Imagining urban mobility futures in the era of autonomous vehicles—insights from participatory visioning and multi-criteria appraisal in the UK and Australia

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Imagining urban mobility futures in the era of autonomous vehicles—insights from participatory visioning and multi-criteria appraisal in the UK and Australia

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ABSTRACT

Autonomous Vehicles (AVs) present enormous uncertainties and challenges for future urban transport and mobility. While urban and transportation planning have significant roles to play in shaping these futures, a critical challenge is identifying and reconciling divergent values and competing visions in relation to this potentially disruptive transport technology and the associated mobility services. In this paper, we demonstrate the use of a participatory multi-criteria visioning and appraisal framework and methodology to enable stakeholders to envision, identify and interrogate essential tensions between imagined AV futures and long-term transport and mobility imperatives. Based on workshops with stakeholders at the forefront of policy and practice, and academia in Greater Manchester (UK) and Melbourne (Australia), we reveal several insights. Regarding the prospects of AVs, our participants are neither 'opponents' nor 'evangelists', but instead, manifest the contrasting attitudes and perspectives of excitement, optimism, ambivalence, scepticism and uncertainty all at the same time. In the visions outlined and appraised, our stakeholders identify AVs prospects in various use cases, such as public transport, personal and shared-use and urban freight and delivery applications, while at the same time recognising the inherent contradictions between automated driving futures outlined and imperatives such as reversing auto-mobility and creating safe and inclusive urban environments. Finally, the study brings to the fore the significant role of governance in mediating the politics and resolving contestations in critical areas including data management and privacy, cybersecurity and implementing viable business models and ownership arrangements.

1. Introduction

Many cities are experimenting with Autonomous Vehicles (AVs) through pilot projects to explore possible use cases, promote public interests and acceptability and assess how they may help address challenges at the intersection of transport and mobility and wider urban development imperatives. New and emerging transport technologies, such as fully-autonomous vehicles, may contribute to addressing the grand challenge of creating inclusive and environmentally sustainable urban mobility futures. Yet, there are enormous uncertainties regarding how AVs and the associated mobility services will impact urban transport systems and societies when they become a diffused mode of transport. As Lyons (2022) notes, as automated driving futures unfold over time, new consequences and responses will evolve such that judging the success or otherwise of steps taken to shape those futures will remain elusive.

AVs are presented as the most significant transformation in urban and transportation planning since the advent of the private motor vehicle nearly seven decades ago (Legacy et al., 2019; Cugurullo et al., 2021). The transition to AVs in cities therefore presents profound challenges in terms of developing the connected environment and infrastructure systems required; creating inclusive urban environments for the movement of people and different transport modes; and shaping the overall emergent patterns of physical development and associated urban forms. Thus, in order to transition in a manner that minimizes disruptions and optimises benefits for people, cities need coherent and

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flexible policies and strategies to inform the diffusion of AVs(Dean and Kockelman, 2022) .

Urban and transportation planning have significant roles to play in bringing about desired urban futures in the era of automated driving. However, the evidence suggests that across countries where AV trials are taking place, there exist significant gaps between visions of AV futures and local transportation planning goals. In their recent study that assessed AV pilot projects in the United States of America (USA), McAslan et al. (2021) concluded that there is a disconnect between on-going pilot projects and local transportation visions. They found that cities in the USA generally lack a long-term vision for how AVs fit into their future transportations systems as well as how they might help address current and future transport and mobility challenges. In Australia, Legacy et al. (2019) argue that while policy-makers recognise the need to regulate and plan to shape AV futures, in order to meet social and environmental imperatives, there appears to be little understanding as to how this might be achieved in practice.

As new transport innovations and mobility services emerge and create further uncertainties about the future of transportation, engagement with different actors in the public and private sectors as well as citizens become ever more critical to shaping those futures. Public engagement is critical to identifying and reconciling divergent values and competing visions about AV mobility futures (Lyons, 2022). Through stakeholder engagements, strategic policy and planning can anticipate and mediate unwanted socio-spatial impacts of transport innovations (Legacy et al., 2019). Multi-stakeholder engagements could also present opportunities for cities to develop long-term visions for how AVs fit into future urban mobility systems, and design strategies to effectively capture public value from transport innovation (Docherty et al., 2018).

Participatory multi-stakeholder visioning approaches that have long-standing history of application in the fields of urban and transportation planning (see e.g. Soria-Lara et al., 2021; Neuvonen and Ache, 2017; Spickermann et al., 2014; Schuckmann et al., 2012), are being employed by researchers to engage different stakeholders to imagine and anticipate possible costs and benefits of AVs. Two broad types of research in this area can be identified in the emerging literature. The first broad category, employs foresight methodologies such as scenario analysis (Milakis et al., 2017a) and the Delphi method (see e.g. Merfeld et al., 2019). These previous studies have not explicitly been about stakeholder engagement for policy-making. Instead, they explored AV development paths, forecast market penetration levels and the identified conditions for market success. The second category of studies have participatory visioning with a policy-making focus as their explicit goal, using forecasting or backcasting approaches (e.g. Lyon, 2022; Brovarone et al., 2021; Nogués et al., 2020; González-González et al., 2019). For example, Lyon (2022) developed and applied an emulsion methodology that brings together people with alternative perspectives on AVs to explore plausible utopias/dystopias into the future. The emulsion approach led to identification of principles to guide present-day policy, rather than generating and appraising alternative visions or discrete AV future scenarios.

The objective of this paper is to demonstrate how multiple stakeholders imagine and evaluate plausible urban transport and mobility futures in the context of fully autonomous vehicles. To this end, we developed and applied a participatory multi-criterion visioning and appraisal framework and methodology with which we engaged stakeholders to collaboratively envision and interrogate possible AV futures. Through visioning workshops held in Greater Manchester (UK) and Melbourne (Australia), the paper presents a comparative analysis of the different ways in which stakeholders directly involved in policy and practice, as well as academia are thinking about their transport and mobility futures in the context of AVs. The study makes important methodological and practical policy-relevant contributions to the emerging literature around AVs and the future of urban transport in the following ways: we demonstrate the utility of a participatory multi-criteria visioning and appraisal framework that can be applied in different contexts to engage stakeholders in constructive dialogue about the implications of new and emerging technologies and associated mobility services. Most importantly, using the empirical case studies, we provide useful insights into how policy-makers perceive the prospects of AVs on the one hand and the essential tensions between the advent of AVs and local transport and mobility goals and expected outcomes on the other hand. Ultimately, the paper highlights some of the on-going debates around future mobility transitions and identifies normative imperatives that would have to prevail for new technologies, such as AVs, to contribute to creating sustainable urban futures.

The rest of the paper is structured as follows: previous AV mobility futures studies employing multi-stakeholder visioning and foresight approaches are reviewed in **section 2**. In **section 3**, the multi-criteria methodology employed in our present study is presented. The results and discussion of the findings and their implications are the focus of **sections 4 and 5**, respectively, followed by our conclusions in **section 6**.

2. Envisioning automated driving futures: an overview of multi-stakeholder foresight approaches

The emerging research on AVs, including studies on public attitudes and acceptance, simulation-based diffusion and impact studies and scenario-based visioning, all grapple with questions around uncertainty; an inherent challenge when anticipating futures where information is limited. Consequently, various assumptions must be made. A survey through the literature suggests that in relation to AVs, there appears to a consensus that the question is no longer about whether they will happen, but rather one of when they will become part of the everyday. Thus, the various strands of the emerging literature begin on the fundamental premise that AVs are imminent. From this premise, the ultimate goal has been to explore and understand the complex links that exist between the advent of AVs and other priority problems in critical areas, such as public health (e.g. Rojas-Rueda et al., 2020; Sohrabi et al., 2020), equity of access (e.g. Emory et al., 2022; Zandieh and Acheampong, 2021; Faber and van Lierop, 2020) and sustainability (e.g. Grindsted et al., 2022; Cugurullo et al., 2021; Williams et al., 2020).

To address the challenge of uncertainty, participatory foresight methodologies are increasingly being employed to anticipate and explore questions about the future of transport and mobility in the context of AVs. They are seen as helpful in exploring unexpected outcomes over long-term future timelines through dialogue and consensus building, and in providing broad legitimacy to present-day decision-making processes about future challenges, possibilities and normative outcomes (Soria-Lara et al., 2021; Spickermann et al., 2014).

One of the common foresight methodologies that has been employed to anticipate AV futures is the Delphi method. As an established participatory foresight methodology, this method elicits diverse opinions of stakeholders, often domain experts with the goal of reaching consensus on a number of issues (Melander, 2018). In the context of AVs, Merfeld et al. (2019) conducted a four-stage exploratory Delphi-study with 40 international experts to elicit the drivers, barriers, and future developments in shared-autonomous vehicles over a ten-year horizon. They identified the interplay of key factors including technological development, legislation, and market acceptance and changing societal conditions as shaping the future development of car-sharing with autonomous vehicles. Despite yielding a number of useful insights regarding the conditions that will be required to support and promote shared-mobility, they focus on a single use case (i.e. car-sharing). Moreover, Merfeld et al.'s (2019) focus was not explicitly about consensus in the context of public policy-making, but rather on business-side issues, such as, identifying the factors affecting shared service proliferation, consumer acceptance and market success.

A closely related study, but with a slightly different focus is that of Milakis et al. (2017a), which employed scenario analysis to identify

plausible future development paths of AVs in the Netherlands, and to estimate potential implications for traffic, travel behaviour and transport planning on a time horizon up to 2030 and 2050. Through a series of workshops involving expert stakeholders, they construct scenarios based on assumptions of different levels of technological development and policy support (or constraints) for AVs. They conclude that complexities of the urban environments where AVs are expected to navigate unexpected incidents could influence AV development paths significantly.

Yet another foresight methodology applied in the literature is backcasting (González-González et al., 2019; Brovarone et al., 2021). Contrary to forecasting approaches, backcasting works from an ideal future scenario to identify critical decisions and steps that are required to achieve that future (Banister et al., 2007). González-González et al. (2019) employed backcasting to investigate whether and how the potential impacts of AVs can support or threaten a range or urban development policy goals. In their approach, they first identified key concepts and values of sustainable place-making. They then work backward to explore critical policy goals that will be needed if AVs are to contribute positively to creating sustainable cities. Their findings highlight the need for urban planning and development that brings about mixed land uses; promotion of shared-mobility services; and the need to restrict vehicle access within and outside city core areas.

More recently, Lyons (2022) employed an emulsion approach to envision automated driving futures. This approach brings together into constructive dialogue (i.e. the emulsion), people with alternative perspectives on AVs (i.e. evangelists, opponents and agnostics) that may not typically mix to imagine plausible utopias and dystopias for an automated driving future. A 'Three Horizons' futures method is then used to explore: (a) the dominant world of today which, in the face of transition, would diminish in dominance going into the future—first horizon; (b) how a future world emerges, from glimpses of the future in the present to becoming dominant in 2050—third horizon; and (c) an intermediate, unstable transition space in which the first and third horizons collide—second horizon. The goal of the emulsion methodology is to generate guiding principles for present day policy. While this methodology has dialogue, consensus building and public policy-making as the primary focus, it does not necessarily lead to the generation of discrete alternative visions of the future that is appraised against identified normative goals and outcomes.

