cannot be ignored. For example, the Sheffield Supertram is said to be currently struggling to renew both fixed and fleet assets.

10.8. It was suggested that a longer-term operating franchise would encourage investment into the system and could be linked to renewals funding. It also allows the operator to make trade-offs between investment in capital, renewals and maintenance in order to optimise whole-life value. The introduction of an Enterprise Asset Management System (EAMS) would be an essential element here but a medium to long term franchise would normally be required to incentivise such an investment. Respondents also recommend that operations and maintenance remain together. This simplifies the interfaces, removes blame culture, and issues are all with one organisation to resolve.

10.9. Modular construction of vehicles and infrastructure were suggested to result in cost and time savings and provide the platform for the system or vehicles to be expanded when required. Maintenance is also made easier and at lower cost as components are bulk produced. Stocks of modular spares can be kept ready for use, but bespoke components can take longer to produce and be more costly.

Planning Considerations

10.10. Responses suggested the mass transit business case should consider how the routing of the system could unlock potential development sites identified in Local Plans and contribute to the City Region's Inclusive Growth ambitions.

11. Feedback on Discussion Area 6

To what extent is it necessary to utilise new or innovative technologies, over and above proven technologies, to achieve the targets and outcomes?

11.1. With the points raised here, there is some cross over particularly to points raised in Discussion Question 1c (Chapter 6).

Illustrative Quotes from respondents

"Don't try and take too much "cutting edge" technology as this has the potential to take too long in development or may not turn out exactly as expected."

"Gain the involvement of an operator as early as possible as a consulting 'shadow operator' to gain their perspective from their global expertise. They will already be considering the next wave of technology (e.g. facial recognition software)"

"Innovation - The principal requirement when considering 'innovation' is that there is clarity on the goals and objectives of the system. A common pitfall is that investment in innovations is encouraged without adequate consideration of the outcomes and benefits that are to be achieved. This then becomes 'innovation for the sake of innovation'. The need for absolute clarity on the system's goals, objectives and outcomes is one of the key messages of this paper".

"For a new tramway there should be a balance between specifying practical probable technology and new bespoke kit. Buying the best available off-the-shelf equipment at the time of procurement is likely to be better that buying cutting edge technology which is not well proven. It is far preferable to adopt proven technologies rather than risk new or innovative technologies which very rarely offer any significant benefits and can introduce major risks. They can impose major delays or increased costs, as for example with the GLT system installed in Caen and Nancy which after years of unreliable operation has had to be replaced by conventional tramway technology".

"Although a Mass Rapid Transit flagship corridor/scheme could sit at the heart of a future network in the longer term, this cannot be at the expense of the evolution and development of the current network in the short and medium term"

"Continuous political commitment to sustainable transport should not be underestimated in its influence on the success of an efficient transport network. High achieving UK cities, such as Brighton and Hove, Nottingham and Reading have strong political support that has led to high and sustained prominence and investment into the public transport network. What sets many high achieving cities apart from other cities goes beyond just political support to a policy and leadership boldness; taking

decisions that may be unpopular in the short term, by recognising and carefully promoting the long-term benefits"

"Tying into proprietary systems can also be risky as one is at the mercy of a single manufacturer and maintenance and upgrading may become increasingly expensive or even impossible. Example: Maglev shuttle at Birmingham Airport. However, there is a place for innovative technologies, particularly in ticketing and customer information systems. This could include MaaS to enable a fully integrated multimode journey. Imposing technologies on suppliers can lead to inadequate system integration, and newcomers into the industry may not be fully aware of the issues that will need to be addressed".

"Perhaps the most important principle governing innovation in light rail is to recognise that most innovations that could benefit a system have yet to be invented. It is therefore important that the design is sufficiently flexible to accommodate new developments, materials, technologies and operational procedures. This may have implications for the maximum weight of vehicles; the design of space within vehicles to accommodate new technology; the ability of infrastructure to be retrofitted with remote condition monitoring equipment; etc.

This principal of flexibility is well illustrated in other sectors. The new Royal Navy aircraft carriers were designed in the early 2000s in the full knowledge that many on-board systems would be redundant during the lifetime of the vessels. However, the design allowed for the accommodation of future technology developments and innovations by building in extra space, additional power and a significant increase in weight over the lifetime of the ships".

Points raised by respondents

11.2. Contributors suggest it is possible to deliver a state-of-the-art mass transit system without taking unnecessary risks on unproven technology. However, it is said to be essential that the scheme promoter properly understands and balances where risks should best sit to determine those which the Authority is willing to take to deliver innovation.

11.3. In important areas for this project (for example batteries), contributors say mainstream technology is already progressing rapidly, and advanced but well proven products are emerging. Therefore, they advise there is no need to take undue risks by trying to incorporate new, yet unproven technologies.

11.4. Incorporating unproven technology into a large and expensive project of this nature is inadvisable as it could result in unacceptable levels of risk of delay and/or cost increase. Contributors highlight that two mass transit systems in France which employed what at the time were innovative technology solutions have proved unreliable and prone to several serious issues, resulting in them being replaced by conventional light rail systems. For this reason, they advise innovation for its own sake is to be avoided and that there are significant benefits in keeping the core system technology as simple as possible.

11.5. It was also suggested to be advantageous to avoid the use of 'propriety technologies' which constrain the promoter to a single supplier in the long term, as this can increase costs.

11.6. Mass transit systems have a lengthy lifecycle. Tram vehicles can have an operational life of 30 years or more. If the selected system is to evolve during its lifespan and be upgraded as new technologies emerge and come into mainstream use, contributors suggest flexibility must be built into the initial designs, for example having sufficient space in a tram vehicle to install hydrogen fuel cells and associated fuel storage.

11.7. A contributor suggested that if the business case identifies that to meet the numbers of passengers to be carried, a type of bus which is not currently used in the UK (for example one which is more than 18m) would be required, this will deliver significant risks to the promoter in their ability to deliver and operate such a bespoke vehicle.

11.8. An experienced mass transit operator is suggested to be able to give advice on the types of technology both existing and emerging which can add value to the project and those which will not. Therefore, contributors advise that a role within the project team of shadow operator will be a vital addition at the earliest possible stage.

11.9. The mass transit system itself and any advanced technologies it employs will not in their own right be able to deliver the level of mode shift from car use which is being sought. Respondents suggest that the solution which is implemented must include complimentary measures which will allow integration with pedestrians, cyclists and other public transport modes. Priority for public transport and demand management measures to discourage car use are suggested to be key components of any solution.

12. Feedback on Discussion Area 7

How should a mass/urban transit solution integrate / complement / compete with existing and future rail services?

Illustrative Quotes from respondents

"Simple, it should be designed to provide the best offer to passengers. It should complement well; it should integrate, and it should not compete. This works exceptionally well in Lyon"

"The utilisation of emerging Mass Transit technologies is key to delivering a number of key Leeds City Region targets However, Targets are dependent on achieving a fully integrated solution that considers pedestrians, encourages walking and cycling and optimises carriageway space utilisation to deliver an integrated sustainable solution"

"The starting point, as noted previously, is to have clarity on the purpose, goals and objectives of the system. These should include urban and regional accessibility and mobility targets linked to the development of other modes. This clarity will also define how integration across modes should best be achieved and which particular design features of a new transit system should be prioritised."

"As we have referenced elsewhere, we recommend that a rigorous approach is taken to fully understanding the costs and benefits of differing levels of "integration". The User Need for a "seamless journey" is best seen as being one of a "frictionless journey" where the "joint" between stages in the journey are intuitive, easy to navigate and are clearly owned by an identifiable service provider. How this is achieved in the "wiring diagram" back of house is not something most customers particularly care about. We would therefore suggest that it is important to initially build up the customer journey maps and corresponding functional requirements such that the need for "integration" can be addressed in the most effective and efficient way, which often may not need the complexity of full physical integration of differing systems with differing standards and operating procedures."

"The case for establishing competing public transport modes is weak and we would discourage designs that set out to compete with existing rail services. Most high quality urban public transport systems require public support, at least for capital works but often (as in the case of regional rail) for operating expenses also. Competition between modes simply dissipates and dilutes the effectiveness of such public support and investment and reduces the quality of service to travellers.

A strong financial case exists for integration of tram, rail and bus services in order to optimise public investment and maximise service levels for passengers. Should a case exist to transfer services from rail to tram (in in the case of some lines in Manchester, Birmingham and Nottingham) then such a conversion is preferable to trying to operate competing services on the same corridor.

It should also be noted that (heavy)rail is not well suited to providing short distance services (say 20km and less) with multiple stops, particularly on a congested network. It is generally difficult to timetable frequent services because of the need to accommodate longer distance trains on the same lines. Performance is also often worse than that of trams because of local services having to share lines with longer distance trains which are more prone to disruption. Finally, heavy rail costs are far higher than light rail and the use of such systems to provide local services is a poor use of resources"

"We should all remain aware that this is an area of fast-moving technology. Three years ago, contactless transactions for payment of transport fares was virtually unheard of. Today, whilst the industry looks to address such challenges as exit card readers on single door buses without increasing dwell time at stops, we should look ahead and consider the possible deployment of proximity detectors, or even facial recognition technology, to record the passage of people onto and off public transport vehicles without the need for any form of physical transaction for the vast majority of passengers"

"Integration and operation of services which operate on both the existing Network Rail and new rapid transit line (Such as tram-train services) are not preferred by investors as they would include potentially very complicated risk profiles and processes"

"We believe that by taking a professional service design led approach to the Leeds City Region's overall mobility needs the fundamental principles of Mobility as a Service can be met. This implies that there should be a concept of a single City Region "system" which users can readily understand – this may be delivered by multiple players, but trust should be developed, earnt and sustained through innovation and competition in the "how" not the "what" is being offered".

