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Foresight through developing shared mental models: The case of Triple Access Planning

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ABSTRACT

Planning for the future involves making sense of the present and examining possible changes in key factors that can influence the future. Actors rely upon mental models of the system that planning addresses: their simplified interpretations of the makeup of system elements and element interactions that together determine how the system works. It follows that a helpful foundation for strong planning is to develop a shared mental model among actors of the system of interest in the present and use this in turn to create mental models of possible futures for the system (scenarios). This paper presents a methodology for doing this that incorporates co-creation of causal loop diagrams that in turn inform development of scenarios. The paper then applies the methodology to offer more insight to the approach, using the case of the Triple Access System and in turn Triple Access Planning. Triple access refers to the transport, land-use and telecommunications systems which each provide different and inter-related means for being able to reach people, employment, goods, services and opportunities which underpins economic prosperity and social wellbeing. The paper highlights how thinking is an important and integral part of planning, especially when dealing with uncertainty in a complex system.

1. Introduction

Planning for the future involves making sense of the present and examining possible changes in key factors that can influence the future. Actors rely upon mental models of the system that planning addresses (and they may also employ quantitative models that offer a simplified but credible representation of the present to determine possible projections into the future). A mental model reflects "how individuals see the world, how individuals know and think about the world, and how individuals act in the world" (Chermack, 2003: 410). Mattieu et al. (2000: 274) define a mental model as a "mechanism whereby humans generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states". Mental models can be incomplete or not reflect well the reality of the system concerned (Chi, 2008) and different individuals with different learning experiences will have different mental models (Denzau & North, 1994).

It follows that it is helpful for individuals to articulate their mental models with others and in turn learn from each other such that a shared mental model is formed which can then be a basis of clearer common understanding of the system that the planning process seeks to influence. As Glick et al. (2012: 489) note "group learning plays a significant role in developing, modifying and reinforcing team mental models".

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Scenario development is ideally a participatory process that helps explore uncertainty about the future. Scenario planning then uses such explorative insight in the broader planning process to help accommodate the uncertainty. In developing scenarios, those participating will draw upon their mental models of the system(s) in question. Yet this tends to take place without first articulating and sharing those mental models.

This paper sets out a methodology that allows participants with different background disciplines and experiences to articulate their mental models of one or more systems and learn together to co-create a shared mental model of how things are understood in the present to then provide the basis for considering how the system(s) could change in uncertain ways into the future. Specifically, Causal Loop Diagrams (CLDs) are developed that inform the development of morphological scenarios. While the approach lends itself to what might be judged a single system, the particular purpose is to address system of systems thinking where multiple sub-systems are deemed to interact and comprise a combined system that is of interest to the planning process.

The paper first introduces the methodology and then describes its application to 'Triple Access Planning' (TAP) (Lyons, 2021). TAP is a new approach to transport planning that seeks to better recognise that people go about their lives fulfilling their need to reach things through use of the transport system, but also the land use and telecommunications systems. The three systems together form the Triple Access System. Insights from the method's application are then considered.

2. Background – creating mental models

2.1. Systems thinking

Systems thinking is used to develop formal models that can help understanding the complex behaviour of a dynamic system (Forrester, 1961; Schlange, 1995). One of the advantages of system thinking is that outputs concerning the system of interest can be used by experts and non-experts, the latter including policymakers and decision makers. Systems thinking has been applied to a wide variety of domains including environment, demographics, economic growth, business development, agriculture, and natural resources (Biglari et al., 2022). Systems thinking can be used to address complexities, uncertainties, and identifying "what if" impacts (Onat et al., 2017). It can therefore be used to test the effectiveness of policy interventions within future complex socio-economic systems over time (Biglari et al., 2022). It has been recently used to explore how to support sustainable development of cities (Kutty et al., 2020), in particular with respect to measures to mitigate climate change and carbon emissions from transport (Esfandabadi et al., 2020; Suryani et al., 2022). It has been used to explore how to design a walkable city for older people (Pei et al., 2019), combining transport and land-use variables, in addition to other variables, such as quality of life. It has also been considered a valuable method to explore uncertainties, such as emerging behavioural patterns post-pandemic and support policy and decision making to mitigate climate change (Armenia et al., 2022).