From the foregoing, it becomes clear that the purpose of the visioning is to determine the approach and methods used. When the goal is to identify and explore the essential tensions among alternative visions of the future, as is the case for our present study, foresight methodologies with multi-criteria analysis (MCA) are considered particularly relevant (see e.g. Jiang et al., 2022). MCA is a foresight methodology that allows identifying policy options and evaluating them against a set of indictors or criteria (Dodgson et al., 2009). Typically, MCA involves establishing the decision context and identifying the overall aim and the relevant stakeholders to be involved. It also involves identifying options/scenarios and a set of criteria to be used to evaluate the scenarios (ibid). Thus, employing MCA, multiple stakeholders can identify a set of evaluation criteria, which reflects their normative goals and expectations regarding a given end state (e.g., what the future of transport and mobility in their city should look like) and attach weights to each of the criteria. The weighted criteria are then used to quantify the extent to which each of the future visions under consideration meets the end goals. Multiple conflicting goals become apparent as each vision is compared against each criteria. Ultimately, as we will later show in this paper, the overall approach can provide a systematic and robust way of reflecting the essential tensions between visions of the future on the one hand and normative expectations of policy on the other hand.

In the section that follows, the participatory MCA-based foresight methodology we developed and employed to envision urban mobility futures in the context of AV is presented.

3. Methodology: participatory multi-criteria visioning framework

The participatory multi-criteria methodology employed to envision and appraise visions of urban mobility futures in the era of AVs is outlined in this section in the following order: Firstly, a brief description of the decision context (i.e. Greater Manchester (UK) and Melbourne (Australia)) is presented to foreground the case study areas in the MCA framework and approach. Next, the MCA implementation protocol is presented, outlining how multiple stakeholders were engaged through a sequence of workshop-based activities to imagine and appraise the consequences of AVs in the future mobility systems of the case study areas.

3.1. The visioning contexts—Greater Manchester and Melbourne

Greater Manchester is a city-region of more than 2.8 million in North West England. The city-region comprises ten boroughs (local governments) which together constitute The Greater Manchester Combined Authority (GMCA). The city-region has an elected mayor who serves as chair and eleventh member of the GMCA and is also the lead for Policy Reform and Transport. In its 2018 Greater Manchester Digital Strategy, the city-region set an ambitious vision to be *"recognised as an international thought leader and do-er in digital innovation and adoption across our economy and communities"* (GMCA, 2018, p.2). To this end, a number of smart city demonstrator initiatives and projects have been implemented across the city-region in recent years (see e.g. Ng et al., 2022). Notable among them is CityVerve, a recent smart city initiative to demonstrate how Internet of Things (IoT) technologies could be leveraged to improve city services across a number of sectors including transport and mobility, energy, health and social care.

AVs have also featured prominently in the city-region's overall digital transitions agenda. In late 2021, under the flagship Project Synergy initiative, AV trails have taken place in the region's Heaton Park, where autonomous pods took visitors on a defined route around the park. The stated objective of the trails is for the TfGM to "understand how connected and autonomous vehicles can help address key transport challenges within Greater Manchester, including accessibility, mobility, traffic congestion and air pollution by using innovative technologies linked to new and emerging business models such as Freight-as-a-Service (FaaS) and Mobility-as-a-Service, (MaaS).[1] Moreover, in October 2019, TfGM with support from public participation charity *Involve* ran 'The Citizens' Conversation on Driverless Vehicles to explore public perspectives on AVs (Involve, 2019).

Larger than Greater Manchester, metropolitan Melbourne is home to a population of over 5 million inhabitants and consists of 31 local governments. Unlike Greater Manchester, metropolitan Melbourne does not have a governing metropolitan body. Instead, transport planning is primarily the jurisdiction of the State of Victoria. Planning in Victoria is conducted through a market-based neoliberal ideology, which precipitated in the 1990s the franchisation of the train, tram and bus systems across the state (see Ashmore et al., 2019), and the reduction of the state transport planning bureaucracy placing considerable stress on the public service to proactively and strategically plan for the future of transport (Legacy et al., 2019).

Despite the limits of the existing public service, discussion about the future of urban transport continue unabated. For instance, the independent infrastructure advisory agency, Infrastructure Victoria (2018) discusses the benefits of automated vehicles by coupling the emergence of this technology with zero emission vehicles, stating, they "may be realised without government intervention", and that "there are important actions that Victorian state and local government should take now

[1] More information about Project Synergy can be found here: http://synergy-cav.com/.

and in the future to enable their deployment" (p. 10). The Department of Transport recognises the role that connected and automated vehicle technology will play, and the benefits they will bring to road safety, as well as offer economic benefits, including increased productivity and network efficiency (Victorian Government, 2020).[2] The peak automobile association, the RACV, also celebrates the opportunities arising from AV technology, speaking on the importance of reducing human error on the roads, and improving accessibility for those with limited mobility (RACV, 2022). Citing their participation in automated technology trials and using the streets of Melbourne as "a living laboratory", major toll-road operators such as Transurban are lending their names (and the roads they control) to such trails (RACV, 2022)[3].

Based on the foregoing, Greater Manchester and Melbourne provide useful contexts for the comparative analysis and understanding of the emerging policy discourse around AVs and how they may shape long-term transport and mobility goals. In particular, the two case studies help illustrate the similarities, both in terms of local transport and mobility imperatives, as well as the different ways in which AVs are perceived and expected to shape the realization of those imperatives, negatively and positively. Most importantly, these comparative case studies also help to identify differences in the regulatory interventions and governance approaches that could emerge in response to AVs and how those, in turn, could either entrench or lead to radically different business models and new possibilities of configuring ownership and operation of future mobility services.

3.2. MCA implementation protocol: visioning workshops and participants

The MCA-based visioning and appraisal methodology involved bringing together multiple stakeholders through the "*Autonomous Vehicles and Urban Mobility Futures Visioning Workshop*" –a one-day workshop held in Manchester and Melbourne. Whereas the workshop in Manchester involved the participants meeting in person, that of Melbourne was held online, using a video conferencing platform, because of the Covid-19 pandemic.

We sought participation from policy-makers and practitioners in the arena of transport and urban development, as well as relevant experts in academia and industry. We compiled an initial stakeholder list of organizations and/or individuals within the organizations and invited them to the workshops via email. Participation in the workshops was voluntary. Ultimately, a total of 16 and 17 participants (excluding members of the research team) took part in the visioning workshops held in Manchester and Melbourne, respectively.

Our Manchester participants included representatives of Highways England and Network rail (owner and infrastructure manager of most of the railway network in Great Britain); City-regional level stakeholders, including officials from Transport for Greater Manchester's (TfGM) Innovation Research, Rail programme, Industrial Strategy and Future Mobility Implementation (Connected Autonomous Vehicles (CAV) Portfolio Management) unit; local government representatives from Manchester City Council (Senior Policy Officer, City Policy), Bolton Council (Strategic Transport Manager) and Rochdale Borough Council (Senior Transport Strategy & Projects Officer Planning & Development). Other participants included an Energy and Transport expert from Arup and academic researchers. Our Melbourne participants had similar backgrounds and expertise as their Manchester counterparts. Participants included officials from the state government and local government (i.e. Transport Planning Authority, Infrastructure Victoria, Merri-bek City Council and City of Melbourne), public transport advocacy, representatives of the Private Tram Operator and the Bus Industry Association, as well as transport academics and consultants. All our participants signed a consent form ahead of taking part in the visioning workshops. As our participants were assured that their contributions will be treated anonymously, in this paper, we only provide a list of their organizations (see Appendix A).

As summarised in Fig. 1, the multi-stakeholder workshops involved three key activities and corresponding outputs. Each of the activity steps is briefly explained as follows:

3.2.1. Workshop activity #1: criteria/indicator identification

The first activity involved identification of a set of evaluation *criteria/indicators*. In MCA, assessment criteria or indicators derive from a set of pre-determined objectives and sub-objectives. A value tree provides a useful way of capturing all components of the decision problem at hand in terms of objectives and sub-objectives (Dodgson et al., 2009). It then guides the identification of a set of criteria by ensuring a logical progression from the objectives and sub-objectives (ibid). Based on a review of relevant policy documents and the wider academic literature, the research team first identified seven objectives, which served as the foundation for a value tree to guide the participants in the criteria identification process (see Fig. 2).

The seven objectives (Fig. 2) were collapsed into four broad fields namely; (a) Environment (b) Accessibility + Integrated Transport (c) Competition + Economic Growth and (d) Safety and Security + Privacy. Four participant groups were assigned to one of the aforementioned fields to build on the foundational value tree to identify a set of indicators/criteria. A facilitator from the research team was assigned to each group to moderate and record proceedings with the aid of flip charts and an audio recording device. Participants first identified and discussed key transport and mobility problems and challenges in their respective local areas and the wider city/city-region (i.e. Greater Manchester and Melbourne). The goal was to ensure that the assessment criteria emerged from and reflected the realities that are unique to each of the study areas. The following two questions were used as prompts to help the participants brainstorm and identify the assessment criteria for the MCA:

> "What do you expect the outcome of transport policy to be in relation to your group's objective (s)? What would you consider a successful policy outcome and how would you measure success?"

Thus, the set of criteria identified reflected the participants' normative goals and expectations regarding the future of transport and mobility in their local areas as well as city/city-region. A criteria/indicator had to be as specific as possible and measurable. Participants were shown examples, such as *"to increase bicycling mode share from 1% to 20%*" to follow in stating a criteria. Ultimately, a common list of assessment criteria was compiled for use at later stages of the visioning process. The criteria were expected partly to reflect the spirit and intent of existing long term transport policies. To this end, we provided summaries of policy goals contained in the City of Melbourne Transport Strategy,2030[4] and the Greater Manchester Transport Strategy, 2040[5] to our participants to inform the criteria identification process.

3.2.2. Workshop activity #2: visioning and scenario generation

At this next stage of the workshop, participant groups imagined, discussed and wrote down plausible AV and future mobility visions for their respective city/city-region (i.e. Greater Manchester and Melbourne). A series of prompts and visual aids were employed to assist the

[2] See https://transport.vic.gov.au/our-transport-future/future-directions-for-transport/our-strategic-directions/new-and-evolving-technologies/connected-and-automated-vehicles.

[3] See, https://www.racv.com.au/on-the-road/driving-maintenance/road-safety/car-safety/autonomous-vehicles.html.