"There are City's like Tallinn in Estonia which have stopped charging for public transport. Such schemes would of course increase the attractiveness of urban transit systems however it would of course result in an increased cost to the city".

"Provide secure facilities for cyclists at stops to integrate cycle routes with other transport modes and perhaps provision of cycle hire"

"To efficiently integrate the new service with existing and future rail services, pay special attention to the journey break points, especially in larger stations where interchange distances could deter people from using the service. Keep interchange simple and quick"

"A digital platform strategy should be developed in parallel and in close collaboration to the physical transport infrastructure planning and modelling. WYCA should investigate their capability to define and 'host' a single digital platform, with standardised APIs to ensure interoperability of data from all modes of transport"

"Ideally you achieve multi modal integration between, train/bus/CAV/bike share and there will be no competition but services complementing each other and enhance connectivity and customer experience"

Points raised by respondents

Integration

12.1. To maximise the benefits of Mass Transit, contributors suggest it is necessary for a fully integrated system to be developed. This will consider all available modes of travel and how best to create a modal shift through a system that avoids competing transport modes.

12.2. Responses suggest that the world's most successful public transport networks can be viewed and used, as a single entity – regardless of the modes available. As the network is developed in Leeds (as the driver of the city region's economy) it is critical that all modes need to be considered together as part of a wider City Region transport network that encourages sustainable travel, expands travel horizons and supports inclusive growth. Responses suggest that any mass transit solution must sit as part of a wider integrated transport network, not just with rail, but bus, coach, demand responsive transport and walking and cycling offers. When modes work together efficiently it leads to more people moved in less space, responsiveness to the growing demands of a larger population, more reliable journey times and a more attractive public transport network.

12.3. Integration must comprise interchange between modes, integrated fares systems, marketing and information systems. Responses suggest ideally WYCA should consider its proposed core service routes and how it wishes to facilitate the movement of people around the region compared to an existing set of routes which may not reflect current requirements.

12.4. Even if not directly integrated, avoiding interface with Network Rail infrastructure is highlighted as being desirable due to regulatory sign off and the costs associated with it.

12.5. Operating mass transit infrastructure adjacent to Network Rail infrastructure can cause issues as mentioned in other responses. Early engagement with Network Rail is suggested by respondents to ensure any issues can be addressed.

12.6. Responses suggest careful consideration should be given to dual mode systems such as tram train. There are advantages to creating a tram-train network that can partly utilise the existing mainline, but mixed systems can import the minimum requirements of both systems, reducing flexibility and increasing costs (both capital and whole life).

12.7. If there is an urban transit solution along the same route as a railway, consideration is needed on the available stops for the rail service and whether the tram will become a feeder to the rail service or collect a different type of passenger. If in the same transport corridor, consideration should be given to changing a premium price for the fast rail service.

12.8. When creating an integrated service, responses suggested WYCA needs to consider how it wishes to deal with removing or reducing barriers to interchange. It is suggested that the time spent on the interchange and keeping waiting and walking times between modal change to a minimum; the costs of using the different services and whether a single, easy to use ticket can be provided; and the additional infrastructure required for e.g. level interchanges between bus and tram

or for providing pedestrian crossing and cycle storage, etc. to encourage walking and cycling as part of the transport offering.

12.9. Respondents suggested investment in the hydrogen fuel economy could also help to improve the business case for hydrogen-powered buses and trains in the region. Integration with other local projects, such as Hydrogen 2021 (H21) in the North of England, could help to further support clean growth in the region.

12.10. Given the current uncertainty around the future of HS2 it was suggested to be important in the short term to maximise the business case for HS2 through integration with any new urban transit scheme. Consideration was suggested to be given to proposed new tram and /or metro routes provide links between the station and new business and property development areas, as well as ensuring that the bus network is expanded to meet the increased passenger demand.

12.11. Contributors suggested that bearing in mind the capacity constraints on the current rail network and challenges associated with expansion of Leeds City Station and the limitations of only two tracks to the east of the station (although it is noted, this extra heavy rail line capacity may be added in future), solutions such as Tram-Train would provide an opportunity to develop an urban transit solution that would provide dual benefit with respect to both urban transit and the wider heavy rail network.

12.12. Responses suggested that any proposed urban transit upgrade should look to connect the airport to the city centre in order to increase passenger numbers and reduce road congestion.

12.13. Responses suggested that the role of the bus must be considered as it inevitably provides a feeder to main rail services.

12.14. Copenhagen is highlighted as a good example of integration, as they developed a long-term plan with conventional rail, metro and LRT intersecting and planned around intersections and demand. This was suggested to be a fully integrated solution.

12.15. Respondents suggested the mass transit system should consider the interfaces with cycling and support expansion of the cycling network (including safety issues).

12.16. A key consideration for the partners is how the delivery of new services impacts the overall transport network operation as they are developed and built. Changes in transport provision take time and infrastructure measures can cause substantial traffic disruptions. Responses advised that effective partnership working between different departments and organisations is critical to ensure a resilient network to cope with change. This in turn will portray a positive message to the public and enhance their interest and commitment to the scheme, limiting resistance

Interchange

12.17. Responses suggest interchange is key. In order to avoid the negatives of mixed systems, it important that the new service is routed so that it is integrated with both direct adjacent interchanges with the key mainline and local railway stations. Speed and ease of interchange are vital requirements. Respondents suggest interchange should consider all modes of travel, not just public transport, so it is important that facilities for cycling and for park and ride be considered at mass transit stops

12.18. A response suggested that enforcing interchanges between modes for short routes is not popular and consideration should be given to running cross city centre with routes terminating at the opposite side of the city to which they enter. This would mean that the trams would provide a major circulatory route in the city centre. If there is a high city centre penetration, the design of the system needs to take account of the high frequency in the central section and have sufficient route capacity to ensure that a blockage (e.g. vehicle failure or traffic accident) at one point does not have a significant impact on the operation of the system i.e. there are diversionary paths around the incident: Manchester's 'Second City Link' is such an example.

12.19. The presentation of public transport as an integrated network where journeys can be planned across multiple modes, accompanied by seamless through ticketing and the ability to purchase multi-modal ticketing products, including account based capped ticketing, were suggested as important components for some people. Respondents suggested that it is important, however, to retain a sense of proportion, as such trips account for only a very small proportion of all public transport trips and even their doubling would be unlikely to result in them accounting for a significant proportion. The costs of implementing and maintaining such systems will need to be evaluated in the context of the benefits conferred.

12.20. Integration of modes around Leeds City Station and the HS2 terminal were highlighted as being key in catering for interchange between modes and integrated first/last mile connections such as bike, e-scooters and taxi. It was suggested this principle of integration would need to extend across the network with a hierarchy of provision. Tram-train solutions may also provide an opportunity to avoid the need to interchange, with services running from heavy rail stations to on street stops in key local nodes. Ticketing and information provision were also seen as key to a seamless journey experience.

12.21. Contributors suggested research has identified that it is transfers in a journey that cause the most stress to passengers and therefore it vital that West Yorkshire Combined Authority consider quality and easy transfers and interchange between modes. Interchange in city centres will be key; cities like Utrecht developed the central station into a multi-modal centre - linking mass transit directly with the rail and coach network for regional and national travel, and with the bus network and active travel options for local onwards travel. However, it is also seen as critical that interchange is considered at local and district hubs, linking feeder services and DRT options to the main network.

12.22. It was suggested that there is also huge potential to expand, develop and link Park and Ride with the rail network in Leeds in the short term. Examples were cited such as Oxford Parkway Station (which combines rail and bus park and ride, with through ticketing and support for other modes) and Cambridge North Station (which combines parking with rail, cycling and the guided bus way) are both good examples of where multimodal Park and Ride schemes can be integrated into the network and bring modal shift.

12.23. It was suggested by many that interchange needs to be as seamless as possible, with timetables between public transport modes co-ordinated wherever possible and integrated with through ticketing. This is only achievable where there is a strong and active partnership between authorities, operators, developers, planners and stakeholders, united by a shared vision. Example – Nottingham Robin Hood Integrated Ticketing Scheme.

Costs

12.24. The cost of using public transport is highlighted as an issue for many, so the business case for mass transit should consider the potential impacts, issues, benefits and costs of offering free travel on at least part of the network.

13. Feedback on Discussion Area 8

Any other observations around the future of Urban Transit, which you think we should take into consideration when developing our proposals?

13.1. Respondents used this question as an opportunity to highlight any other areas which they thought the Combined Authority should be considering in the context of Urban / Mass Transit. It is an opportunity to highlight any lessons which can be learnt from other cities.

13.2. Several respondents used this question as an opportunity to highlight the benefit/disbenefits of modes and these points are noted but not repeated here.

Illustrative Quotes from respondents

"The most important piece of advice we could offer is to not try to re-invent the wheel. Look to other systems, learn from mistakes, plan and ensure you have the correct local support (especially Political) to implement the full changes you wish to."

"Decisions around a future urban transit solution should consider the long-term economic, climate and social demands and be free from short-term influences (e.g. political) as much as possible."

"It is sensible to have a full and final long term plan of what you want for the city and surrounding areas of Leeds and even if this is implemented in stages, over a period of time, it is better than trying to undertake a large project all at once, however, knowing the final full picture of where you want to be is essential."

"No one knows what is likely to happen, but we have to act anyway. Build-in flexibility and don't rely on solutions that try to fix everything"

"Market sounding is a key initiative to the development of a great urban transit system. If WYCA hasn't already done so, working with existing transit agencies to understand what is working well and what isn't working for them will provide valuable insight."