2.2. Scenario planning

Scenario planning is defined by Schwartz (2012) as a tool to explore alternative futures in which decisions might be played out. Scenarios can be classified into predictive, explorative, and normative (Svenfelt et al., 2010). Predictive scenarios seek to address the probable ('What will likely happen?'). Explorative scenarios describe the possible ('What could happen?'). Normative scenarios describe the preferable ('What should happen?'). Explorative scenarios are the most appropriate for developing and assessing policies and strategies (Borjeson et al., 2006). Scenario planning is particularly helpful for strategic planning, especially when dealing with deep uncertainty, and it also helps to strengthen consensus among stakeholders towards a vision for the future (Mahmud, 2011).

Sarpong and Maclean (2011) call it 'scenario thinking', as it encourages creativity (MacKay & McKiernan, 2010) to support decision making (Chermack, 2004) and innovation (Drew, 2006). They define it as: "the bundles of human actions and practices in context directed towards understanding the past and the future in the present in order to cope with future uncertainties within the contingencies of the moment" (Sarpong & Maclean, 2011: 1156). Uncertainty can be defined as limited knowledge about future, past, or current events (Walker et al., 2013). When considering uncertainty in policy and decision making, this can be defined as the gap between available knowledge and the knowledge decision makers would need to make the best policy choice (Marchau et al., 2019). Working with future scenarios does not remove uncertainties but creating a diverse set of futures can open the mind and prepare the user(s) for a range of possibilities, allowing stakeholders to make sense of complexity and deal with uncertainty (Svenfelt et al., 2010).

Scenario planning has been used in land use and environmental policy development (Svenfelt et al., 2010) to address deep uncertainty due to the high complexity of the relationships with one or more social systems (Anderies et al., 2004). It has been also widely used in transport (Lyons et al., 2021) to support policy and practice. Scenarios can help to: (i) better understanding the future, especially in case of complex dynamic systems; (ii) improve planning and policy making, identify policy and planning requirements, and engage the stakeholders involved in the decision-making process; and (iii) test the robustness of policies, exploring how they perform across a range of different scenarios (Lyons et al., 2021). The literature highlights that stakeholder engagement is a core element of scenario development and planning. However, stakeholders are experts and non-experts, representatives of the public and holding on to special interests, with clear stakes or clearly affected. It becomes therefore very important to carefully define the types of stakeholders who need to be engaged, and to ensure diversity and inclusion, considering different expertise, interests, and power, to avoid bias (Andersen et al., 2021).

2.3. When system thinking meets scenario planning

Explorative scenarios are designed considering specific critical uncertainties about the future - variables within the system that are, looking forwards, expected to be important and uncertain. It is therefore of value to be able to identify such variables and understand how they might change in the future and what impact this might have on other variables and hence on the future system as a whole. This underlines the importance of systems thinking. Accordingly, causal cognitive maps and causal links can be used for developing scenarios (Goodier et al., 2010; Amer et al., 2013; Kosko, 1997) and to increase their robustness (van Vliet et al., 2010; Jetter & Schweinfort, 2011). The causal map design process can encourage stakeholders to discuss the scenarios and share knowledge and experience to identify the most important and uncertain variables (Soetanto et al., 2011).

Systems thinking and the related causal maps (or mental models) help to account for factors (and their inter-relationships) that are considered important by stakeholders, but which would otherwise be excluded because of a lack of supporting empirical evidence or mathematical formulation of their interaction (Penn et al., 2022).

There are some examples of an integrated use of system thinking and scenario development (e.g., Morandi et al., 2014; Hilty et al., 2006; Strohhecker, 2005; Clemens, 2009; Pizzitutti et al., 2017). In particular, Hilty et al. (2006) used qualitative system thinking and scenario development to address uncertainty concerning the environmental impact of Information and Communication Technologies, including a range of sectors such as transport, industry, agriculture, and energy. They suggest that the use of qualitative methods and stakeholder/expert engagement is key in addressing uncertainty.

3. Methodology

We now set out a methodology to create a shared mental model of a present system and possible futures for that system. In the subsequent section, application of the methodology is then considered.

The methodological approach is based on stakeholder engagement and co-creation of representations of a system or system of systems, with the aim of enriching such representation through a diverse range of knowledge, experience and perspectives. Such a participatory system dynamics approach aims to involve multiple participants to: (i) obtain consensus on the problem articulation; (ii) create a common understanding among the key players seeking to model the system; and (iii) enable subsequent testing of a range of policies (Schmitt Olabisi et al., 2010; Biglari et al., 2022). This approach has been found more useful than producing predictive or empirically validated models (of necessarily narrower scope), especially when considering complex and rapidly developing policy areas that include multiple domains (Barbrook-Johnson & Penn, 2021, 2022).