[4] See https://www.melbourne.vic.gov.au/parking-and-transport/transport-planning-projects/Pages/transport-strategy.aspx for more on the City of Melbourne Transport Strategy 2030

[5] See https://tfgm.com/2040-transport-strategy for more on Greater Manchester Transport Strategy 2040

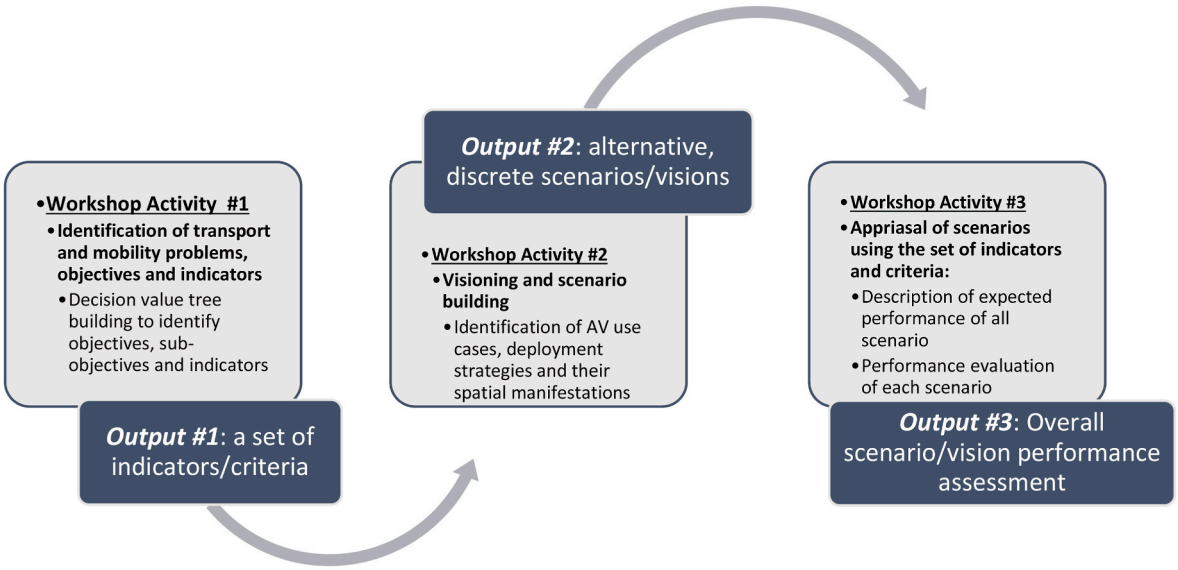

Fig. 1. MCA-based visioning workshop protocol showing activities, tasks and outputs.

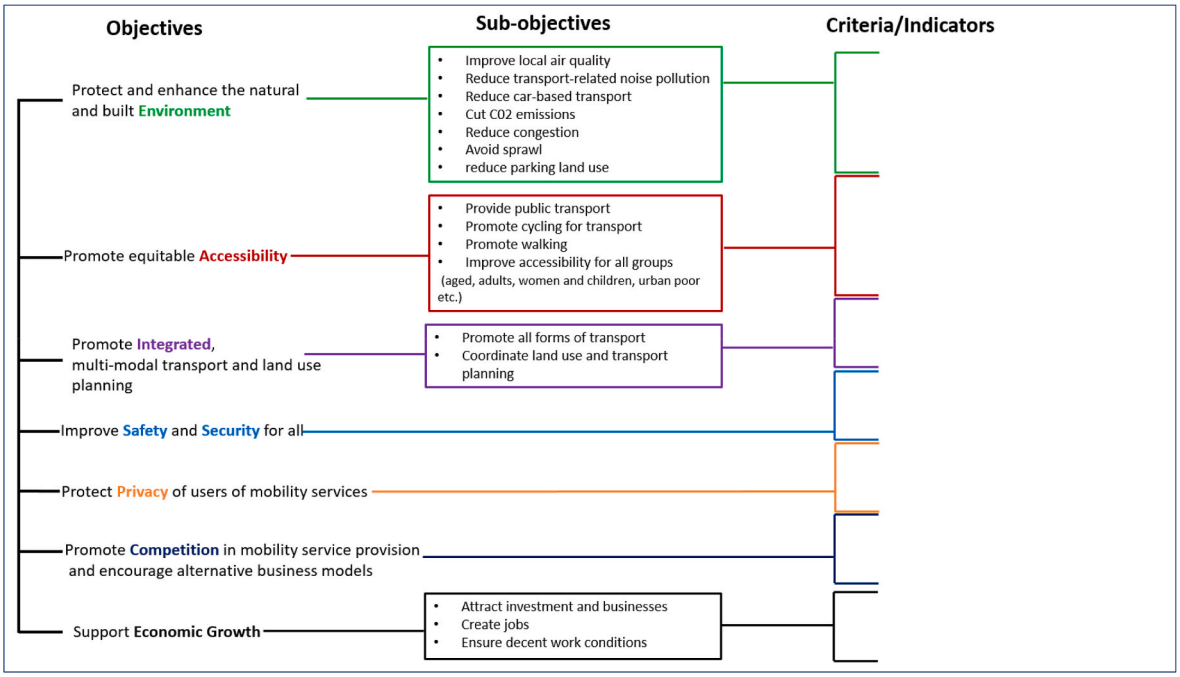

Fig. 2. Decision value tree used to guide identification of MCA assessment criteria.

participants in this process. For example, the participants were asked to reflect on and discuss plausible visions by answering the following question: *"What are the different ways in which autonomous vehicles could be used in Greater Manchester/Melbourne for transportation and mobility?"*. Visual aids, including short video clips of imagined use cases of AVs selected from video portals such as YouTube were also provided to aid the participants in this exercise. Automated driving technologies are still evolving, with the ultimate goal being that vehicles will achieve full automated driving capabilities in all safety-critical conditions. For the purpose of the visioning exercise, we asked our participants to consider the highest level of automation according to the Society of Automotive Engineers (SEA) taxonomy (i.e. 'Level 5: Full driving automation').

For every AV use case or deployment strategy identified as part of a broader future mobility vision, participants were asked to include detailed descriptive attributes. Such attributes included specifying the dominant modal options (e.g. ownership, sharing, and public transport) and engine fuel source (e.g. electric, hybrid or fossil) expected; indicating the spatial dimensions (on a map provided) to show specific areas of their city/city-region where certain applications are expected to be targeted or realised; and indicating the infrastructure requirements and implications.

3.2.3. *Workshop activity #3: overall vision appraisal*

The last activity step of the workshop involved stakeholders appraising the emergent future mobility visions (i.e. output of activity #2) against the set of identified assessment criteria (i.e. output of activity #3). This activity proceeded in three key interrelated steps. Firstly, each group provided a *performance matrix (PM) or consequence table* offering an initial qualitative description of how they thought the vision they have generated performs against each of the agreed assessment

criteria. Initial judgements about consequences of the group's vision were noted in the PM table as being either positive (+), negative (−) or unsure (0), and accompanied by a brief justification. They then presented their vision and initial consequence appraisal to all the workshop participants. Next, the overall assessment of the emergent mobility visions was carried out through *criteria weighting* and vision *preference scoring*. The Participants assigned weights to each of the assessment criteria, on a maximum weighting scale of 100 to reflect the importance they attach to a criteria, ensuring that the assigned weights across all criteria sums up to 100. Using a numerical scoring scale ranging *0 (least preferred)* to 100 (*most preferred*), the participants scored each of the future mobility visions.

The scoring process followed a quasi-Delphi approach, whereby each individual participant wrote down their weight and preference score for a criteria and vision respectively. The individual scores were then compiled and displayed to the room. Participants were then given the opportunity to debate the allocated weights and scores, and ultimately agree on a final set of criterion. It was important that we allowed the participants to evolve their own heuristic for assigning weights to criteria rather than imposing an approach. Across the two case studies, our workshop participants evolved similar heuristics that involved: prioritising the criteria in order of importance, agreeing on what the highest and lowest possible weights would be; and assigning, reviewing and adjusting weights until the weights across the full set of criteria summed up to 100. This approach ensured that weights were informed by sufficiently wide representative opinions, thereby reducing bias in the overall appraisal process. Participants in both Greater Manchester and Melbourne decided that the values '5' and '1' would represent their highest and lowest weights respectively, reflecting a ranking of their priorities in terms of relative importance (see Appendices B and C).

The overall performance assessment of each of the AV future mobility visions then proceeded in two steps, using the Simple Additive Weighting (SAW) MCA method: First, we computed the product of a criteria's weight and the associated preference score as follows:

$$w_j * s_{ij} \tag{1}$$

Next, we computed each vision's overall performance assessment using the formula:

$$s_i = \sum_{j=1}^{n} w_j s_{ij} \tag{2}$$

Where:

s_i is overall weighted score for vision/scenario i.
s_{ij} is the preference score for vision/scenario i on criterion j.
w_j is weight for each criteria.
n is number of criteria.

4. Results

4.1. Transport and mobility priorities as reflected in criteria weights

A total set of 32 and 25 criteria were identified and weighted by the workshop participants for Greater Manchester and Melbourne respectively. These criteria have been grouped under nine broad themes (see Appendices B and C and Fig. 3). For analysis and discussion we averaged the weights of the set of criteria within each theme (Fig. 3). The resulting averaged weights are interpreted in this paper as a comparison of ranked transport and mobility priorities between the two case studies.

The criteria weights reflect what participants considered to be the highest and lowest transport and mobility priorities in their respective areas. As shown in Fig. 3, the workshop participants identified the need for '***efficient and affordable public transport***' as one of their highest priorities for both Greater Manchester (average criteria weight = 3.86) and Melbourne (average weight = 4.17). Across the two case studies, the workshop participants expected transport and mobility futures that removed the existing inequalities of access to public transport. Whereas in Greater Manchester participants highlighted that the prevailing accessibility deficit was greater for areas experiencing high levels of multiple deprivation, in Melbourne the participants suggested that public transport accessibility was particularly poor for suburban residents. Thus, addressing first-and-last-mile accessibility deficits in the existing public transportation systems was identified as a top priority under this theme. The need to ensure that public transport is affordable for all groups was also identified as an equally important expectation by participants in the two case study areas. In the context of the increasing ageing populations, the workshop participants expected that the current

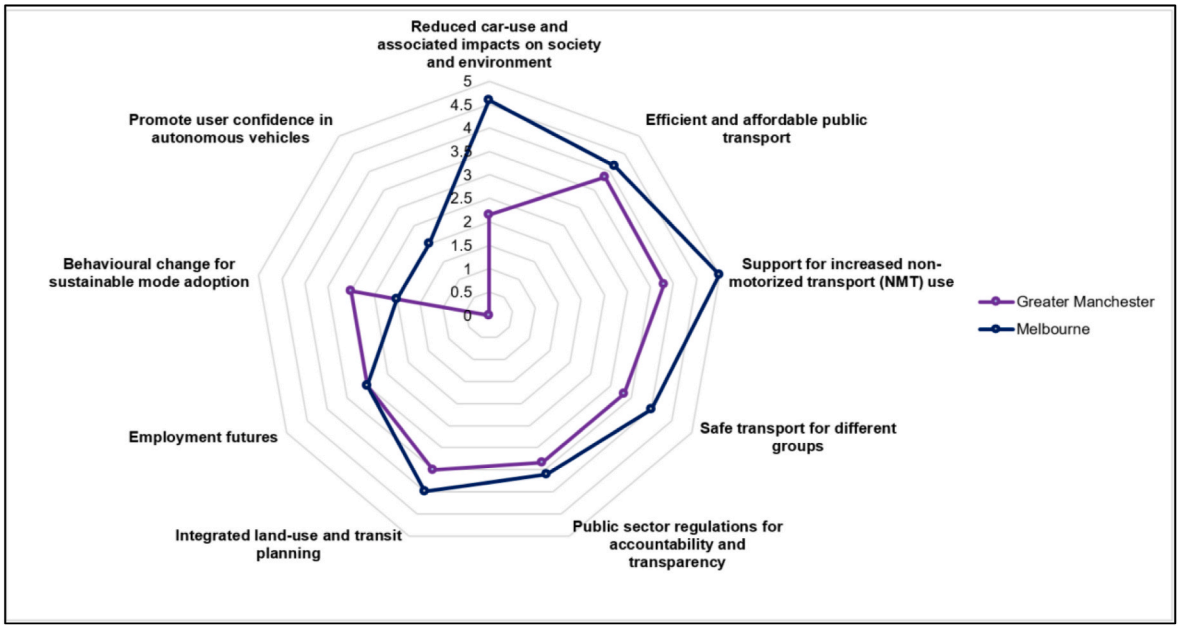

Fig. 3. Radar plot showing criteria weights averaged for the nine thematic indicators identified.

situation whereby the elderly are able to use public transport for free would be maintained in the future.