"value for money should always influence choices"

"To achieve inclusive outcomes means thinking of the system from a whole systems point of view, and from all users perspectives, which we hope will form a common basis of understanding for developing a system that can leapfrog current systems, not only in terms of their technology and purpose, but also how they integrate, connect and include communities alongside the route… this can be physically, digitally, and through attractive built environment with last mile connections also sought and delivered by sustainable modes.

"Autonomous vehicles will reduce public transit usage…. Autonomous Vehicles + Congestion = Autonomous Congestion"

"For private investors, there needs to be certainty and the transport mode is proven and reliable. Private finance is unlikely to be attractive to unproven technology / transport modes."

"For private financing projects also need to be of sufficient size to justify the associated tendering and legal costs, but not of a scale that creates challenges to raising private finance."

"Typically, in Australia we have seen initial networks built (core part) which are around 12km in length but are appropriately designed and constructed (as well as a suitable commercial framework) to allow rapid expansion."

"The policy relationship between transport, planning and parking policy is key. For those that have access to a car, public transport is seen as being 'more expensive than the car'. Paying a bus or rail fare brings with it an immediate and noticeable cost to using public transport; something that is often unthought-of when travelling by car, leading to the perception that public transport is more expensive. This is exacerbated when parking charges (where there is an immediate cost) are relatively low compared to fares. Pricing strategies are significant motivators for driving behaviour change, especially when there is a direct cost penalty to using the car, but it still often requires a cultural shift and availability of a quality alternative to inspire residents to make that sustainable choice. For the Leeds City Region, policies to reduce the relative levels of parking in the city centres will need to be considered in tandem with the increased offer at Park and Ride/Rail sites."

"Softer measures - A fully functioning public transport network is more than just high-quality vehicles running in their own space. It is vital that a series of initiatives are implemented in conjunction with the infrastructure investment to ensure that a whole journey is reliable and desirable compared to the private car. These peripheral considerations include integrated multi-modal ticketing systems, improved accessibility for people with impaired mobility, real time information, integration of the public transport system with cycling and park and ride facilities, and security systems and promotion of initiatives on safer travel on public transport"

"Not all passengers will be connected (e.g. access to a smartphone) or they may be reliant on cash. The share will continue to decline, but to deliver social inclusivity accommodating these requirements (while not limiting technical ambition) will be important"

"The policy relationship between transport, planning and parking policy is key. For air quality issues and climate change to be addressed it is essential that the public transport network is effective enough to reduce people's dependency on the private car and ensure that sustainable transport choice becomes the best option for them, meaning that is it quicker, more reliable and affordable to bring the workforce to employment nodes in order to meet the transport requirements of inclusive growth in a sustainable way"

Key Feedback Received from Respondents

13.3. It was suggested to avoid the temptation to innovate for innovations sake – don't reinvent the wheel. Look to purchase an existing chassis which can be 'customised' to meet local needs (for example the design of the front end, colours, seat layout).

13.4. Respondents said that the key is to find emerging technology that can deliver on reliability and operability goals – this must be emphasised to ensure long term acceptability of the system. But it was also suggested to beware excessive innovation without adequate proof of concept and evidence of testing – for example, resist dismissing conventional steel-on-steel solutions too quickly and beware the promises of untried, untested and poorly understood technologies such as on-street AVS.

13.5. It was suggested that a new transit system will take a decade to plan, design, build and emerge as a fully-fledged regional system. By this point, many existing systems will be redundant and new technologies will have been developed in such areas as communications, asset management, traction control, any new transit system should have enough flexibility designed into it to accommodate innovation and new developments.

13.6. Strong advice was to ensure interoperability and not to constrain the system to a specific supplier's technology for the totality of the system, or it will become very expensive in the future.

13.7. In the procurement, advice was given to specify clear operational parameters but avoid detailed design specifications, as these will inhibit innovation, and ensure these are maintained though all phases of design and delivery.

13.8. It was felt to be important to consider the expandability of the system at an early stage. For example, ensure P&R sites and depot are capable of expansion and suitably sited for the entire system and not just phase 1.

13.9. Advice was given to consider the operation and maintenance of the system at the earliest stage and develop the solution around a clear perspective of the operational objectives.

13.10. It was suggested that any future Invitation to Tender (ITT) contains robust requirements for quality and evidence criteria to ensure a qualitative evaluation can be carried out.

13.11. The policy relationship between transport, planning and parking policy was highlighted as being key. For air quality issues and climate change to be addressed it is said to be essential that the public transport network is effective enough to reduce people's dependency on the private car.

13.12. A response suggested that any authority considering a new transport system for the first time are really in a unique situation in that they can consider and learn from best practice elsewhere, including the mistakes from UK and overseas. Information gained will inform what the best solution, or combination of solutions for West Yorkshire might be addressing every area including such issues as technology, integration, procurement and operational models and contract options. This is particularly true for Leeds / WYCA given their ambitious agenda.

13.13. Clarity of goals, objectives and outcomes were suggested to be critically important– a new transit system will be one of the largest investments any local or regional

authorities ever make. It is essential that the purpose is clear, including the social and economic goals. It is also important that the relative role of other modes is understood when the new transit system is being designed in order to ensure a high level of integration, to remove duplication and to maximise value-for-money.

13.14. It was pointed out that not all passengers will be connected (e.g. access to a smartphone) or they may be reliant on cash. The share will continue to decline, but to deliver social inclusivity, accommodating these requirements (while not limiting technical ambition) will be important

Find out more

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All information correct at time of print (March 20)

Appendix 1:

Market Testing Prospectus issued in August 2019

West Yorkshire Combined Authority

Working in partnership with the

Leeds City Region Enterprise Partnership

Advanced Urban Transit Technologies - Prospectus

World Wide Market Testing: Call for Evidence

August 2019

£69.6 Billion GVA

A region packed with ambition and untapped potential

In partnership with:

University of Huddersfield
Institute of Railway Research

University of Leeds
Institute for Transport Studies

Foreword

Councillor Kim Groves

Chair of West Yorkshire Transport Committee

As Chair of the West Yorkshire Combined Authority Transport Committee, I am committed to driving forward the development of a transport system that is fast, reliable, integrated and which supports our ambitious target of a zero carbon City Region by 2038.

We are investing now to strengthen our transport network for the future. However, even with that investment we know that future development will place extra demand on our transport network and that some communities will require improved transport links. We also want to ensure that as a region we maximise the positive impact of – and ensure all our communities' benefit from – major national infrastructure projects including HS2 and Northern Powerhouse Rail.

Working with its council partners and the Leeds City Region Enterprise Partnership (The LEP), the West Yorkshire Combined Authority has identified those communities that will require better connections, to each other, to our town and city centres, and to key development sites, which will ensure they benefit from future growth.

Transport has a key role to play in achieving our 2038 net zero carbon target. We need to explore innovative mass/urban transit technologies that will enable our City Region to increase transport capacity and underpin clean growth. A multi-modal shift away from car is needed to tackle key issues such as congestion and air quality, which are having a big impact on local people's health and quality of life.

With a population of over 3 million, the Leeds City Region is the largest metropolitan area in Europe without an urban transit system. We are now exploring how such a system, and the latest innovative technologies available, could meet our needs.

We have two, world-class transport research institutions in the City Region - the University of Leeds' Institute for Transport Studies and the University of Huddersfield's Institute of Railway Research and we are delighted to be undertaking this Market Testing in partnership with these industry leading institutions.

This market testing process is our opportunity to learn from your experiences and research and development programmes, to shape a potential future urban transport system.

The conclusions from this important and high-profile market testing will also sit alongside our wider work programme across road, rail, bus, walking and cycling, to shape a Leeds City Region Connectivity Strategy.

Finally, I would like to thank you in advance for your time and input. We look forward to working with you as this work progresses.

1. This Market Testing - Overview

1.1. The West Yorkshire Combined Authority ("The Combined Authority") is at the early stages of developing new proposals for an Advanced Urban Transit System, which supports the Leeds City Region priorities of raising productivity, delivering inclusive growth and addressing the climate emergency through clean growth, all of which must be underpinned by a 21st Century Transport system.

1.2. The new high-speed HS2 and Northern Powerhouse Rail lines are due to open in Leeds from 2033 along with Network Rail's £2.9 billion TransPennine Route Upgrade. To ensure their benefits are felt throughout the City Region, the new Advanced Urban Transit system will need to integrate with the wider public transport network to provide the local connectivity and capacity necessary to support key growth areas.

1.3. The purpose of this market testing is to shape our thinking on the scope, scale and deliverability of the potential technologies available, at the early stages of development. The feedback received through this market testing will help to develop and design an Advanced Urban Transit system that integrates the public transport network and puts us at the forefront of technologies for many years to come. It will help to ensure we design and development the most innovative system, which meets our local priorities and is deliverable before 2033.

1.4. We are seeking the views from all promoters, manufacturers, suppliers, constructors, engineers, system developers and operators of Urban Transit systems from across the world.

1.5. We want to discuss your views on how Urban Transit technologies are expected to evolve over the next decade; what 'best in class' means for Urban Transit technologies; and your views around how an Urban Transit system can help meet the Authority's priorities of raising productivity, delivering clean and inclusive growth and delivering a 21st Century Transport system.

1.6. This market testing is being undertaken in partnership between[1]:

1.6.1. The **West Yorkshire Combined Authority**
1.6.2. The **University of Leeds**, Institute for Transport Studies
1.6.3. The **University of Huddersfield**, Institute for Railway Research

[1] Further details on who we are can be found in Chapter 8.

Leeds City Region – Key to the Northern Powerhouse

The largest and one of the most diverse city regions in England – situated at the very centre of the UK - West Yorkshire is part of Leeds City Region and is characterised by:

Innovation

Our pioneering inventions have driven the UK economy and changed lives across the globe for almost two centuries. Our businesses are working with our education institutes to create global opportunities for the next century.