The process involves developing Causal Loop Diagrams (CLDs). CLDs are comprised of (i) variables (nouns) which can either increase or decrease; (ii) links between variables showing directions of influence between variables; and (iii) signs on the links showing the nature of effect of one variable on another ('+' indicates that the influencing variable increasing would lead to an increase in the influenced variable (or similarly both decreasing), while '-' indicates that the influencing variable increasing would lead to a decrease in the influenced variable (or decreasing leading to increasing)). Fig. 1 illustrates these building blocks. As the variables and links between them are built up, the composition of the system and how it is understood to behave is made apparent.

The methodology can be applied online or through face-to-face participation although in view of the time investment asked of participants, and their possible geographic spread, an online approach (making use of Microsoft Teams combined with the digital whiteboard facility Miro – though alternatives are available) has distinct advantages. The participatory nature of the applied process allows the team of participants to co-create a shared mental model of the system of interest through a series of workshops. This in turn informs the creation of a set of explorative future scenarios for the system. Stakeholder engagement and participation in the creation of the shared mental model and the future scenarios aim at bridging the gap between theory and practice (Banister & Hickman, 2013), providing a greater understanding of the problem (Nonaka, 1994), and contributing to social learning (Rauschmayer & Wittmer, 2006). The final output is not empirically based but rather is a qualitative model that reflects understanding and outlook on the part of the individuals involved in its co-creation.

The methodology is shown in overview in Fig. 2. It is described in more detail below in two parts, explaining: (i) how sub-system CLDs and in turn a combined system of systems CLD are developed to reflect understanding in the present; and (ii) how a set of possible future 'system of systems' scenarios is developed. Steps with workshops are centred upon participant input. Other steps are addressed by those applying the methodology.

3.1. Shared mental model of a system as understood in the present

Participatory system mapping follows a general structure that can be modified to suit the particular purpose and circumstances of the mental modelling exercise (Penn & Barbrook-Johnson, 2019). For complex and changing systems especially, the composition of the

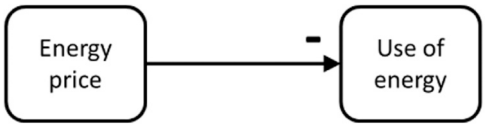
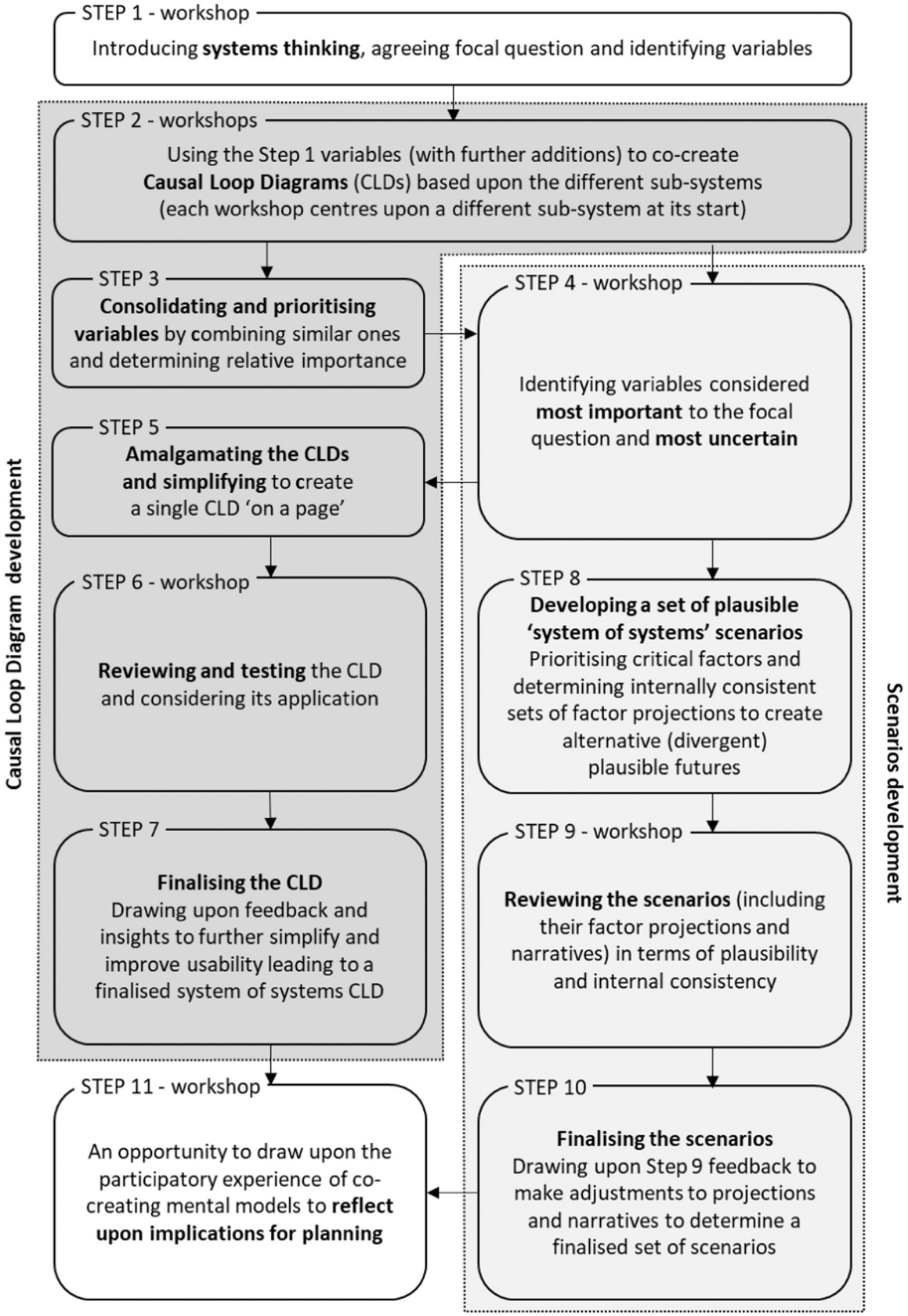