The related themes of providing 'support ***for increased non-motorized transport (NMT) use***' and ensuring ***'safe transport for different groups'*** were reflected in and ranked highly as policy priorities in the two case study areas. There was consensus among participants across the two cities that successful policy outcomes would be seen in terms of creating pedestrian friendly town/city centres; increasing bicycle mode share to about 10% and ensuring safe transport among vulnerable road users (pedestrians and cyclists) and marginalized groups.

Another theme that emerged from the criteria identified and weighted by the study participants was the need to '***reduce car-use and associated impacts on society and the environment***'. Participants in Greater Manchester and Melbourne attached different levels of priority to this imperative as far as their transport and mobility futures are concerned. As reflected in the average weighted criteria values, reducing car-use and associated negative impacts was ranked lower overall in Greater Manchester (average criteria weight = 2.14) than in Melbourne (average criteria weight = 4.6). In both study areas, the workshop participants recognised the need to reduce private car ownership and car use in favour of cleaner energy (electric) alternatives of shared-mobility (car-based and non-car-based) and public transport. However, during the workshops, it became apparent that participants in Melbourne expected more ambitious targets of policies around car use than their Greater Manchester counterparts. For example, reducing provisions for parking as a policy criteria to reverse decades of car-centric urban planning and development was identified and assigned the minimum weight of 1 by participants in Greater Manchester (Appendix B). In contrast, participants in Melbourne identified and assigned the maximum weight of 5 to a similar criteria of reducing parking provisioning and demand by 50% (Appendix C). Moreover, in Greater Manchester, the participants were of the view that reducing second car ownership should be prioritised rather than targeting car ownership in general. Similar differences in weightings between the two case studies for criteria related to car-based transport can be seen in Appendices B and C, respectively. In both case studies, the workshop participants identified ***'behavioural change promotion to shift toward more sustainable modal choices'*** as an important complementary measure in creating sustainable futures.

Furthermore, in both case studies, the workshop participants identified and weighted highly policy evaluation criteria that reflected the importance of ***'integrated land use and transport planning'***. The priorities here included ensuring that urban and transport planning is conducted in a way that supports the concentration of new housing and job investments in inner-city brownfield areas and linked with efficient public transport. In Greater Manchester, participants supported the idea of compact development through brownfield infilling, but also highlighted that this strategy ought to be balanced with ensuring dispersed economic growth across the city-region.

Moreover, in Greater Manchester and Melbourne, the workshop participants identified and ranked as high priority, transport and mobility policy evaluation criteria that reflect the need for ***'Public sector regulation for accountability and transparency'***. In both case studies, the workshop participants highlighted the need for strong public sector oversight and regulatory frameworks for future transport service provisioning and user data management. There was a recognition that business models involving different arrangements of private and public sector involvement in public transport operations would be necessary. However, there were divergent views in relation to the extent of public sector involvement between the two case studies. In Melbourne, there was a general consensus that private transport service providers will play a crucial role in public transport service operations, such as mass transit and on-demand and/or shared-mobility services. In Greater Manchester, however, the workshop participants were divided on the issue of public sector involvement, mirroring on-going debates around the subject in the city-region. Whereas most of the participants from local authorities advocated for a complete public sector ownership and operation of the bus network in the region (in addition to the publicly owned/operated tram system), participants from the region's transportation agency, Transport for Greater Manchester (TfGM), stood in sharp opposition to this view. Thus, while greater public sector involvement in public transport provisioning was identified as a criteria, the group ultimately assigned the lowest weight to this criteria among the set of criteria identified under this theme. In doing so, the participants seemed to have reached consensus by recognising the issue as important but contested, and hence capturing it as a policy aspiration.

In recognition of the implications of Artificial Intelligence and automation for jobs and livelihoods in the transportation sector, the workshop participants also identified and weighted a set of criteria that reflected the theme of ***'employment futures'***. This theme emerged as a relatively important policy priority as reflected in the average weight of 3 assigned by the workshop participants in both case studies. Workshop participants in Greater Manchester and Melbourne emphasized the need for policy to minimize the associated risks of unemployment among transport sector workers, such as taxi and bus drivers in the transition to automated forms of urban transport.

4.2. Future transport and mobility visions in the context of AVs

In imagining the transport and mobility futures of their respective areas in the context of AVs, the workshop participants began with identification of possible use cases. Building on the use cases, they provided as much detail as possible for the vision that would ultimately emerge, including specific areas within the city that certain use cases would be realised as part of an AV deployment strategy; expected modes of deployment (e.g. ownership, shared and/or public transport); energy source fuel of vehicle fleet, as well as any accompanying measures they considered critical to the vision. Two complete visions each emerged from the multi-stakeholder workshops conducted in Manchester and Melbourne. Summary descriptions are presented in Tables 1 and 2 for Greater Manchester and Melbourne respectively. We elaborate on the summaries in the following paragraphs by highlighting the participant's reasoning and some of the important contextual factors that became apparent through the dialogue among the participants as they articulated their visions.

Public transport featured prominently in all the transport and mobility visions articulated by the participants in the two study areas. In Greater Manchester, public transport use cases for AVs featured strongly in the two broad visions generated by the participants. There were also notable similarities in terms of how each participant group imagined the public transport use cases of AVs across the city region. In both visions (**Manc-Vision 1a and 1b**), the applications of AVs in the future public transport system of Greater Manchester were conceived largely in terms of possible deployment in existing 'transit deserts' where first-and-last mile public transport accessibility deficits are pronounced within the city-region. From the participants' perspective, public transport accessibility deficits prevailed in the city-region's more peripheral boroughs. Thus they imagined scenarios where AVs provided demand responsive public transport services and/or provided feeder access to main public transportation lines. Notably, the participants recognised that fully- and partially-automated vehicles as well as conventional vehicles will co-exist in their imagined futures. This however raises implications for not only future *public transport infrastructure* but also consequences for future *built environments*. In response, the participants, as reflected in **Vision 1b**, indicated the need for *dedicated or segregated transport infrastructure* as a way of avoiding possible conflicts between vehicles with automated capabilities (full and partial) on the one hand and conventional human-operated vehicles on the other hand.

Similar to the visions articulated by the participants for Manchester, participants in Melbourne recognised and identified possible public transport use cases of AVs in their future transportation systems. Across

Table 1
Autonomous vehicles and urban mobility futures vision for Manchester.

Manc-Vision 1a: A future of full public ownership of transport and mobility services	Manc-Vision 1b: A future of 'Partnership' in public transport service delivery
• **Public transport**: fully automated and conventional buses will provide public transport. We expect 100% electric fuel source for both automated and conventional public transport. AVs will be employed to address first/last mile accessibility issues in areas where public transport accessibility deficits are more pronounced, such as Bolton, Rochdale and other boroughs at the periphery of Manchester city. • **Shared mobility:** Shared AV shuttles and taxi services will serve major business and retail parks across Greater Manchester. They will provide flexible on-demand mobility options for shoppers and other travellers. AV shuttles will also link major transportation hubs, especially airports with the aim to significantly reduce parking demand within these major transportation hubs. Personal ownership of AVs will be possible but must be regulated. • **Food delivery**: AVs will be employed in food delivery. We expect this to be concentrated only in the city centre area where people live very close to restaurants. • **Patient transport and hospital environment applications**: AVs will be used as ambulances to improve emergency response. Within large hospitals, electric AV shuttles will also be employed to transport staff, patients and logistics. • **Business models and regulation**: Full public ownership and operation of all forms of public transport, AV and conventional, is expected in the future. A governance regime whereby local governments own and operate public transport services should replace the current deregulated (bus) market in Manchester • **Complementary infrastructure (NMT):** Infrastructure for Non-motorized forms of transport, including cycling and walking should be prioritised with the aim to reduce car-based transport in particular. Priority should be given to completing Manchester's Bee Cycling Network and school children should be given compulsory cycling training to get more of the upcoming generation to take up cycling. • **Other measures:** the transition to AVs should not lead to unemployment. It is crucial that transport sector workforce who will be directly affected by automation are trained and equipped with relevant skills to ensure contained employment and preservation of their sources livelihoods.	• **Public transport**: AVs will provide public transport services, linking suburban and peripheral settlements to the city centre. To avoid conflict with other conventional and/or partially automated vehicles, dedicated infrastructure should be provided. Manchester's disused railway lines could be repurposed and used as AV corridors, connecting poorer, inaccessible areas to the city-regional core. We expect sustainable and environmentally friendly fuel sources (e.g. electric, hydrogen) for both automated and conventional public transport. • **Rapid, demand responsive shared-mobility**: AVs will provide rapid transport for the elderly who are unable to drive as well as on-demand shared mobility services for other user groups. • **Security and law enforcement applications**: AVs will be used by the police force for community patrols to ensure public security and safety and to transport criminals to police stations across the city-region. • **Deployment during special events**: In the future, during special public events that attract larger numbers of people, such as concerts and football marches, shared AV shuttles could be used to transport passengers quickly and efficiently to and from even sites to ease congestion especially in the city centre. • **Food delivery**: AVs will be employed in food delivery. We expect this to be possible anywhere in the city-region. However, there should be designated zones for delivery robots in each borough. Delivery robots traffic should be segregated from bicycle-lanes and pedestrian walkways. • **Business models and regulation**: public transport services will be provided through partnership arrangements between local governments and private sector operators. It is expected that a franchising arrangement will replace the currently deregulated public transport market ensuring strong public sector oversight with the goal to improve the overall quality of public transport services. Transportation Network Companies (TNCs) are expected to continue provide shared and demand responsive AV services • **Other measures:** retraining of workers in the transport sector, including bus drivers, taxi drivers and ancillary workers to be able to adapt to the changes that automation will bring and to avoid unemployment.

the two visions articulated for the city, there was broad consensus among the participants that AVs could be employed to improve overall accessibility within the transportation system by providing feeder linkages to low-density suburban locations, where currently, first/last mile accessibility deficits are pronounced.

Table 2
Autonomous vehicles and urban mobility futures vision for melbourne.