Diversity

Our diversity is our strength, creating a resilient economy that has remained strong throughout the economic shocks of recent years. Our young, talented population is supporting the fastest growth of private sector jobs in the UK outside London.

Quality of *Life*

A strong economy coupled with an outstanding quality of life makes this one of the best places in the country to build a great business, a great career and a great life.

Connectivity

A city region that's going places, our region already has great national and international connections, and major new investment in the pipeline.

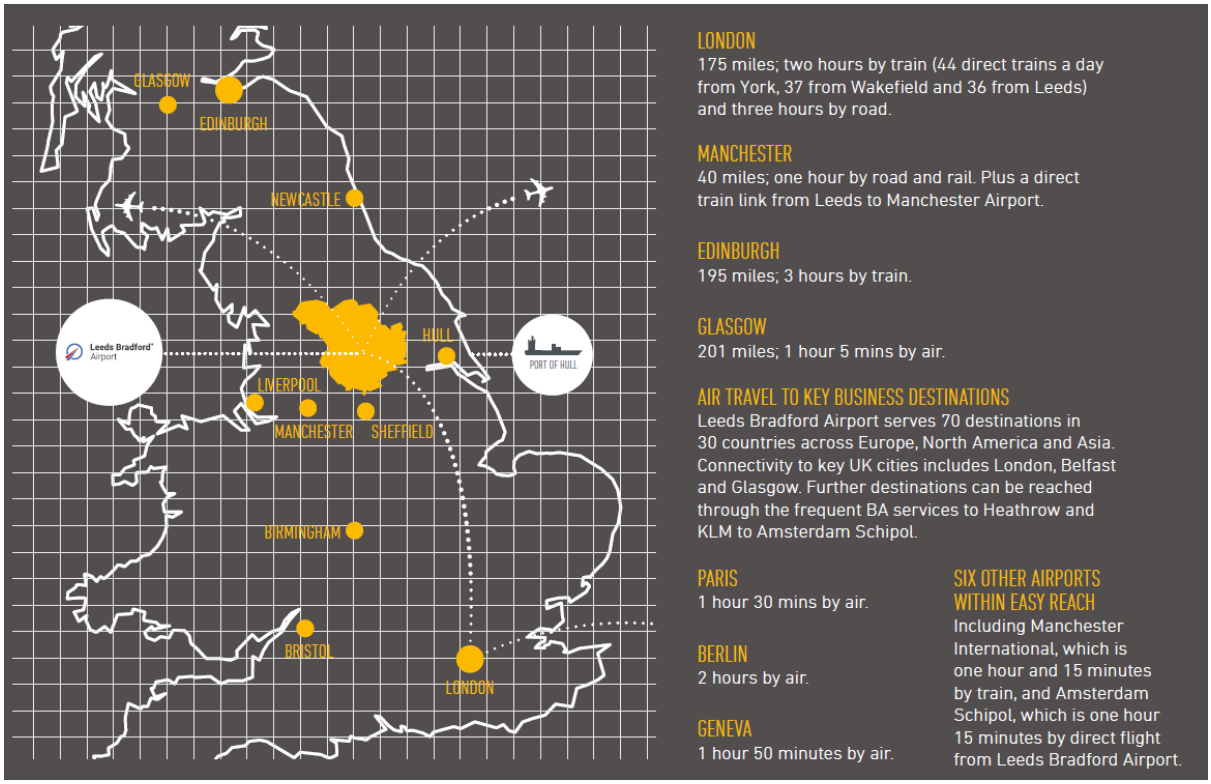
Partnership

Local civic and business leaders have been working together for well over a decade to ensure that the City Region is recognised globally as a strong, successful, inclusive economy where everyone can thrive.

Key Facts about Leeds City Region

- A region with more than 3 million people. The UK's fastest growing young population and the largest population centre and workforce outside London
- At £66.9billion, the City Region economy is bigger than 9 EU countries and the biggest outside the Greater London economy in the UK.
- With over 1.4 million jobs in Leeds City Region, more than in any LEP area outside London and the biggest contributor to the Northern Powerhouse – generating one-fifth of the North's economic output *(Source: Office for National Statistics)*
- Leeds City Region is home to almost 126,000 businesses – more than any LEP area outside of the South East. *(Source: Office for National Statistics)*
- The fastest growing private sector in the UK. In addition to Leeds, only London and Cambridge have achieved over 20% growth in annual turnover or staff growth in three consecutive years *(Source: Centre for Cities)*
- The highest concentration of academic institutions outside of London
- Largest regional financial services centre outside of London in the UK. Home to 30 national and international banks and over 21,000 people working in banking.
- Largest manufacturing centre anywhere in the country

Leeds City Region's National and International Connectivity



2. Our Ambition

2.1. The Combined Authority and Leeds City Region Local Enterprise Partnership[2] (LEP) work in partnership with one another - and with local councils and businesses – to ensure everyone in our region benefits from a strong, successful economy and a modern, accessible transport network.

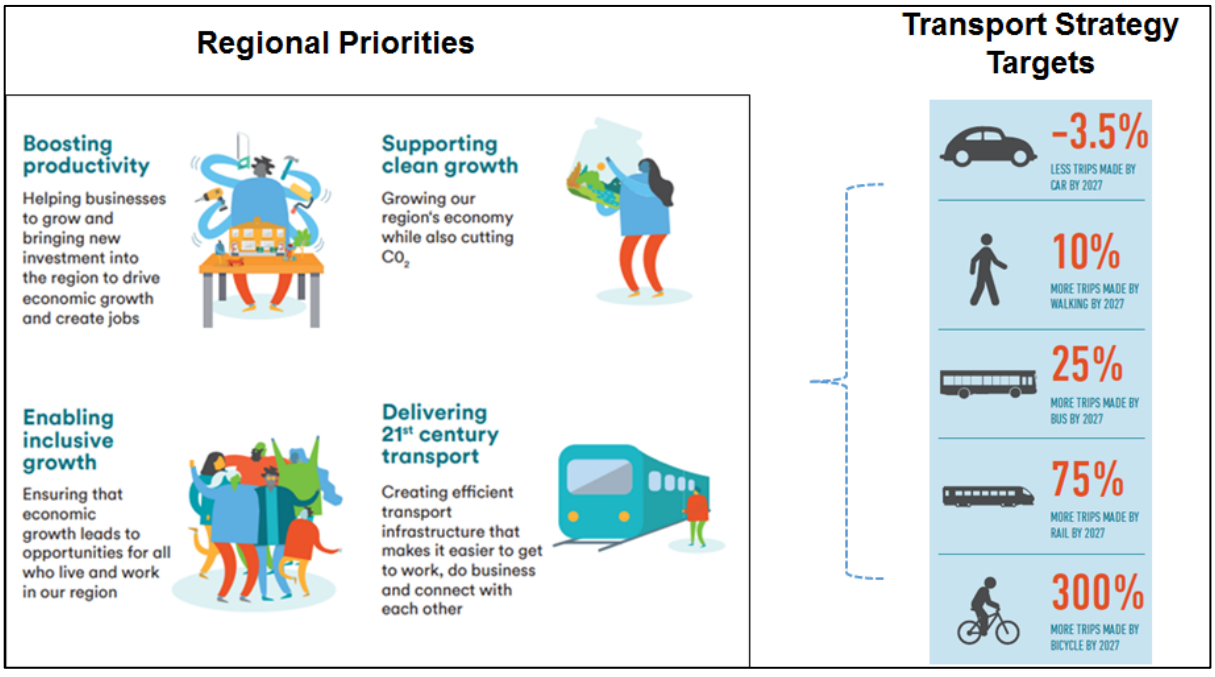
2.2. We want the Leeds City Region to be recognised globally as a place with a strong, successful economy where everyone can build great businesses, careers and lives supported by world-class transport, housing and digital connectivity.

2.3. We will achieve this by planning and delivering economic and transport schemes and programmes across the region in partnership with the public and private sectors – focusing on the areas of work which will make the biggest difference.

2.4. The Combined Authority has formally declared a climate emergency, alongside those of the partner councils, and the call for urgent collaborative action to tackle emissions can also be expected to influence the type of transport investments that will be delivered by the Combined Authority and partners in future. We are now developing a carbon budget and the pathway for changes to transport systems to deliver zero-carbon targets for the region.

2.5. As a region we have four strategic priorities as illustrated in Figure 1. To help achieve them , we have a series of targets for our transport system, which focus on delivering increasingly sustainable and active public transport modes and reducing car trips.

Figure 1: Leeds City Region Priorities



[2] https://www.the-lep.com/about-us/

3. Scope of 'Urban Transit' for this Market Testing

3.1. We are yet to determine the precise 'Urban Transit' vehicle technology[3] necessary; the conclusions of this important market testing will help shape our thinking on the scope, scale and potential technologies available as part of the development of a business case. The vehicle needs to be considered as part of an overall Transit System including the vehicle and associated infrastructure and integration into the cityscape and urban environment.