Fig. 1. Components in a CLD – variable, link between variables, and sign (+/-) of one variables effect on another variable.



(caption on next page)

Fig. 2. Outline methodology for creating present (CLD) and future (scenarios) mental models of a system.

participants is a significant determinant of what is produced from shared thinking and diversity of expertise and experience should be encouraged.

With reference to Fig. 2, the following sequence is followed (steps with workshops involve participants while other steps are separately undertaken by the core team applying the methodology):

3.1.1. Step 1 – preparation

In this step participants are brought together for the first time in a workshop setting. Participants are introduced to the notion of systems thinking and specifically to the use of CLDs. To ensure a clear orientation to the co-creation of a shared mental model, the system and sub-systems of interest are confirmed. Participants discuss and agree on a focal question that gives orientation and clarity of purpose to the process of co-production ahead. Participants are then asked to identify key variables for use in building CLDs that they consider relevant to the system of interest and its sub-systems. Later in the process participants can, if they wish, include further variables to the pool created in this step.

3.1.2. Step 2 – creation of sub-system CLDs

In a series of workshops the variable list is used to build a set of sub-system CLDs. In each workshop the 'centre of gravity' of attention (framed by the focal question) considers one of the sub-systems. In this way the resulting CLDs are not mutually exclusive but collectively span the overall system and each emanates outwards from its centre of gravity. Each workshop draws on, and is able to add to, variables identified in Step 1. Ideally two or more break-out groups of participants are formed in each workshop, allowing alternative sub-system CLDs to be generated and then compared.

3.1.3. Step 3 – consolidating and prioritising variables

Similar variables created by participants in Step 1 and Step 2 are consolidated (which is likely to reduce the overall list of identified variables). An indicative ranking of variables is then produced whereby the more prevalent (how often a variable is included across the CLDs produced) and interrelated with other variables (the number of links to/from it across the CLDs) a given variable is, the higher it is rated.

3.1.4. Step 4 – identifying critical uncertainties in the system

The next workshop's purpose is to identify those variables considered most important in the system, and of these which are considered most uncertain in terms of how they could change in future. Participants are given a set of the highest ranked variables from Step 3 as a starting point and catalyst and are then able to substitute with or add more from the wider pool of variables. Participants then sort the resulting set of variables according to their relative importance and uncertainty.