Melb-Vision 1a: Everything is on the table (AV ownership, sharing and public transport expected)	Melb-Vision 1b: The future is public transport and sharing, no private AVs
• **Personal mobility (ownership):** people are likely to own autonomous cars and ownership is expected to exist alongside public transport options throughout Melbourne. This is expected in suburban neighbourhoods with poor walkability and where first/last mile public transport accessibility problems exist. A typical example of such neighbourhoods is Gowanbrae. • **On-demand shared-mobility:** AVs will provide shared, door-to-door mobility at the request of customers. Individuals who own an autonomous vehicle would be able to rent out their cars for use by other individuals in throughout Melbourne. This will be a departure from the current model whereby few businesses offer shared-mobility services. • **Public transport:** autonomous buses and shuttles will provide more frequent services at a much greater intensity than currently exists. AVs will provide shuttle services to major facilities such as hospitals or provide feeder access to airports, with dedicated/segregated lanes exclusively used by AVs linking these key facilities. Fully-automated trackless trams, providing rapid transit in Melbourne. Places in Melbourne undergoing Urban renewal, such as Wyndham could benefit from this type of transport infrastructure investment in the future. Automated suburban rail system provides transit services in suburban Melbourne. The existing rail network will need repurposing to enable this. • **Freight movement:** AVs are used for street cleaning and moving waste throughout the city of Melbourne, and to transport light goods in the city and within depots and warehouses. • **Business models and regulation**: A variety of business models are expected. It is expected that the private sector will play a significant role in public transport service operations, including the provisioning of on-demand shared mobility services. Strong public sector regulatory oversight will be necessary.	**Feeder access to Public transport:** Shared AV provide feeder services in low-density areas, by connecting passengers from major public transport service hubs to their homes. This is to overcome first-and-last-mile accessibility challenges in the city. There will be no personal AVs, only shared AVs providing feeder services to buses, trams and trains to prevent wasteful use of land. **Public transport and shared-mobility:** Envisage a future of automated trains, trams and buses. Buses will likely be automated first due to the cost of train and tram rolling stock. AV buses will provide public transport services along the arterial roads across Melbourne. Bus drivers will be retrained to become fleet captains of automated bus fleets, reducing unemployment. We propose Geofenced AVs, which serve within a specified ring, or incur higher cost. Designated Kerbside stops for AVs should be installed. Hybrid autonomous/driven, vehicles will make it possible to revert to human-driven in denser, pedestrian-heavy areas. **Freight movement:** AVs used in industrial areas and freight movement corridors. This would be more practical because such zones and corridors see less traffic from pedestrians and other motorized forms of transport. **Business models and regulation**: A variety of business models are expected. It is expected that the private sector will play a significant role in public transport service operations, including the provisioning of on-demand shared mobility services. Strong public sector regulatory oversight will be necessary.

While participants in Melbourne recognised the importance of public transport, two contrasting perspectives emerged with respect to private *Ownership* and use of AVs. On the one hand, there was a recognition that people would likely want to own AVs and that ownership is to be expected to exist alongside public transport alternatives (**see Melb-Vision 1a**). In a contrasting alternative **vision (see Melb-Vision 1b)**, participants were of the view that ownership of AVs should not be permitted and instead, the priority should be on deploying a fleet of *shared AVs* to provide feeder services to main public transport service lines such as bus, tram and train. For Manchester, the participants envisioned rapid, demand responsive and shared AV use cases within the city-region. They imagined shared AVs providing connectivity to major business and retail parks, as well as providing demand-responsive mobility services to specific groups such as the elderly and/or individuals with mobility impairments. The reasoning behind and the intended outcomes for

prioritising shared use cases of AVs were similar. For Melbourne, the main reasoning was that curtailing ownership and promoting sharing will prevent wasteful use of land for infrastructure such as roads and parking that has come to be associated with personal car ownership and use. For Manchester, the expectation was that on-demand, shared use of AVs will complement public transport to help significantly reduce high private car use that currently typifies journeys to major shopping and retails centres.

Aside from the aforementioned passenger transport use cases of AVs, other use cases that featured prominently in the transport and mobility future of the two case studies were AVs being used for *urban freight transport* and for localised food *and parcel delivery* services. Moreover, in Manchester, the study participants identified AVs potential use cases in *security and law enforcement applications* as well as applications in health services delivery to improve *health emergency response* (see Table 1).

The final aspects of the future mobility visions worth highlighting relate to *business models and regulatory regimes*. For Melbourne the workshop participants anticipated that the private sector will continue to play significant roles in future public transport service operations with the public sector providing regulatory oversight. In Manchester, however, as outlined in their future mobility visions (see Table 1) the two groups of study participants offered diametrically opposing views in relation to future transport business models and regulatory approaches. On the one hand, one group of the study participants favoured *partnership arrangements* between local governments and private sector operators in the delivery of future public transport services. The other group of participants, however, favoured *full public ownership and operation* of all public transport services in the city-region. It is worth highlighting that these contrasting visions emerged from a shared recognition that the currently deregulated public transport market has not yielded the benefits expected of a competitive market. Instead, there was a unanimous agreement that despite decades of deregulation, the market is still dominated by a handful of operators; service provisioning is uncoordinated with an integrated ticketing system lacking; and the overall quality of bus service in particular has declined. Against this backdrop, the group of participants who favoured public-private partnerships proposed a franchising arrangement whereby public transport operators will provide services under contract to a local transport authority, with the latter providing strong regulatory oversight.

4.3. Multi-criteria appraisal of the future transport and mobility visions

As a final step, the workshop participants appraised the future mobility visions (see section 4.2) using the set of transport and mobility priorities identified earlier (see section 4.1) as the assessment criteria. The full appraisal contingency tables generated by the workshop participants are presented in Appendices A and B for Manchester and Melbourne, respectively. Summary tables are presented in Tables 3 and 4 for Manchester and Melbourne respectively to highlight and synthesize the findings.

Analysis of the visioning appraisal data revealed a broad pattern whereby our participants in Manchester assigned performance scores in the high to medium ranges for the two visions outlined while their Melbourne counterparts' performance scores fell within the medium to low ranges (see Tables 3 and 4). The performance scores reflect the workshop participants' overall perceptions of the potential (dis)benefits of AVs in relation to current and future transport and mobility priorities in their respective cities. Therefore, the results suggest that whereas our workshop participants in Manchester appeared to be generally more *optimistic* about the potential benefits of AVs to the city-region's long term transportation goals, our Melbourne participants may be characterised as being *ambivalent* and more *cautiously optimistic* in this regard.

In the sections that follow, we elaborate on the results of the participants' performance appraisal, focusing on six major thematic indicators and highlighting similarities and differences within and between the two case studies.

4.3.1. Reducing car use and associated impacts on society and environment

Both of the two future mobility visions outlined for Manchester received mixed performance scores against the broad indictor that reflect the need to reduced car use and the associated negative impacts. By prioritising public transport and shared-use cases, both automated driving future visions were deemed by the workshop participants to present opportunities to *increase usage of sustainable modes of transport to a 50%* target and *reduce poor air quality* particularly in the central areas of the city-region, as reflected in the high performance score assigned. Regarding achieving the ambitious target of 100% of cars being electric by 2040, the workshop participants were of the view that Manc-Vision 1a presented more opportunities and thus performed better on this criteria than Manc-Vision 1b. This difference in performance scoring resulted mainly from the fact that the proponents of the former vision were more specific by setting a 100% electrification target, as compared to the latter in which the target for clean engine source fuel seemed quite general and rather vague. Moreover, on the indicator of reducing private car ownership in favour of public transport and shared alternatives, Manc-Vision 1a performed relatively lower than Manc-Vision 1b because the former envisaged a future where individuals would be able to own AVs. Finally, as reflected in the performance scoring, the participants recognised that both of their automated driving future visions would not necessarily reduce the need for parking as well as bring about network efficiency and the attendant possibility of reallocating the resulting redundant road space for green infrastructure.

In the case of Melbourne, the workshop participants, similar to their Manchester counterparts recognised that AVs as a next generation transport technology will likely integrate clean engine fuels (i.e. electric). Consequently, the two automated driving futures they envisioned performed strongly on the priority indicators of *achieving 100% vehicle electrification* and *reducing poor air quality*. Expectedly, Melb-Vision 1b, in which the proponents envisaged a future of only public transport and shared-use of AVs, performed strongly on most of the priority indicators

Table 3
Appraisal contingency table for future transport and mobility visions by Manchester participants.

Criteria (Thematic areas)	Manc-Vision 1a				Manc-Vision 1b			
Reduced car use and associated impacts on society and environment	👍[3]		👐 [2]	👎[2]		👍[4]	👐 [2]	👎[1]
Efficient and affordable public transport	👍[2]	👍[3]				👍[1]	👐 [3]	
Support for increased and safe non-motorized transport (NMT) use		👍[4]	👐 [2]				👐 [1]	👎[5]
Safe transport for different groups		👍[2]	👐 [1]		👍[2]	👍[1]		
Integrated land-use and transit planning		👍[1]	👐 [1]	👎[1]	👍[1]		👍[1]	
Public sector regulations for accountability and transparency		👍[3]				👍[1]	👍[2]	
Employment futures		👍[1]		👎[2]		👍[3]		
Behavioural change		👍[1]						👎[1]
	Highest (100)	High (69–99)	Medium (50–68)	Low (>50)	Highest (100)	High (69–99)	Medium (50–68)	Low (>50)

Table 4
Appraisal contingency table for future transport and mobility visions by Melbourne participants.

Criteria (Thematic areas)	Melb-Vision 1a				Melb-Vision 1b			
Reduced car use and associated impacts on society and environment		[1]	[1]	[3]		[4]	[3]	
Efficient and affordable public transport			[2]	[4]		[2]	[1]	[3]
Support for increased and safe non-motorized transport (NMT) use				[2]				[2]
Safe transport for different groups			[1]	[4]			[2]	[3]
Integrated land-use and transit planning			[1]	[1]			[1]	[1]
Public sector regulations for accountability and transparency			[1]	[2]		[1]	[1]	[1]
Employment futures				[1]			[1]	
User confidence				[1]				[1]
Behavioural change				[1]			[1]	
	Highest (100)	High (69–99)	Medium (50–68)	Low (>50)	Highest (100)	High (69–99)	Medium (50–68)	Low (>50)

that reflected the need to reduce car use and associated negative impacts on society and the environment than the alternative vision (i.e. Melb-Vision 1a).

4.3.2. Efficient and affordable public transport

The results of the visions appraisal revealed significant differences between our workshop participants in Manchester and Melbourne regarding their assessment of the possibilities of realising an efficient and affordable public transport through the automated driving visions they articulated. For both visions evaluated by our Manchester participants, their performance scores suggested that they anticipated AV benefits in addressing existing public transport accessibility challenges. Consequently, both visions outlined performed strongly against the priority indicators of improving first-and-last-mile accessibility challenges, providing 24 h public transport service and making public transport affordable to both the elderly and younger populations. Moreover, in both of the visions articulated, the participants sought to address the existing lack of an integrated public transport system for the Greater Manchester city-region. As indicated by the performance scores, the two visions performed strongly on this priority indicator, implying that the participants thought AVs offered possibilities to achieve an integrated public transport system in service operation and enabling an integrated ticketing system which does not exist currently.

By contrast, participants in Melbourne provided relatively lower performance scores for their future AV mobility visions against most of the public transport related priority indicators (see Table 4). Furthermore, between the two visions outlined, Melb-Vision 1b—in which public transport use cases of AVs received overriding prominence—performed stronger on the priority indicators of improving first-and-last-mile public transport accessibility and overall accessibility by public transport in Melbourne. Together, these findings suggest that in both Melbourne and Manchester, our workshop participants prioritise public transport use cases of AVs. However, in relation to AVs potential contributions to creating an efficient and affordable public transport system, our workshop participants in Melbourne appear to be ambivalent and less optimistic than our Manchester participants.

4.3.3. Integrated land-use and transit

With regards to the cross-cutting priority of achieving land use and public transport systems integration in the era of AVs, our Melbourne participants assigned low performance score to the specific priority indicators to 'achieve the vision of 80% of population living in a '20-min city'' and 'concentrate new housing and job development in inner-city brownfield areas linked with public transit'. The underlying reasoning was that potential accessibility enhancement benefits and mobility freedom that AV may bring, could encourage further suburban development and sprawl. Besides this, there was also a shared recognition among the participants that policies and strategies that are much wider beyond the mobility visions they have articulated will be required to achieve the long-term goal of effective land use and public transport systems integration.