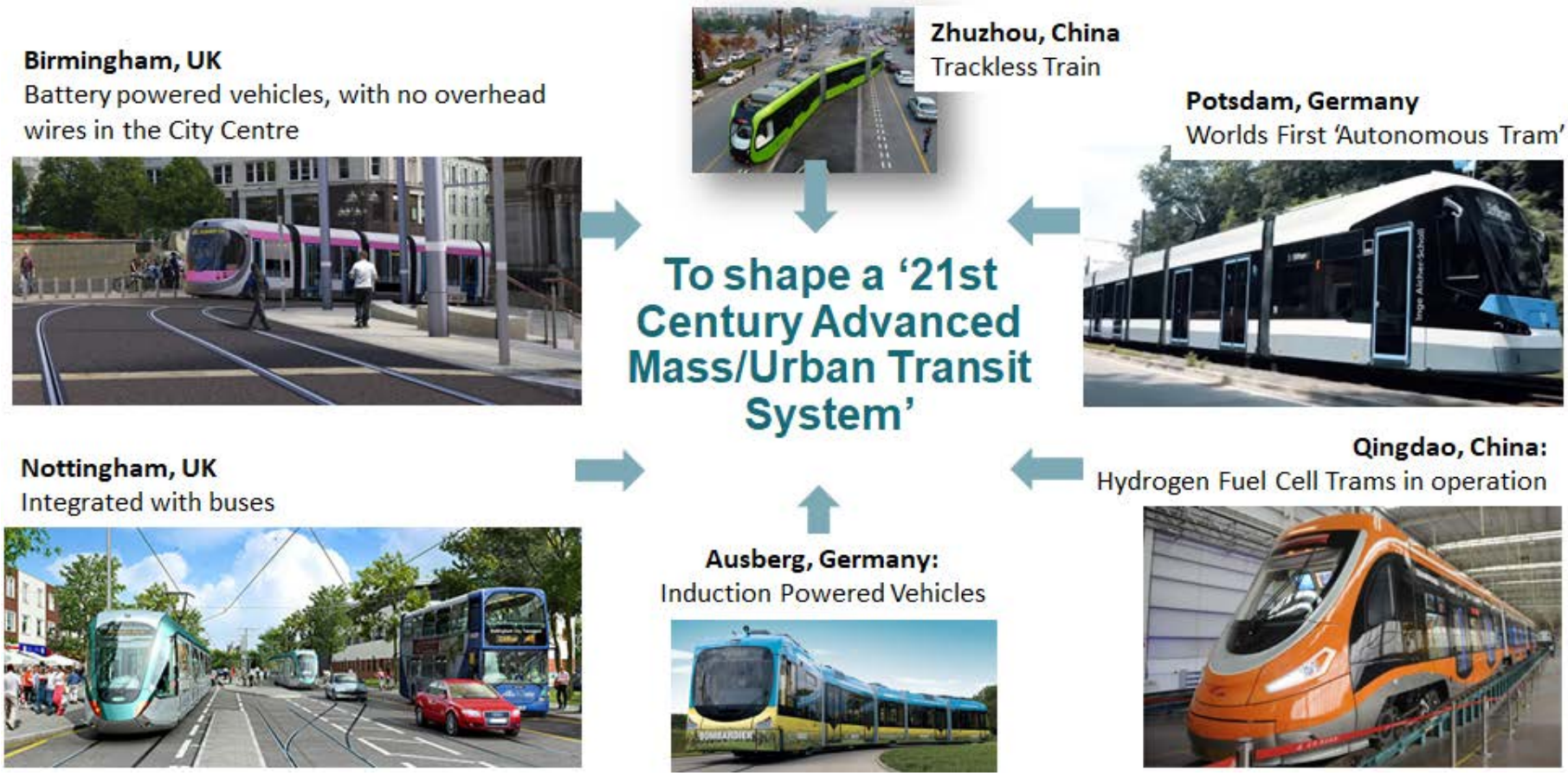
3.2. For the purposes of this market testing, we suggest that an 'Urban/Mass Transit' vehicle could include, but is not limited to, traditional Light Rail (steel wheel based), Tram-Train, or Bus Rapid Transit (rubber wheel based) types of vehicles where:

- Each individual vehicle/unit can allow 200-300 people to get on/off at every stop
- Each vehicle can operate through pedestrian and heritage environments in city centre urban areas
- Routes can have an end to end distance of between 10-30km
- Routes have frequent stops in city centres and general stopping patterns at around every kilometre
- The vehicles would be in operational service for up to 20-30 years, and
- As part of an 'Urban Transit system' the vehicle will need to plays its part in addressing the Climate Emergency.

3.3. We are open to discussing other types of vehicles which you view to be Urban Transit. However, for this Market Testing, an 'Urban Transit' system does not include a traditional double decker bus solution or a traditional Heavy Rail solution. Illustrations of the types of vehicles which are under consideration are set out in Figure 2.

[3] Further information on the current position can be found in Chapter 10 of this document

Figure 2: Blending together the best in class



4. Market Testing - Discussion Areas

Through this market testing, we are looking to discuss the following areas. These areas would form the agenda for any meetings and your responses:

Discussion Area 1

4.1. How do you think technologies used in the Urban Transit sector will change over the next decade?

We are interested to learn and understand your views around:

- Significant innovations and research and development in the industry, which we should be considering when planning an advanced Urban Transit system.
- Whether new Urban Transit systems should be designed for autonomous vehicle operation.
- What types of system technology and infrastructure we should consider (for example systems which do not need overhead wires, or grass tracks systems).

We are also interested to understand when emerging technologies are likely to become commercially viable, including life cycle costs and not just immediate costs, and, what might the enablers, longer term technology challenges and risks be?

Please consider how your views differ whether the Urban Transit solution is 'steel rail based' or 'rubber wheel based'?

Discussion Area 2:

4.2. How will the Urban Transit industry innovate to help address climate change and support the Authority's ambitions to address air quality to become a zero-carbon region by 2038?

We are particularly keen to stress that any new systems must help reduce transport carbon emissions which are predicted to increase under a business as usual scenario.

We are interested to understand whether new Urban Transit systems delivered over the next decade could be zero emitting and use different propulsion technologies (such as Hydrogen or Battery power operation) for the entire system, as well as other innovative technologies which can reduce operating costs and address climate change.

We would also like to understand the full lifecycle costs of the differing propulsion technologies.

Please consider how your views differ whether the Urban Transit solution is 'steel rail based' or 'rubber wheel based'?

Discussion Area 3:

4.3. *How should Advanced Urban Transit systems be designed to meet UK safety and regulatory requirements and support existing public transport services, whilst also complementing Mobility as a Service and the moves towards the autonomous vehicle revolution?*

We are interested to discuss best practice around how Urban Transit can integrate with existing bus services, local community bus and demand responsive services, and driverless 'uber style' systems?

Discussion Area 4:

4.4. What do you view as the operational and supply chain challenges and opportunities associated with developing and delivering Urban Transit systems in England?

As part of our ambition to deliver good growth and long lasting economic benefits to our region, we are keen to understand what you think the region should do to ensure there are the skills, labour market and resources available to deliver an Urban Transit system in West Yorkshire. For example, we are interested to hear you views of best practice around the skills programmes which can maximise the opportunity around development and delivery of an Urban Transit system.

We are also aware that there are currently no specific major Light Rail manufacturing / assembly bases in England and the trend is for manufacturers to set up bespoke factories to deliver new orders. What scale of Urban Transit system would be required in Leeds City Region for a manufacturer to set up a new assembly/manufacturing base for Urban Transit vehicles in this region? Or would it be more likely that a manufacturer might reconfigure an existing plant to deliver a variety of vehicles?

How would your views differ whether the Urban Transit solution is 'steel rail based' or 'rubber wheel based'?

We are mindful of the challenges involved in constructing the infrastructure for a modern urban transit system and the potential disruption that this might cause along the routes, particularly for businesses and residents. We would therefore like to hear your views on the merits of differing technologies and systems from the point of view of the ability to construct the infrastructure and minimisation of resulting disruption.

Also, for a project of this type what might be the timescales involved in the development and delivery of an urban transit system. What safeguards could be adopted to prevent overruns in the project delivery timescale?

Discussion Area 5:

4.5. How should the development, construction and operation of new advanced Urban Transit systems be funded and financed and how could phased introduction or expansion of Urban Transit systems be incorporated efficiently within funding structures?

How would the value for money of these funding models be measured and what safeguards could be considered to prevent the project exceeding budget?

How would your views differ whether the Urban Transit solution is 'steel rail based' or 'rubber wheel based'?

Discussion Area 6:

4.6. To what extent is it necessary to utilise new or innovative technologies, over and above proven technologies, to achieve the targets and outcomes set out in Figure 1? How could we best incorporate digital innovation in a new urban transit system?

What would you feel are the potential risks of utilising innovative technologies and do you have any examples of where such initiatives have gone well or have not perhaps delivered the expected results?

Discussion Area 7:

4.7. How should a mass/urban transit solution integrate / complement / compete with existing and future rail services?

Discussion Area 8

4.8. Any other observations around the future of Urban Transit, which you think we should take into consideration when developing its proposals

5. Audience - Who Should Respond

5.1. We want to hear views from:

5.1.1. Turnkey providers, promoters and operators of Urban Transit systems from across the world.

5.1.2. Industry Suppliers, technology providers, system developers and manufacturers of Urban Transit vehicles and infrastructure from across the world.

5.1.3. Bus companies operating within West Yorkshire as well as those operating elsewhere in the UK and across the world.

5.1.4. Academia and research institutions from across the world

5.1.5. City planners from across the world

5.1.6. Engineering and construction companies from across the world

5.1.7. Private/third sector consultancies, where these have worked in partnership with any of the types of organisations listed above.

6. Timescales - When you should respond

6.1. The following programme will allow the feedback received from this Market testing to feed into the Strategic Outline Business Case around this work, which is planned to be completed in early spring 2020.

- Issue PIN Notice: 23 August 2019
- Respondees issue email to (urbantransit@westyorks-ca.gov.uk) notifying the Combined Authority of your intent to take part in this market engagement: Emails must be received by **Thursday 31 October 2019 at 4pm BST (i.e. GMT + 1hr)** at the latest.
- Please feel free to respond as early as possible ahead of the deadline, in order to arrange a meeting. As emails are received during September/October, we will develop a schedule of meetings.
- Meetings arranged to take place: during Autumn/Winter 2019
- All meetings will need to have been concluded with all written representations received by **20 December 2019 at 4pm GMT**
- Report drafted and circulated to respondents: spring 2020.