3.1.5. Step 5 – amalgamating the CLDs and simplifying

The CLDs produced by breakout groups in Step 2 for each sub-system are consolidated into a combined CLD for the respective workshop. These combined CLDs are then amalgamated to form a single overall CLD representation of the system. This is likely to depict a representation of the system that planning seeks to address, the richness and complexity of which compromises its legibility and usability. Accordingly, an iterative simplification process (Bureš, 2017) can then be used to prune the number of variables and links to converge upon a 'system on a page'. The intention in simplifying is to help make it possible for all stakeholders (in particular, non-experts) to make more sense of the system of interest (Perrone et al., 2020). The simplification process should not remove any of the most important variables identified in Step 4.

3.1.6. Step 6 – reviewing and testing the draft 'on a page' CLD

In the next workshop participants are presented with the draft simplified CLD and the process followed to create it. Participants are then invited to 'walk around' the CLD while talking aloud to articulate the dynamics within the system and make sense of how the mental model 'works' in terms of the variables and connections. Feedback is gathered. Discussion can also be encouraged regarding how the mental model can be used in the planning process associated with the system of interest.

3.1.7. Step 7 – finalising the CLD on a page

Drawing upon insights from Step 6, further refinement to the CLD is made including reworking of presentational aspects to further improve legibility and accessibility. The resulting CLD on a page then reflects an approximation of the shared mental model of the system of interest.

3.2. Scenarios development to explore possible futures for the system of interest

A set of possible future scenarios is then developed to help expose uncertainty in key system dynamics over time that set a context for the planning process that seeks to influence the future of the system.

Scenario development does not need to be associated with development of a CLD as is the case here (and typically is not). However, by engaging in systems thinking and the production of a CLD, a helpful basis is created for an important early stage in scenarios

development, namely determining the important factors influencing the future (drawing upon the variables in the CLD). The approach below focuses on the development of explorative scenarios.

Explorative scenarios can help us better understand how the world might change in future. They can in turn be used to help judge how planning can help set a course towards a preferred future and outcomes (vision) that is better able to account for and accommodate the uncertainty ahead (that is partly or fully beyond the control of the planning authority). In short, this can lead to more robust decision making. With reference again to Fig. 2, the subsequent steps in the methodology are applied:

3.2.1. Step 8 – scenario development

The following process is used to develop a set of divergent possible future scenarios for the system of interest (though different approaches to scenario development are available (Lyons et al., 2021)):

- The variables considered most important and uncertain in Step 4 are reviewed further and consolidated into a small number (five to ten) of 'critical uncertainties'.
- Two future projections are identified (high/low, strong/weak etc.) for each critical uncertainty.
- Taking all critical uncertainties and their possible future projections creates a large number of combinations of possible future states for these uncertainties, though not all will be credible (in terms of internal consistency within a combination). Three considerations are weighed up in identifying a shortlisted set of combinations of variable projections (scenarios): (i) a set of scenarios that are divergent from one another (thereby reflecting a good degree of the uncertainty over the future); (ii) scenarios for which the variable projections are compatible and credible – i.e. the scenarios each appear internally consistent and plausible (they make sense); and (iii) a small enough number of scenarios shortlisted to be manageable in subsequent use (as described in more detail in Lyons et al., 2021).
- A limited number of other important factors (deemed by participants to be more certain) can be added to help enrich the subsequent narrative creation, in relation to the focal question.
- Each scenario is given a name, and a narrative depiction of the scenario - built around the critical uncertainties and optionally added important certain factors - is written.

3.2.2. Step 9 – reviewing the draft scenarios

The next workshop introduces the reconvened participants to the draft set of possible futures for the system of systems. Participants are encouraged to consider the plausibility and internal consistency of each scenario (while recognising the subjective nature of plausibility, and whether it introduces a critical look at how we think and design our present systems by looking to the future - Urueña, 2019). Testing the narratives on participants allows them to bring challenge, informing further revision of the scenarios (see next step). The opportunity can be given for participants to provide further written feedback on the credibility of the scenarios.

3.2.3. Step 10 – finalising the scenarios

The feedback from Step 9 is used to review and refine the scenarios (in terms of both the factor projections and narratives).

3.2.4. Step 11 – opportunity for reflection

The final workshop in the process of creating mental models of the system is intended as an opportunity for participants to draw upon their engagement in the process and to reflect upon the outputs created to consider the implications for planning.