Participants in Manchester scored both visions high on the priority indicator to encourage dispersed growth—mainly housing and businesses—across the city-region. The reasoning was that the likely benefits of AVs to improving the transportation by improving connectivity and accessibility between the regional core and peripheral areas as well as within individual urban centres could provide the catalyst for more balanced growth. On the priority indicator of concentrating housing and job development in inner-city brownfield areas, the participants view as reflected in the performance score assigned was that both mobility visions may have minimal impact. Similar to the views expressed by the Melbourne participants, our Manchester participants indicated that prioritising town/city centre (re)development may be beyond the immediate embrace of their mobility visions and that specific policies and strategies would be required to achieve those imperatives.

4.3.4. Non-motorized transport (NMT) and safety for different groups

In one of the future mobility visions for Manchester (i.e. Manc-Vision 1a), the proponents clearly identified the need for investment in infrastructure to support non-motorized forms of transport as part of the portfolio of future transport and mobility priorities. Consequently, this vision performed strongly against all NMT-related priority criteria, including the expectation (see Table 1 and Appendix B). As reflected in their performance assessment, by prioritising investments in cycling infrastructure, this vision also provided possibilities to meet the ambitious target of increasing cycling mode share to about 10% from the current less than 1%. In the alternative vision (i.e. Manc-Vision 1b), however, the proponents did not explicitly address NMT infrastructure provisioning goals and strategies and thus achieved relatively lower performance scores (see Table 1).

Our workshop participants in Melbourne on the other hand, recognised that any automated driving future would likely perpetuate and entrench car-dependence and thus appears fundamentally incompatible with any visions of the future in which non-motorized forms of transport such as cycling and walking are expected to dominate. Consequently, they scored their automated driving future visions low against all the set of indicators that reflect the need to promote sustainable mobility through NMT use.

Moreover, on the potential contribution of AVs to transport and traffic safety in the future, our workshop participants in Manchester and Melbourne expressed opposing views as reflected in vision appraisal performance scores. Whereas participants in Manchester were of the view that each of the automated driving futures they envisioned would likely contribute positively to traffic transport and traffic safety, their Melbourne counterpart expressed the contrary. There was a broad consensus among our Manchester participants that measures including the provisioning of dedicated corridors for AVs and protected cycling infrastructure would separate AVs from conventional vehicles and

vulnerable road users such as cyclists and pedestrians and thus bring about the anticipated NMT safety benefits.

4.3.5. Public sector regulatory oversight for accountability and transparency

Against all the priority indicators under this theme, Manc-Vision 1a, in which the proponents envisioned a future of full public ownership of all transport service delivery and operations, performed strongly, as reflected in the very high performance scores assigned by the participants. The alternative vision (Manc-Vision 1b), which proposed a more flexible franchising arrangement of future public transport service operation, with a stronger public sector regulatory oversight, was assigned high performance score on the priority indicator of effective regulated private transport business. While the priority indicator seeking full public ownership was incompatible with this vision and reflected in a relatively lower performance score assigned, the participants also recognised that under the franchising arrangements and regulatory regime proposed, it may be challenging to realize the transparency and accountability imperative regarding user data management. For Melbourne, on the other hand, as reflected in the performance scoring, the two visions outlined did not perform strongly on all three priority criteria captured under the theme of regulation, accountability and transparency, (see Table 4 and Appendix B). The main reasoning behind the performance scores was that the development of AVs and the associated mobility futures are heavily driven by neoliberal logics, with businesses leading and shaping these futures. Given these powerful driving forces behind the unfolding transition, the workshop participants were of the view that stronger public sector regulation imperatives may not materialize.

4.3.6. Employment futures

The priority indicators under this theme allowed for the AV visions outlined to be appraised in terms of their implications for the future of employment in the transportation sector. Both of the visions articulated by our Manchester participants explicitly addressed the future employment and livelihood implications of transport automation. In both visions, proponents identified the need for retraining the workforce in new skills and competences in response to automation. As a result, both visions articulated performed strongly against the future employment-related priority indicators (see Table 1 and Appendix B). On the contrary, our Melbourne participants, recognising the inherent uncertainties in anticipating AVs likely impacts on employment and livelihoods, did not make any explicit proposals addressing these implications. Consequently, both visions outlined performed poorly against their corresponding priority indicators (see Table 2 and Appendix C).

5. Discussion

The ongoing experimentations with different levels of automated driving technologies imply that the likelihood of AVs being employed to meet everyday transport and mobility needs in cities, is now closer than ever. However, as we have highlighted at the onset of this paper, the emerging evidence suggest that while in some contexts long-term visions about the place of AVs in future transportation systems are lacking (McAslan et al., 2021), in others, there seem to be a disconnect between imagined automated driving futures and their anticipated impacts (Olin and Mladenović, 2022), as well as a dearth of understanding about how AVs could help address the socio-environmental challenges facing cities (Legacy et al., 2019). Even more challenging for researchers and policy-makers is the inherent uncertainties about anticipating and planning for transport and mobility futures, in the context of a technology that is still undergoing development and testing (see e.g. Lyons, 2022; Acheampong and Cugurullo et al., 2021). In this paper, we have sought to contribute to addressing these grand challenges, by offering a multi-criteria visioning and appraisal framework and methodology that bring multiple stakeholders together to consider the various possibilities that AVs may present for the future. Most importantly, we have demonstrated how the framework and approach can enable stakeholders to collaboratively identify and interrogate essential tensions and incompatibilities between imagined AV futures and long-term transport and mobility imperatives.

Deploying the multi-criteria visioning and appraisal methodology in participatory workshops conducted in Greater Manchester (UK) and Melbourne (Australia), we sought to achieve two interrelated goals. Firstly, to identify what our study participants considered to be the key transport and mobility priorities for the two study areas. To this end, our study participants identified and assigned weights to a set of priority criteria/indicators that reflect both their current transport and mobility situations as well as normative goals/expectations for the future. The results reveal similar imperatives identified for the two case studies, with the top priorities including the need to make public transport affordable and efficient; achieve increased use of non-motorized forms of transport (i.e. cycling and walking); ensure safety of different transport mode users; reduce car-use; protect employment and livelihoods; and realize maximum public value from new transport technologies and mobility services through regulation. Secondly, working with our participants, we sought to generate plausible AV and urban mobility future visions for Greater Manchester and Melbourne, and appraise the visions against the set of weighted priority criteria identified. To this end, our study participants articulated discrete visions in which they identified various AV use cases as well as a wider portfolio of AV implementation strategies.

A number of profound insights emerged from the vision articulation and appraisal exercises with our workshop participants, which we outline and discuss around four key areas. The first major insight relates to what we learned about our participants in relation to their broad attitudes towards AVs. We found that our study participants were not necessarily opposed to the prospects of AVs. Neither were they *'evangelists'* who are "persuaded that driverless cars will be a (great) benefit to (parts of) society and want to play a part in making them happen" (Lyons, 2022, p.6). Instead, in manifesting their attitudes and perceptions, our participants were constantly having to not only entertain, but also balance the essential tensions among excitement and optimism on the one hand, and ambivalence, scepticism and uncertainty on the other hand. Consequently, as reflected in their performance assessment of the visions outlined, their attitudes filtered through and oscillated between different layers of cautious optimism about the future prospects of AVs.

The second key insight that emerged from the analysis is that our participants' perception of the contradictions between AVs and the long-term transportation and mobility priorities of their cities varied, depending on the issues being interrogated and between the two case studies. For example, from the visions outlined, it became clear that in both Melbourne and Manchester, our workshop participants recognised AVs' greatest prospects in various public transport applications, including contributing to improving overall efficiency of public transport and providing feeder access in areas experiencing first-and-last-mile accessibility deficits. Yet, as reflected in the vision performance assessments, our workshop participants in Melbourne appeared to be less optimistic compared to their Manchester counterparts about the prospects of AVs in creating desired public transport futures of their cities. Similarly, our Melbourne participants were broadly of the view that AVs were fundamentally incompatible with the need to reverse car ownership and dependence, and hence, empathized the need to restrict their use as public transport. Curtailing AV ownership may be seen as a less liberal proposition and even as a drastic departure from the present-day reality where many have the option to own a car. Indeed, this proposition even appears to directly contradict the city of Melbourne Transport Strategy 2030) goal to "maintain access for essential car trips, especially for people with a disability, trade, service and emergency vehicles". We elaborate on our participants' thinking around this as follows: AVs are expected to contribute toward inclusive mobility and

accessibility benefits by removing age-related impairments and physical and sensory disabilities as barriers to car-based travel for example (see e.g. Curl et al., 2018; Kovacs et al., 2020; Zandieh and Acheampong, 2021)—prospects that were also recognised by the study participants. From our participants' point of view, however, ensuring equitable transport by addressing diverse mobility and accessibility needs is still possible without AV ownership. Instead, they argued that in the pursuit for inclusive and equitable mobility, public transport, including different forms of on-demand, shared-use mobility schemes should be prioritised over ownership. From our point of view, we see this as highlighting the long-standing debate and contestations around recognised sustainable transport and mobility imperatives on the one hand and the equity implications of adopted measures on the other hand—a critical challenge that policy-making around automated driving futures must grapple with.

Moreover, our Manchester participants recognised that AVs would likely perpetuate auto-mobility, but they also appeared to be more optimistic about the prospects of AVs improving shared-mobility systems and possibly reducing the need for car ownership in the future. Our Manchester participants recognised the potential benefits of shared-use of AVs in helping to achieve the region's policy goal of reducing overall car ownership and usage by discouraging second car ownership in particular. Indeed, AVs enabling flexible car-sharing is one of the main benefits that is widely acknowledged in the literature (see e.g. Chan, 2017; Milakis et al., 2017b), but there are significant barriers to overcome to get more people to car-share. This is because, as the evidence show, not only are levels of shared-use of conventional vehicles very low globally (e.g. Currie, 2018; Shaheen and Cohen, 2013), but also regarding AVs, individuals tend to find shared-use options less preferable compared to other alternatives such as ownership (e.g. Acheampong et al., 2021).

Thirdly, both of our participant groups in Melbourne and Manchester recognised the fundamental contradictions between deploying AVs and making their cities safe for walking and cycling, goals that are emphasized in the long-term transport strategies of both regions. The latter group, however, outlined a number of measures they thought could ensure the safety of vulnerable road users when AVs become a diffused mode of transport, including providing dedicated corridors for AVs on highways and in busy urban environments, as well as segregated cycling and walking infrastructure. Indeed, the belief that the introduction of AVs in cities will necessitate various means of infrastructure level segregation of traffic, in order to ensure traffic safety, appears to be gaining prominence among urban and transport planners (see e.g. Litman, 2018; González-González, 2019; Owens et al., 2018; Manivasakan et al., 2021). For example, in their survey of experts in the USA on the implications of AVs for walking and cycling, Botello et al. (2019) reported that nearly all their respondents indicated that NMT planners should begin to account for AVs in their plans, citing the implementation of some of the above infrastructure segregation measures. From this, we can also begin to imagine the profound changes to transport infrastructure and urban built-environments that AVs will likely trigger. As Millard-Ball (2018), posits, a plausible scenario is a future where physical barriers may have to be installed to prevent pedestrians from getting in the way of AVs. It may also become necessary that pedestrians and cyclists wear detectable electronic beacons in busy urban environments for recognition by AVs (Botello et al., 2019). However, as Thompson et al. (2020) argue, adjusting to the behaviour and risks presented by AVs in urban environments could create new sources of error and conflicts that will offset some of the assumed safety benefits.