7. How to respond

7.1. Any organisation that wishes to take part in this Market Testing should notify the Combined Authority by sending an Expression of Interest email to urbantransit@westyorks-ca.gov.uk, by the dates set out in Chapter 6. The email should:

7.1.1. Set out the name of the organisation

7.1.2. Provide contact details of their representatives who will take part

7.1.3. Set out *how* the organisation wishes to take part in the engagement. *(See paragraph 7.3 below)*

7.1.4. Where an organisation would like to hold a 1:1 meeting, the organisation should also suggest potential dates for this during September/October/November 2019.

7.1.5. Responses to the 'Discussion Areas' outlined in Chapter 4 are not required for the expression of interest email.

7.2. The Steering Group[4] will review correspondence received and oversee the itinerary of meetings.

7.3. We will be happy to discuss your response through:

7.3.1. A face to face meeting, preferably at our offices in Leeds, West Yorkshire, United Kingdom (other locations can be agreed as required); and/or

7.3.2. A virtual meeting over the phone or via video conferencing facilities; and/or

7.3.3. Receiving written representations (written responses should be no longer than 15 sides of A4 in total). The minimum font size is size 12)

7.4. Meetings will be chaired by a representative from the Combined Authority.

7.5. Depending on the number of emails received, we may not be able to hold 1:1 meetings with all respondees and may suggest that written representations are received from some organisations.

7.6. Responses after the closing date may not be considered. All correspondence should be via the following email address: urbantransit@westyorks-ca.gov.uk[5]

[4] The Steering Group includes representation from the University of Leeds, University of Huddersfield, Cllr Kim Groves (Chair of West Yorkshire Transport Committee) as well as officers from the Authority.

[5] We use the information received in accordance with our privacy notice.

8. Who we are

8.1. This Market testing is being undertaken in partnership between:

8.1.1. The West Yorkshire Combined Authority
8.1.2. The University of Leeds, Institute for Transport Studies
8.1.3. The University of Huddersfield, Institute for Railway Research

8.2. We provide background on each organisation below. The partners meet through a Steering Group.

West Yorkshire Combined Authority

8.3. The West Yorkshire Combined Authority[6] (The "Combined Authority") is the Local Transport Authority for the West Yorkshire region, serving a population of 3 million, which includes the major cities of Bradford and Leeds and the urban centres of Wakefield, Huddersfield and Halifax.

8.4. We work closely with the private sector through the Leeds City Region Enterprise Partnership (LEP) to ensure that our work meets the needs of employers in the region. We also operate the Metro network of bus stations, travel centres and public transport information in West Yorkshire.

8.5. The Combined Authority and Leeds City Region Local Enterprise Partnership[7] (LEP) work in partnership with one another - and with local councils and business – to ensure everyone in our region benefits from a strong, successful economy and a modern, accessible transport network. Although the Combined Authority and LEP are separate bodies, we have a shared vision for our region and a shared organisation to support delivery of this.

8.6. Leeds City Region is the UK's largest regional economy and is a national and international leader in key industries and one of the best places in the UK for businesses to grow. Leeds City Region comprises the ten districts of Barnsley, Bradford, Calderdale, Craven, Harrogate, Kirklees, Leeds, Selby, Wakefield and York

8.7. The Leeds City Region is a national centre of excellence for financial, legal and professional services, and a leader in digital technologies, manufacturing, healthcare and innovation, Leeds City Region generated a total gross value added (GVA) of £69 billion in 2017.

8.8. Leeds City Region lies at the heart of the Northern Powerhouse[8]. The Northern Powerhouse is the government's vision for a super-connected,

[6] https://www.westyorks-ca.gov.uk/about-us/
[7] https://www.the-lep.com/about-us/
[8] https://northernpowerhouse.gov.uk/about/

globally competitive northern economy with a flourishing private sector, a highly-skilled population, and world-renowned civic and business leadership.

University of Leeds – Institute for Transport Studies

8.9. The University of Leeds was established in 1904 and is one of the largest higher education institutions in the UK. We are renowned globally for the quality of our teaching and research.

8.10. The strength of our academic expertise combined with the breadth of disciplines we cover, provides a wealth of opportunities and has real impact on the world in cultural, economic and societal ways.

8.11. The University strives to achieve academic excellence within an ethical framework informed by our values of integrity, equality and inclusion, community and professionalism. Within the University, the Institute for Transport Studies[9] is one of the UK's leading departments for transport teaching and research. We deliver internationally excellent research outputs, which impact upon transport policy and practice, and contribute to the wider economy and society. Our research feeds directly into our teaching, which means you'll learn about the latest developments in your field from world-leading researchers.

8.12. We are a leading transport research centre worldwide. We deliver internationally excellent research outputs, which impact upon transport policy and practice, and contribute to the wider economy and society. Our research mission is to support the development of intelligent mobility systems that are connected, inclusive, productive and resilient. To find out more, browse a selection of our current and past research projects.

8.13. For example, The University of Leeds driving simulator is one of the most advanced driving research environments in the world; and allows research into driver behaviour to be performed in accurately controlled and repeatable laboratory conditions. The facility consists of a large motion-based driving simulator, an advanced commercial truck simulator, and an immersive pedestrian laboratory.

[9] https://environment.leeds.ac.uk/transport

University of Huddersfield – Institute of Railway Research (IRR)

8.14. The Institute of Railway Research (IRR)[10] within the School of Computing and Engineering at The University of Huddersfield is a world leading centre in the field of railway engineering and risk.

8.15. Our research has helped to improve the knowledge of the way in which railway vehicles interact with the track including key performance aspects such as suspension performance, wheel-rail contact, traction and braking. In partnership with industry and academic partners, this work has led to a number of tools and techniques being developed which are now used to predict deterioration of railway wheels and rails, to optimise the vehicle track interface, to increase safety and reliability levels, reduce cost and improve performance of the railway system.

8.16. We are part of the UK Rail Research and Innovation Network (UKRRIN) and within UKRRIN we host the Centre of Excellence in Rolling Stock. Together with the other academic and industry partners in UKRRIN we are developing innovations to support the next generation of railway vehicles. We are currently investing £10m in our rolling stock laboratory including a pantograph test rig and a passenger and driver motion platform which, together with our full-size roller rig will provide test facilities to support the testing of innovative vehicle designs.

8.17. Our Centre for Innovation in Rail (CIR) works together with its key industry partners to offer specialist technology and business services, funding opportunities and routes to market for developed concepts. We provide access to highly experienced academic rail specialists and advanced testing facilities to help our partners realise the full potential of services or products and successfully deliver these to the rail market.

[10] https://research.hud.ac.uk/institutes-centres/irr/

9. Conditions of Market Testing

9.1. This market testing assessment is being carried out in accordance with the fundamental EU principles of equal treatment, transparency and non-discrimination and in line with EU interpretative communication on public procurement (2006/C 179/02).

9.2. The Combined Authority published a Prior Information Notice (PIN) in the Official Journal of the EU (OJEU) confirming its intention to carry out a structured soft market testing exercise (not of the commencement of procurement). The Combined Authority also advertised the market testing exercise on Contracts Finder on gov.uk.

9.3. The Combined Authority understands that responding to this market testing process does not necessarily mean that any respondent necessarily supports in principle (or opposes) Urban Transit and any information is provided without prejudice to future engagement with the Combined Authority.

9.4. The Combined Authority retains the right to share the general findings of this process with Leeds City Region District Partners members.

9.5. The Combined Authority is committed to open government and the proactive release of the information it holds. As a public sector organisation, the Combined Authority is bound by the terms of Freedom of Information Act legislation and consequently any information provided to the Combined Authority may be requested by third parties. Respondents should note that the Combined Authority may be obliged to release information under Freedom of Information regulations. Respondents should clearly highlight any information which should remain confidential.

9.6. The Combined Authority will not pay for travel, accommodation or subsistence costs associated with attending market testing meetings or taking part in the market testing process.

9.7. The Combined Authority are keen to ensure that this market testing exercise is not onerous on respondents and therefore proposes to go through the following process in order to complete the market testing assessment:

9.7.1. Each interested party responding to the PIN/tender notice will be issued with this market testing discussion pack, thereby providing an equal opportunity to respond.

9.7.2. Following supply of this information pack to respondents, the Combined Authority will request individual discussions, either in person, on the phone, or in writing, with each respondent.

9.7.3. Each respondent will be given the opportunity to formally reply to the questions raised in this document.

9.7.4. The Combined Authority will collate responses from respondents and produce a market testing report, which would inform future scheme development.

9.7.5. The Combined Authority may ask further follow-up questions that need to be asked of parties to ensure that consistent information has been provided.

9.7.6. The Combined Authority will produce a market testing report to summarise the findings of the exercise. This report will be shared in draft form with respondees who can request amendments and/or redactions.

9.8. The Combined Authority would like to thank in advance the time and support provided by those organisations which take part in this market testing.

10. Background - Developing a New Connectivity Strategy

10.1. The information set out below is based on a report endorsed by the West Yorkshire Transport Committee:

10.2. Leeds City Region is growing. At the heart of the North of England, it is an attractive place to live, increasingly attracting highly skilled, knowledge intensive service sector workers as well as new tourism/cultural/leisure opportunities. However, as the population has increased, transport congestion and air quality have become major constraints on inclusive growth.