4. Application

The methodology is not prescriptive since generating representations of a system of interest in the present and future is not an exact science and the time and resource available for doing so will be variable. It should be seen as a guide to how to structure a process that combines participation with processing and synthesising of insights by the team applying the methodology.

This section of the paper now sets out a specific case of applying the methodology. This is intended to further illuminate the methodology itself and move from abstract to more applied consideration. For some readers the system in focus may also be of more direct interest. This system is what is known as the Triple Access System (Lyons & Davidson, 2016) – a system of systems that brings together the transport, land-use and telecommunications (sub-)systems. The motivation for this particular application is to address the ongoing evolution of transport planning. Transport planning's focus has traditionally been the shaping of the transport system, albeit with a growing recognition of the significance to this of the land use system and changes to it. However, as the digital age has collided and merged with the motor age, the telecommunications system has growing relevance for the future of the transport system and its use.

We first provide some background to the application area before then setting out how the methodology was used and with what outputs.

4.1. Changing transport planning and the importance of a triple-access lens

4.1.1. From a forecast-led mobility focus to a vision-led accessibility focus

Transport planning has traditionally concerned itself with a forecast-led ('predict and provide') approach of examining how demand for transport (especially use of the private car) is likely to change in future and then determining how transport supply could be

changed to address that demand. The transport system and its use has been the primary focus. This approach has come under increasing scrutiny and has been criticised for its: (i) demand led approach which has often resulted in negative effects from increasing levels of road traffic; (ii) reliance upon being able to forecast likely future demand in the face of uncertainty; and (iii) focus upon motorised road traffic rather than more widely considering the underlying need to fulfil requirements for access to people, goods, jobs, services and opportunities that supports economic and social activity. The imperative of responding to climate change has heightened the appetite for something different.

Lyons and Davidson (2016) set out an alternative approach which they termed 'decide and provide' and which is vision-led rather than forecast-led. It identifies a preferred rather than predicted future. It focuses upon access rather than (only) upon transport. It exposes and seeks to accommodate uncertainty. They drew attention to what they called the Triple Access System (see Fig. 3) – wherein access fulfilment in society is achieved through the transport system (physical mobility), the land use system (spatial proximity) and the telecommunications system (digital connectivity). In accordance with this decide and provide paradigm, Lyons (2021) coined the term 'Triple Access Planning' to reflect the new mindset and approach to transport planning embodied in the decide and provide paradigm. This coincided with the launch of a new pan-European project called 'Triple Access Planning for Uncertain Futures'[1] which is intended to deepen an understanding of how to apply Triple Access Planning, with a focus on urban areas.

Transport planners need to be enabled to unthink and in turn rethink their understanding of the system – or system of systems – they wish to shape through the plans they develop and then implement. There is, we would argue, a need for a triple access mindset rather than a mobility mindset – something which systems thinking and scenario development can help achieve.

4.1.2. Thinking about access

Travel is a derived demand. It is (typically) derived from the need or desire to participate in activities at alternative locations. Implicit in, and at the heart of, such understanding is accessibility – being able to reach people, goods, jobs, services, and opportunities. Yet within transport planning, as Banister notes, there has been a "predominance of transport solutions to urban problems" constituting pursuit of a demand-based "transport-led future" (Banister, 2008: 73). Yet if travel is a derived demand, it should be apparent that the root cause of that demand lies beyond only transport and concerns fulfilment of society's access needs and desires. Transport solutions may not be the only recourse to addressing transport problems.

This has given rise to considerable interest in paying more attention to accessibility as opposed to (only) mobility in transport planning (Curl et al., 2011; Kilby & Smith, 2012; Halden, 2014; Shia et al., 2020). Yet interest has not translated as readily into transport planning practice. As put by Handy (2020: 2) "[a] seemingly simple idea, that goods and services and other activities should be easy to reach, is somehow difficult to implement in practice". When it comes to accessibility measures and instruments, there is a recognised 'implementation gap' (Silva & Larsson, 2018) – something Handy (2020) attributes to the relative difficulty in being able to measure accessibility compared to measuring mobility. Complex, hard to grasp accessibility measures may be standing in the way of accessibility being at the heart of practice. Reflecting upon nearly three decades of experience, she advocates the importance of embracing accessibility as a way of thinking to in turn influence practice, foregoing the difficulties above, of complex accessibility measurement, in favour of simple indicators.