The final key insight from this study centres on the governance and politics of future transport and mobility in the context of AVs. The visions and perspectives shared by our workshop participants echo critical and yet highly political areas of regulatory intervention, including future business models and their implications for mobility service ownership and operational configurations; cybersecurity, privacy and data management. Governments' need to play different roles, including as regulator, mediator, catalyst and promoter to ensure the creation and maintenance of markets for AVs and the mobility services they will provide (Aoyama and Leon, 2021). These roles are often conflicting, and as the findings of our study show, while the public sector role is recognised, there is a lack of consensus on the nature and extent of what city governments' regulatory response should be. For example, in the context of perceived failures of decades of deregulation of transport, on the issue of business models, our participants in Manchester were sharply divided between the perceived advantages of complete public ownership and operation of future mobility services on the one hand, and what others considered to be more business-friendly franchising arrangements in which the public sector provides strong regulatory oversight, on the other hand. Negotiating and resolving these and other similar highly political issues remain a significant challenge for city governments. Indeed, as studies in different contexts, such as the USA, Germany, UK and Singapore have shown, governments find themselves at crossroads, having to balance the contrasting imperatives of being seen as supporting innovation and promoting AV development and implementing effective regulatory responses (see e.g. Taeihagh and Lim, 2019; Hansson, 2020; Tan and Taeihagh, 2021; Aoyama and Leon, 2021). So far, the emerging evidence from these studies suggest that long-term regulatory uncertainties remain. In the short-term, governments have avoided stringent measures in favour of more flexible and non-binding regulations in key areas such as privacy, cybersecurity and liability issues. Similar to what we find in our Manchester and Melbourne case studies, critical issues around viable business models and ownership arrangements of AVs and future mobility services remain to be addressed.

6. Conclusion

In this paper, we have developed and demonstrated how a participatory multi-criteria visioning and appraisal framework and methodology can help stakeholders to envision the role of AVs in future transportation systems, and identify and interrogate essential tensions between imagined AV futures and long-term transport and mobility imperatives. The study has revealed what stakeholders at the forefront of policy and decision-making consider to be the priorities and their evaluation of potential role of AVs in bringing about desired transport and mobility futures. We show that respondents are neither 'opponents' nor 'evangelists' regarding the prospects of AVs. Instead, their attitudes manifest the contrasting perspectives of excitement, optimism, ambivalence, scepticism and uncertainty all at the same time. They identify AVs prospects in various use cases, while at the same time, recognising the inherent contradictions between automated driving futures and imperatives such as reversing auto-mobility, and creating safe and inclusive urban environments. Finally, the study shows the significant role governance and politics will play, especially in the areas of implementing viable business models and ownership arrangements of AVs and associated mobility services, in bringing about desired urban futures.

Public participation is critical in envisioning and creating sustainable urban transport and mobility futures, given the inherently political nature of the process. To this end, our goal with this study is to provide a methodological framework that scholars and practitioners can apply in different decision contexts to co-imagine and appraise alternative futures, and ultimately generate principles and strategies for action. The approach and insights presented in this paper are not without limitations. Firstly, we recognise that any attempt at imaging the future is fraught with uncertainty. This is even more challenging to do at a time when AVs are still in an early experimental phase. We therefore see the value of this paper partly in terms of reflecting policy-makers and other relevant stakeholders' emerging understanding of what the prospects of AVs are likely to be and identifying contradictions and contestations that need mediating and resolving. Secondly, in this study, we endeavoured to bring together similar stakeholders of relevance to the topic in our visioning workshops in both Manchester and Melbourne. In line with the

objectives of the study and the workshop format used, our goal was neither to derive a representative sample of participants nor achieve generalizability in terms of the results. That said, we also recognise that changes to the workshop participants, even for the same set of case study cities, could potentially affect the outcome of the participatory visioning exercise presented here. Thus, the visions and appraisal outcomes presented in this paper are not intended as predictions of the future with any degree of certainty. Instead, they are intended to highlight on-going debates around AVs and how they fit into future transportations systems, and as a starting point to identifying principles that can shape the ways in which AVs might be deployed to create desirable futures.

CRediT authorship contribution statement

Ransford A. Acheampong: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing. **Crystal Legacy:** Conceptualization, Investigation, Writing – review & editing. **Richard Kingston:** Conceptualization, Investigation, Writing – review & editing. **John Stone:** Conceptualization, Investigation, Writing – review & editing.

Data availability

Data will be made available on request.

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Appendices.

Appendix A: Workshop participants' organization/designation

Greater Manchester	Melbourne
• Academics: Transport and Mobility Researchers (3), based in Manchester • Advocacy: Cycling and Public transport (2 representatives who prefer organizations/individuals not to be named) • Consultancy: Arup, Manchester (Energy and Transport Division); Jacobs, Manchester (Emerging Technology and Innovation) • Greater Manchester Combined Authority (GMCA): Industrial Strategy • Highways England • Local Government: Bolton Council, Manchester (Highway and Engineering Division) • Local Government: Manchester City Council (City Policy Office) • Local Government: Rochdale Borough Council (Planning and Development) • Network Rail (2 representatives) • Transport for Greater Manchester (TFGM): representations from CAV portfolio and Management Delivery; Rail Programme; and Innovation Research and Insight Units/Departments • Transport Strategy Manager, Stockport Council (Transport Strategy unit/division)	• Academics: Transport and Mobility Researchers (2), based in Melbourne • Bus Industry Association (1 representative) • Community Activist (Prefers individuals/organizations not to be named) • Consultancy (3 participants who prefer their organizations not to be named) • Infrastructure Victoria (1 representative) • Local government: City of Melbourne (Transport Planning) • Local government: Merri-bek City Council (Transport Planning) • Private Tram Operator (2, representatives who prefer their organizations not to be named) • Public Transport Advocacy (2 representatives who prefer organizations/individuals not to be named) • State Government (2 representations from Transport Planning Authority)

Appendix B: Criteria and MCA evaluation of future mobility visions for Greater Manchester

Theme	Criteria	Manc-Vision 1a			Manc-Vision 1b		
		Weight (w_j)	Preference Score (s_{ij})	$w_j * s_{ij}$	Weight (w_j)	Preference Score (s_{ij})	$w_j * s_{ij}$
Reduced car use and associated impacts on society and environment	50% of journeys to be made by sustainable modes of transport)	3	100	300	3	75	225
	Reduce private car ownership in favour of sharing and PT	1	25	25	1	70	70
	Reduce need for second car to curtail private ownership,	4	25	100	4	75	300
	Reduce poor air quality in city centre/town centres	4	100	400	4	75	300
	Reduced demand for parking spaces in new development	1	50	50	1	50	50
	Increase the fleet of electric cars (by 100%, 2040)	1	100	100	1	50	50
	Reallocation of redundant road space for green infrastructure	1	50	50	1	20	20
Efficient and affordable public transport	Achieve level 5 public transit accessibility in highly deprived areas	4	50	200	4	100	400
	Improve first/last mile access to public transport across greater Manchester	4	100	400	4	70	280
	Make transport affordable for the elderly (maintain free public transport for the elderly)	4	80	320	4	60	240
	Make transport affordable to young people	4	80	320	4	50	200
	Integrate ticketing system between public transport modes (tram, buses)	4	80	320	4	50	200

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(*continued*)

Theme	Criteria	Manc-Vision 1a			Manc-Vision 1b		
		Weight (w_j)	Preference Score (s_{ij})	$w_j * s_{ij}$	Weight (w_j)	Preference Score (s_{ij})	$w_j * s_{ij}$
	Provide night-time public transport services for 24hr job access (different work patterns)	3	100	300	3	100	300
Support for increased non-motorized transport (NMT) use	Complete Manchester bee network (cycling infrastructure to promote cycling for transport)	3	75	225	3	15	45
	Increase bicycle mode share to 8–10% across Greater Manchester	3	70	210	3	20	60
	Make town and city centres pedestrian friendly	3	75	225	3	25	75
	Protect pedestrians	5	50	250	5	40	200
	Ensure safe travel for cyclists	5	50	250	5	40	200
	Apply mandatory cycling training in schools	1	75	75	1	50	50
Safe transport for different groups	Safe transport for vulnerable groups in society (women, children, LGBT)	4	80	320	4	100	400
	Reduce road accidents and fatalities (by 95–99%)	5	50	250	5	70	350
	Ensure safe transport for the elderly and people with physical impairment.	4	85	340	4	100	400
Integrated land-use and transit planning	Concentrate housing and job development in inner-city brownfield areas.	3	20	60	3	50	150
	Supporting dispersed economic growth across the region	4	85	340	4	100	400
Public sector regulations for accountability and transparency	User data must be managed in a transparent and accountable way	5	75	375	5	50	250
	Ensure public ownership (integration?) of public transport service (100%, bus network)	1	75	75	1	60	60
	Support regulated private transport business providers (on-demand/shared mobility services)	4	80	320	4	80	320
Employment futures	Minimize risks of unemployment resulting from automation (taxi drivers, bus drivers etc.)	3	20	60	3	80	240
	Train a workforce with the right skills to cope with automation	3	75	225	3	80	240
	Profitability: High businesses turnover in the transport sector	3	15	45	3	70	210
Behavioural change	Promote behavioural change to shift more sustainable modal choices	3	75	225	3	20	60
		100	**1995**	**6755**	**100**	**1895**	**6345**

Appendix C: Criteria and MCA evaluation of future mobility visions for Melbourne

Theme	Criteria	Melb-Vision 1a			Melb-Vision 1b		
		Weight (w_j)	Preference Score (s_{ij})	$w_j * s_{ij}$	Weight (w_j)	Preference Score (s_{ij})	$w_j * s_{ij}$
Reduced car use and associated impacts on society and environment	Reduce private car ownership in favour of sharing and PT (by 50%)	5	39	195	5	62	310
	Reduce poor air quality in city centre/town centres	5	57	284	5	60	300
	Reduce kms travelled per person	3	34	101	3	59	176
	Reach 100% green energy (electric) sources for all transport modes	5	80	400	5	80	400
	Reduce parking demand by 50% and reallocate road space to support non-private car modes	5	36	179	5	73	366
Efficient and affordable public transport	Achieve level 5 public transit accessibility in the main urban/built-up areas	5	49	244	5	70	351
	Integrate ticketing system between public transport modes (tram, buses)	1	41	41	1	47	47
	Make transport affordable for the elderly (maintain free public transport for the elderly)	5	32	161	5	44	219
	Make transport affordable to young people	5	32	162	5	44	219
	Improve first/last mile access to public transport across city/city-region	5	63	314	5	72	359
	Provide night-time public transport services for 24hr job access (different work patterns)	4	54	218	4	59	237
Support for increased non-motorized transport (NMT) use	Increase bicycle mode share to 10% from 1 to 2% currently	5	30	149	5	39	193
	Make town and city centres pedestrian friendly	5	32	161	5	46	232
Safe transport for different groups	Ensure safe transport for vulnerable groups in society (e.g. women, children, LGBTQ and disabled)	5	62	309	5	66	329
	Avoidance of collision with AV and non-AV on roads (by 80%)	5	40	201	5	50	248
	Transport infrastructure should support safety of all road users (e.g. separated spaces on roads)	5	31	154	5	66	329

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(*continued*)

Theme	Criteria	Melb-Vision 1a			Melb-Vision 1b		
		Weight (w_j)	Preference Score (s_{ij})	$w_j * s_{ij}$	Weight (w_j)	Preference Score (s_{ij})	$w_j * s_{ij}$
	Manage expectation that safety can be resolved through technology (70%)	1	40	40	1	40	40
Integrated land-use and transit	Concentrate new housing and job development in inner-city brownfield areas linked with public transit	4	34	135	4	47	187
	Achieve the vision of 80% of population living in a '20-min city'	4	52	207	4	53	213
Public sector regulations for accountability and transparency	Support regulated private transport business providers (on-demand/shared mobility services)	3	67	201	3	54	162
	Strong public oversight/regulatory framework of the future transport service provision (regardless of type of ownership)	4	46	186	4	70	281
	Legislation/regulatory framework to require that data is shared (should be public)	4	40	161	4	49	197
Employment futures	Provide support to workers during the transition to autonomous vehicles (minimize risk of unemployment)	3	42	126	3	63	189
User confidence	Promote user confidence of autonomous vehicles	2	42	84	2	40	81
Behavioural change	Promote behavioural change to shift more sustainable modal choices	2	43	85	2	67	134
	Total	100	1116	4496	100	1419	5796

References

Acheampong, R.A., Cugurullo, F., Gueriau, M., Dusparic, I., 2021. Can autonomous vehicles enable sustainable mobility in future cities? Insights and policy challenges from user preferences over different urban transport options. Cities 112, 103134.