10.3. Significant interventions are planned through the West Yorkshire Transport Fund and Connecting Leeds programmes and by the rail industry. However, there remains insufficient resilience and capacity in our urban transport system, particularly to the key employment centres. This will constrain business labour markets catchments and constrain the ability to train and develop the next generation, by restricting access to colleges and universities. As identified by the National Infrastructure Commission, this is affecting many urban centres across the North of England and will increasingly inhibit economic development, living standards and our ability to help rebalance the national economy.

10.4. Urban transport infrastructure to distribute the benefits of HS2 / Northern Powerhouse Rail ("NPR") cannot drive inclusive growth alone; a range of factors are essential to creating a coordinated programme of activity aiming to create more and better jobs, with a highly skilled workforce to sustain them. But the lack of urban transport capacity/infrastructure will inhibit growth.

10.5. To address this, the West Yorkshire Combined Authority is developing a new Connectivity Plan[11] to identify how transforming key strategic urban transport infrastructure in the communities of greatest economic need will help raise productivity, living standards and improve air quality, thereby helping to deliver Inclusive Growth.

10.6. West Yorkshire Combined Authority, as part of its Future Mobility Zone (FMZ) bid, is also pursuing a globally significant future mobility demonstrator project featuring an innovative approach to address mobility equity, using Connected and Autonomous Vehicles (CAV's) in a targeted trial and comprehensive evaluation of its effectiveness and interaction with a wide variety of groups in the community. This project will form an exportable template for other cities specifically looking to address equity of access, and will demonstrate a solution that can be replicated in cities across the globe looking to maintain access whilst improving environments and protecting citizens.

[11] Further details can be found online: 39. Planning for Growth: The Leeds City Region Connectivity Strategy: https://www.yourvoice.westyorks-ca.gov.uk/1851/documents/2007

10.7. Through analysing a range of evidence sources across: socio-economic demographics; major housing and employment opportunities; anticipated land use changes and new employment growth zones; the environmental and clean energy opportunities; the known transport constraints as well as the forecast changes to travel demand patterns and capacity, we have identified the key 'places to connect' for the four corridors identified and examined so far.

10.8. The work to date proposes three new public transport services to increase capacity between key local urban communities into national hubs. Some of these services have the potential to require entirely new infrastructure and whilst complementary to the existing transport system, offer the opportunity to reimagine how other modes such as bus and rail can integrate with it. Together these new services would form the first tranche of the 'City Region Transit Network' to open in parallel with HS2 Phase 2B opening in Leeds 2033.

10.9. Through the analysis undertaken to date, it is likely that Urban Transit vehicles (i.e. vehicles which can carry between 200-300 people – a vehicle of this size requires a steel rail) are anticipated to be required to meet the capacity need in delivering these new City Region Transit Network services.

10.10. Different modes of transport serve different needs and provide different levels of capacity. Technologies have moved forwards significantly in the last decade. For example, new battery technologies, hydrogen propulsion and autonomous innovations are changing Advance Urban Transit vehicle technologies, which also improve air quality. There are a range of pros and cons for each individual vehicle technology option.

10.11. Respondents should note that detailed alignments, confirmation around mode choice and business case value for money assessments would be developed as part the next stage of development works and would also be informed by feedback and amendments resulting from the proposed forthcoming public engagement as well as this market testing exercise

Appendix 2:

Copy of Prior Invitation Notice issued in August 2019

Print Close

LANGUAGE:	EN
CATEGORY:	ORIG
FORM:	F01
VERSION:	R2.0.9.S03
SENDER:	TED05
CUSTOMER:	WESTYORKSCA
NO_DOC_EXT:	2019-000032
SOFTWARE VERSION:	/
ORGANISATION:	West Yorkshire Combined Authority
COUNTRY:	UK
PHONE:	/
E-mail:	urbantransit@westyorks-ca.gov.uk
NOTIFICATION TECHNICAL:	/
NOTIFICATION PUBLICATION:	/

I.II.IV.VI.

Prior information notice

This notice is for prior information only

Services

Legal Basis:

Directive 2014/24/EU

Section I: Contracting authority

I.1) **Name and addresses**
West Yorkshire Combined Authority
Leeds
United Kingdom
E-mail: urbantransit@westyorks-ca.gov.uk
NUTS code: UKE
Internet address(es):
Main address: https://www.westyorks-ca.gov.uk/

I.2) **Information about joint procurement**

I.3) **Communication**
Additional information can be obtained from the abovementioned address

I.4) **Type of the contracting authority**
Regional or local authority

I.5) **Main activity**
Other activity: The West Yorkshire Combined Authority is the driving force for economic growth across Bradford, Calderdale, Kirklees, Leeds and Wakefield districts and the city

of York Council area

Section II: Object

II.1) **Scope of the procurement**

II.1.1) **Title:**
Advanced Urban Transit Technologies: Market Testing and Call for Evidence

II.1.2) **Main CPV code**
60000000

II.1.3) **Type of contract**
Services

II.1.4) **Short description:**
The purpose of this 'Advanced Urban Transit' market testing is to shape the West Yorkshire Combined Authority's thinking on the scope, scale and deliverability of the potential transit technologies available, at the early stages of development. The feedback received through this market testing will help the Authority develop/design an 'advanced Urban Transit system' which integrates the public transport network together and allows us to remain at the forefront of technologies for many years to come. It will help to ensure design/development work is undertaken to create the most innovative system which meets our local priorities and is deliverable before 2033. The Authority are seeking the views from all promoters, manufacturers, suppliers, constructors, engineers, system developers and operators of 'Urban Transit' systems from across the world.

II.1.5) **Estimated total value**

II.1.6) **Information about lots**
This contract is divided into lots: no

II.2) **Description**

II.2.1) **Title:**

II.2.2) **Additional CPV code(s)**
66000000
60000000

II.2.3) **Place of performance**
NUTS code: UKE

II.2.4) **Description of the procurement:**
Full details of the 'Advanced Urban Transit Market Testing' can be found in the accompanying brief document. The Authority wants to hear the views from: - Turnkey providers, promoters and operators of Urban Transit systems from across the world. - Industry Suppliers, technology providers, system developers and manufacturers of Urban Transit vehicles and infrastructure from across the world. - Bus companies operating within West Yorkshire as well as those operating elsewhere in the UK and across the world. - Academia and research institutions from across the world - City planners from across the world - Engineering and construction companies from across the world - Private/third sector consultancies, where these have worked in partnership with any of the types of organisations listed above.

II.2.14) **Additional information**

II.3) **Estimated date of publication of contract notice:**
02/09/2019

Section IV: Procedure

IV.1) **Description**

IV.1.8) **Information about the Government Procurement Agreement (GPA)**
The procurement is covered by the Government Procurement Agreement: yes

Section VI: Complementary information

VI.3) **Additional information:**

VI.5) **Date of dispatch of this notice:**
02/05/2019

Appendix 3:
List of Participants

- 2getthere
- AECOM
- Abbott Risk Consulting
- Acorel –
- Alexander Dennis
- All Party Parliamentary Light Rail Group
- Alstom
- Amey
- ARUP
- Ascendal Group Limited
- BYD CO
- Balfour Beatty
- BDP
- Beem Car Holdings Ltd
- Bombardier
- BRT UK
- Buro Happold -
- BWB
- CAF
- CarLina (SEA) Aida
- Chamber of Commerce
- Chartered Institute of Logistics & Transport
- City Fibre
- Corderoy
- Costain
- COWI UK Limited
- CCCC
- CRBC
- CRRC Changchun Railway Vehicles
- CRRC Sifang
- CRRC Zhuzhou Times Electric Co
- CRRTEC
- CRSC
- Cubis Systems
- Deloitte
- DPP
- First Group
- Gaist
- Hassell
- Hitachi Rail
- Hollysys
- Huawei
- IBM
- Idox Software Ltd
- ITP / CEG
- Jacobs
- James Fairchild Ltd
- Jarrett Walker + Associates
- Jordans Consultancy
- Keolis
- Leonardo
- Light Rail Safety and Standards Board
- Light Rail Transit Association
- LLC
- M&G Barry Consulting Ltd
- Marubeni
- Mobility Lab
- MTR
- Network Rail
- Optare
- Pandrol
- Pelican
- Rand Europe
- Ridge Partners
- Rloop
- Samocat
- SCP
- Serco
- SET Limited
- Siemens
- Sinosure
- Squibb Group
- Stantec
- Stadler Rail
- Steer
- Suzhou Huaqi
- Thales Group
- TIG/m
- Tongxum
- Tony Gee & Partners
- Track 11
- Transdev
- TRIA Rail
- TSO
- University of Cambridge
- Van Elle
- Vivarail
- Waldeck
- Wood
- Worldline
- Xiamen Golden Dragon Bus
- Zhengzhou Yutong
- 15 individual members of the public

Not all participants submitted response documents

Appendix 4:

Summary of images provided by respondents

Advanced Urban Transit Technologies: Market Testing

Appendix 4
Summary of images provided by respondees

West Yorkshire Combined Authority

Tram - Catenary System

West Yorkshire Combined Authority

Tram - Battery Powered

West Yorkshire Combined Authority

Tram - Continuous Power System in Roadway

Hitachi Continuous Power Tramwave System installed in carriageway

West Yorkshire Combined Authority

Hydrogen Powered Vehicles

Alstom Coradia iLint heavy rail vehicle

West Yorkshire Combined Authority

Zero Emission Bendy Bus

West Yorkshire Combined Authority

Bus Rapid Transit

Belfast Glider - Van Hool ExquiCity 18 articulated buses of a light tram design with three doors and approximately 18 metres in length.

West Yorkshire Combined Authority

Advanced Very Rapid Transit (AVRT)

Proposals for affordable Mass Transit for Cambridge and the wider Region

West Yorkshire Combined Authority

Monorail / Personal Rapid Transit / Elevated Pods

BeemCar four seater pod

CarLina elevated pod system

West Yorkshire Combined Authority

Hyperloop

Virgin Hyperloop One

West Yorkshire Combined Authority

Automation

West Yorkshire Combined Authority

Autonomous Metro

Hitachi Supplied Driverless and CBTC Controlled Metros

West Yorkshire Combined Authority

Autonomous Electric Bus

Alstom Aptis electric bus

West Yorkshire Combined Authority

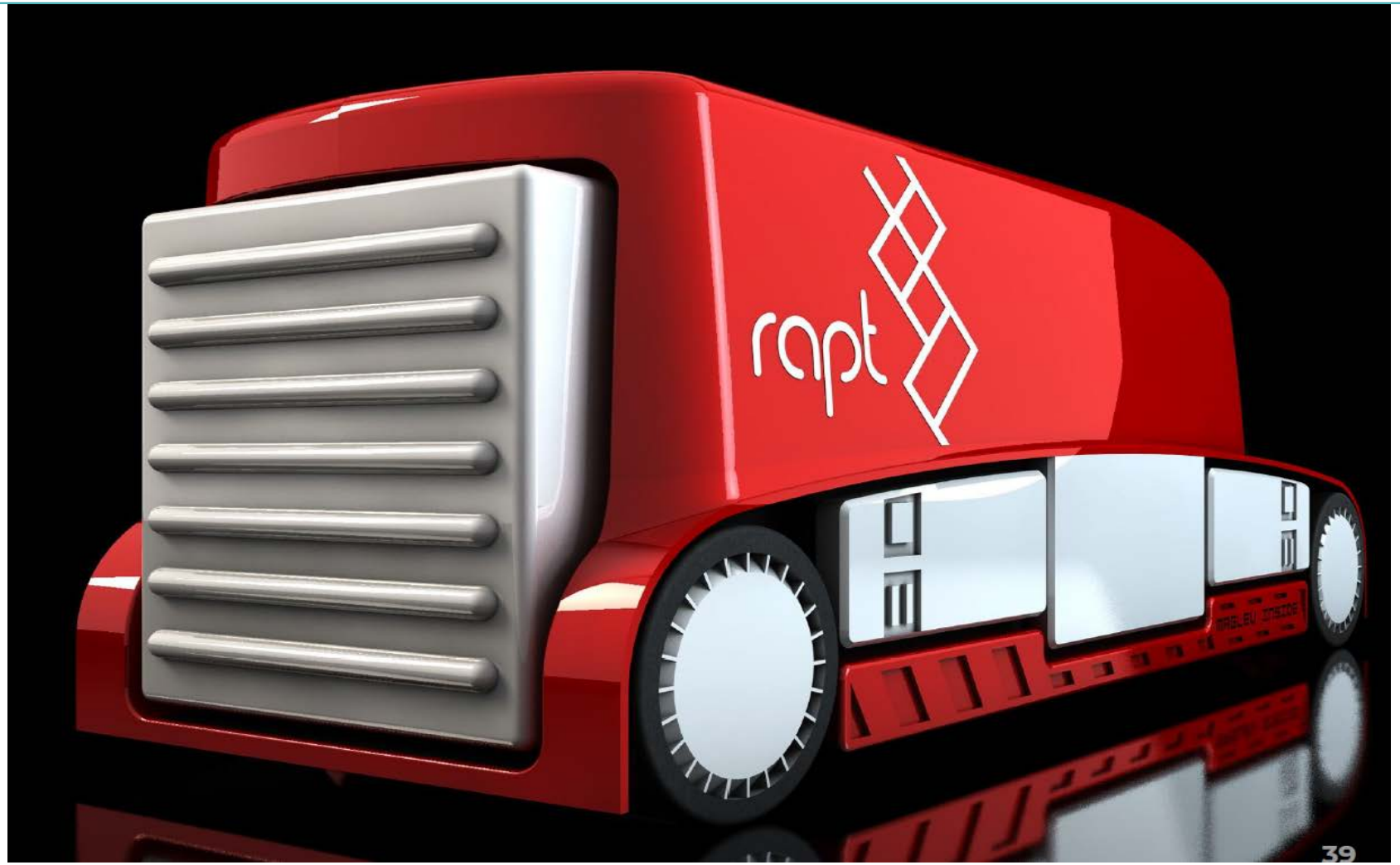
Autonomous Shuttle

Autonomous Transit System, Jacksonville U2C

Autonomous Personal Rapid Transit (PRT)

West Yorkshire Combined Authority

Autonomous Freight Shuttle



Rloop Autonomous Freight Shuttle concept

West Yorkshire Combined Authority

Autonomous Car Transporter

Rloop Autonomous Car Transporter concept

Driver Aids

Obstacle Detection Assistance System

Arrangement of ODAS cameras in the drivers cab

Online-displayed visualization of current energy consumption in different colours helps drivers adjust their drive-style.

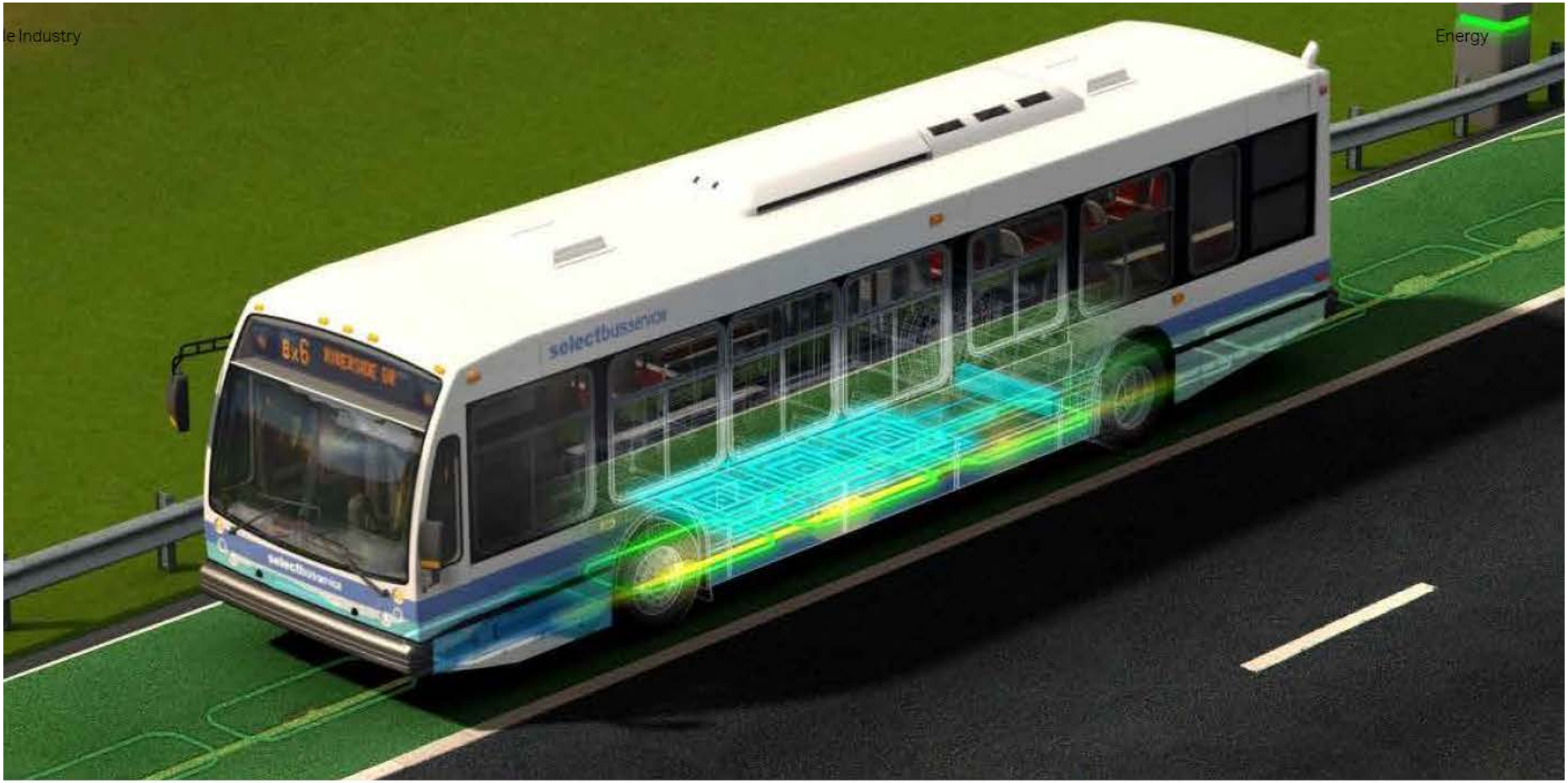
Intelligent Driver's Desk

West Yorkshire Combined Authority

Energy Storage & Charging

West Yorkshire Combined Authority

In-Carriageway EV Charging



In carriageway inductive loop charging for battery powered vehicles

West Yorkshire Combined Authority

Catenary Charging Pad at Terminus

West Yorkshire Combined Authority

Battery Propulsion - Catenary Charging in Stops

West Yorkshire Combined Authority

Hydrogen Refueling Station

West Yorkshire Combined Authority

Hybrid Super-Capacitor Battery Tram

CRRC - Qinghai-Tibet Plateau, China

West Yorkshire Combined Authority

Interchange & Urban Environment

West Yorkshire Combined Authority

Frictionless Interchange

Nottingham NET Tram Bus interchange point

West Yorkshire Combined Authority

MRT Integration – Urban Environment

Manchester Metrolink – St Peter's Square

West Yorkshire Combined Authority

Urban Architecture & Landscape

Strasbourg Tramway

West Yorkshire Combined Authority

Grass Track

West Midlands Metro

West Yorkshire Combined Authority