Aoyama, Y., Leon, L.F.A., 2021. Urban governance and autonomous vehicles. Cities 119, 103410.

Ashmore, D.P., Stone, J., Kirk, Y., 2019. The need for greater transparency when assessing the performance and prospects of Melbourne's rail franchise contracts. Urban Pol. Res. 37 (1), 82–96.

Banister, D., Hickman, R., Stead, D., 2007. Looking over the horizon: visioning and backcasting. In: Perrels, A., Himanen, V., Lee-Gosselin, M. (Eds.), Building Blocks for Sustainable Transport. Emerald Group Publishing Limited.

Botello, B., Buehler, R., Hankey, S., Mondschein, A., Jiang, Z., 2019. Planning for walking and cycling in an autonomous-vehicle future. Transp. Res. Interdiscip. Perspect. 1, 100012.

Brovarone, E.V., Scudellari, J., Staricco, L., 2021. Planning the transition to autonomous driving: a policy pathway towards urban liveability. Cities 108, 102996.

Chan, C.Y., 2017. Advancements, prospects, and impacts of automated driving systems. Int. J. Transport. Sci. Technol. 6 (3), 208–216.

Cugurullo, F., Acheampong, R.A., Gueriau, M., Dusparic, I., 2021. The transition to autonomous cars, the redesign of cities and the future of urban sustainability. Urban Geogr. 42 (6), 833–859.

Currie, G., 2018. Lies, damned lies, AVs, shared mobility, and urban transit futures. Journal of Public Transportation 21 (1), 3.

Curl, A., Fitt, H., Ahuriri-Driscoll, A.L.M., Fletcher, A., Slaughter, H., Dionisio-McHugh, R., 2018. Autonomous Vehicles and Future Urban Environments: Exploring Changing Travel Behaviours, Built Environments, and Implications for Wellbeing in an Ageing Society. Url: https://ir.canterbury.ac.nz/bitstream/handle/10092/15402/Doc?sequence=2. (Accessed 27 February 2023). accessed.

Dean, M.D., Kockelman, K., 2022. Our self-driving future will be shaped by policies of today. Nat Electron 5, 2–4. https://doi.org/10.1038/s41928-021-00708-4.

Docherty, I., Marsden, G., Anable, J., 2018. The governance of smart mobility. Transport. Res. Pol. Pract. 115, 114–125.

Dodgson, J.S., Spackman, M., Pearman, A., Phillips, L.D., 2009. Multi-criteria Analysis: a Manual. http://eprints.lse.ac.uk/12761/1/Multi-criteria_Analysis.pdf.

Emory, K., Douma, F., Cao, J., 2022. Autonomous vehicle policies with equity implications: patterns and gaps. Transp. Res. Interdiscip. Perspect. 13, 100521.

Faber, K., van Lierop, D., 2020. How will older adults use automated vehicles? Assessing the role of AVs in overcoming perceived mobility barriers. Transport. Res. Pol. Pract. 133, 353–363.

Grindsted, T.S., Christensen, T.H., Freudendal-Pedersen, M., Friis, F., Hartmann-Petersen, K., 2022. The urban governance of autonomous vehicles–In love with AVs or critical sustainability risks to future mobility transitions. Cities 120, 103504.

González-González, E., Nogués, S., Stead, D., 2019. Automated vehicles and the city of tomorrow: a backcasting approach. Cities 94, 153–160.

Greater Manchester Combined Authority, 2018. The Greater Manchester Digital Strategy 2018–2020. Greater Manchester Combined Authority, Manchester, UK. https://www.greatermanchester-ca.gov.uk/media/1090/digital-strategy-2018-2020.pdf. (Accessed 11 May 2022). accessed.

Hansson, L., 2020. Regulatory governance in emerging technologies: the case of autonomous vehicles in Sweden and Norway. Res. Transport. Econ. 83, 100967.

Involve, 2019. Citizens' Conversation on Driverless Vehicles. Event Report. Url: https://www.involve.org.uk/sites/default/files/field/attachemnt/FINAL%20Citizens%27%20Conversation%20on%20Driverless%20Vehicles%20Report_0.pdf. (Accessed 11 May 2022). accessed.

Infrastructure Victoria, 2018. Advice on Automated and Zero Emissions Vehicles Infrastructure, October 2018, Melbourne. https://www.infrastructurevictoria.com.au/wp-content/uploads/2019/04/Advice-on-automated-and-zero-emissions-vehicles-October-2018.pdf.

Jiang, L., Chen, H., Chen, Z., 2022. City readiness for connected and autonomous vehicles: a multi-stakeholder and multi-criteria analysis through analytic hierarchy process. Transport Pol. 128, 13–24.

Kovacs, F.S., McLeod, S., Curtis, C., 2020. Aged mobility in the era of transportation disruption: will autonomous vehicles address impediments to the mobility of ageing populations? Travel behaviour and society 20, 122–132.

Legacy, C., Ashmore, D., Scheurer, J., Stone, J., Curtis, C., 2019. Planning the driverless city. Transport Rev. 39 (1), 84–102.

Litman, T., 2018. Autonomous vehicle implementation predictions. In: Implications for Transport Planning. Victoria Transport Policy Institute. https://www.vtpi.org/avip.pdf.

Lyons, G., 2022. The Driverless Cars Emulsion: Using participatory foresight and constructive conflict to address transport's wicked problems. Futures 136, 102889.

Manivasakan, H., Kalra, R., O'Hern, S., Fang, Y., Xi, Y., Zheng, N., 2021. Infrastructure requirement for autonomous vehicle integration for future urban and suburban roads–Current practice and a case study of Melbourne, Australia. Transport. Res. Pol. Pract. 152, 36–53.

McAslan, D., Najar Arevalo, F., King, D.A., Miller, T.R., 2021. Pilot project purgatory? Assessing automated vehicle pilot projects in US cities. Humanit. Soc. Sci. Commun. 8 (1), 1–16.

Melander, L., 2018. Scenario development in transport studies: methodological considerations and reflections on Delphi studies. Futures 96, 68–78.

Merfeld, K., Wilhelms, M.P., Henkel, S., Kreutzer, K., 2019. Carsharing with shared autonomous vehicles: uncovering drivers, barriers and future developments–A four-stage Delphi study. Technol. Forecast. Soc. Change 144, 66–81.

Milakis, D., Snelder, M., Van Arem, B., Van Wee, B., de Almeida Correia, G.H., 2017a. Development and transport implications of automated vehicles in The Netherlands: scenarios for 2030 and 2050. Eur. J. Transport Infrastruct. Res. 17 (1).

Milakis, D., Van Arem, B., Van Wee, B., 2017b. Policy and society related implications of automated driving: a review of literature and directions for future research. J. Intell. Transport. Syst. 21 (4), 324–348.

Millard-Ball, A., 2018. Pedestrians, autonomous vehicles, and cities. J. Plann. Educ. Res. 38 (1), 6–12.

Neuvonen, A., Ache, P., 2017. Metropolitan vision making–using backcasting as a strategic learning process to shape metropolitan futures. Futures 86, 73–83.

Ng, M.K., Koksal, C., Wong, C., Tang, Y., 2022. Smart and sustainable development from a spatial planning perspective: the case of Shenzhen and greater Manchester. Sustainability 14 (6), 3509.

Nogués, S., González-González, E., Cordera, R., 2020. New urban planning challenges under emerging autonomous mobility: evaluating backcasting scenarios and policies through an expert survey. Land Use Pol. 95, 104652.

Olin, J.J., Mladenović, M.N., 2022. Imaginaries of road transport automation in Finnish governance culture—a critical discourse analysis. Sustainability 14 (3), 1437.

Owens, J.M., Sandt, L., Habibovic, A., McCullough, S.R., Snyder, R., Emerson, R.W., et al., 2018. Automated vehicles and vulnerable road users: envisioning a healthy, safe and equitable future. In: Automated Vehicles Symposium. Springer, Cham, pp. 61–71.

Rojas-Rueda, D., Nieuwenhuijsen, M.J., Khreis, H., Frumkin, H., 2020. Autonomous vehicles and public health. Annu. Rev. Publ. Health 41 (1), 329–345.

Schuckmann, S.W., Gnatzy, T., Darkow, I.L., Heiko, A., 2012. Analysis of factors influencing the development of transport infrastructure until the year 2030—a Delphi based scenario study. Technol. Forecast. Soc. Change 79 (8), 1373–1387.
Shaheen, S.A., Cohen, A.P., 2013. Carsharing and personal vehicle services: worldwide market developments and emerging trends. Int. J. Sustain. Transport. 7 (1), 5–34.
Soria-Lara, J.A., Ariza-Álvarez, A., Aguilera-Benavente, F., Cascajo, R., Arce-Ruiz, R.M., López, C., Gómez-Delgado, M., 2021. Participatory visioning for building disruptive future scenarios for transport and land use planning. J. Transport Geogr. 90, 102907.
Sohrabi, S., Khreis, H., Lord, D., 2020. Impacts of autonomous vehicles on public health: a conceptual model and policy recommendations. Sustain. Cities Soc. 63, 102457.
Spickermann, A., Grienitz, V., Heiko, A., 2014. Heading towards a multimodal city of the future?: multi-stakeholder scenarios for urban mobility. Technol. Forecast. Soc. Change 89, 201–221.
Tan, S.Y., Taeihagh, A., 2021. Adaptive governance of autonomous vehicles: accelerating the adoption of disruptive technologies in Singapore. Govern. Inf. Q. 38 (2), 101546.
Taeihagh, A., Lim, H.S.M., 2019. Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks. Transport Rev. 39 (1), 103–128.
Thompson, J., Read, G.J., Wijnands, J.S., Salmon, P.M., 2020. The perils of perfect performance; considering the effects of introducing autonomous vehicles on rates of car vs cyclist conflict. Ergonomics 63 (8), 981–996.
Williams, E., Das, V., Fisher, A., 2020. Assessing the sustainability implications of autonomous vehicles: recommendations for research community practice. Sustainability 12 (5), 1902.
Zandieh, R., Acheampong, R.A., 2021. Mobility and healthy ageing in the city: exploring opportunities and challenges of autonomous vehicles for older adults' outdoor mobility. Cities 112, 103135.