4.1.3. An important and growing dimension to access

Overwhelmingly, interest in accessibility and accessibility planning has concerned itself with the relationship between land-use and transport, whereby land-use determines where activities are available, and transport is the means for such activities to be reached. Meanwhile, the last two decades have seen accessibility affected by a rapidly maturing digital age in which access needs are increasingly being fulfilled for some people some of the time by digital connectivity rather than physical mobility. There has been much research examining how the digital age has influenced society's: mobility and flows; spatial and physical aspects; human aspects; and activities (Yousefi & Dadashpoor, 2020). Kenyon et al. suggested that 'virtual mobility' could enable "an Internet based increase in accessibility as an alternative to an increase in physical mobility" (Kenyon et al., 2002: 207). Yet this has not featured very strongly in the considerable body of work on accessibility in relation to transport planning. The COVID-19 pandemic has strongly highlighted our collective reliance on triple-access, the resilience it can offer to society and the adaptability in the makeup of access fulfilment within the Triple Access System.

4.1.4. Thinking about the Triple Access System

The Triple Access System highlights the fallibility of considering the transport system in isolation when it comes to making sense of society's present and future mobility demands. Indeed, by insufficiently considering the land-use system and telecommunications system and their influences on, and interdependencies with, the transport system, our ability to understand change affecting the transport system is lessened, thereby increasing (or deepening) uncertainty.

Fig. 3 may be conceptually appealing (and has proven to be attractive in its simplicity), but it offers limited insight into the finer grain functioning of an urban system. A greater depth of thinking (systems thinking) is called for.

[1] https://www.tapforuncertainty.eu/

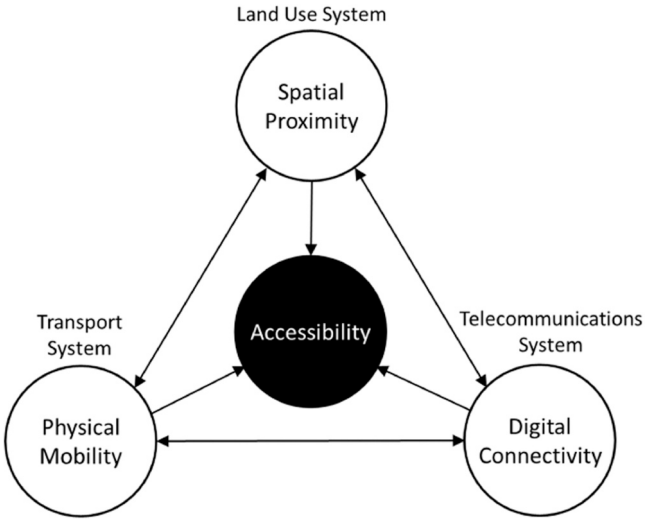


Fig. 3. The Triple Access System (reproduced from (Lyons & Davidson, 2016: Fig. 2)).

4.2. Developing a shared mental model of the Triple Access System and its possible futures

We now describe the application of the methodology to the Triple Access System.

Participation within the process involved individuals from across the 'Triple Access Planning for Uncertain Futures' project consortium. This spanned five countries – Italy, Netherlands, Slovenia, Sweden and the UK. It involved 34 representatives from across 16 organisations – university research groups, urban transport authorities, national transport authorities, and consultancies. Participants reflected a diversity of expertise relating to transport and travel behaviour, spatial planning, digital connectivity and freight and logistics. The authors were responsible for the design, organisation and running of the workshop series and the related analysis. The workshops took place online. While this was necessary because of the travel restrictions relating the COVID-19, it was also desirable in view of the geographic spread of participation involved across Europe. Not all 34 representatives took part in all workshops although there was a strong collective continuity of involvement through the set of workshop steps in the methodology.

Step 1 and Step 2 took place over a one-month period (25 May to 22 June 2021). The focal question was '*What factors affect demand for access in a post-COVID more digitalised world?*'. Over 100 variables were identified by participants and a set of three workshops in Step 2 considered the land-use, telecommunications and transport sub-systems in turn. In each workshop there were three breakout groups resulting in creation of a total of nine sub-system CLDs. Steps 3 and 4 consolidated and prioritised the variables and sorted them according to importance and uncertainty. From 29 variables considered most important (each marked to show '(number of the

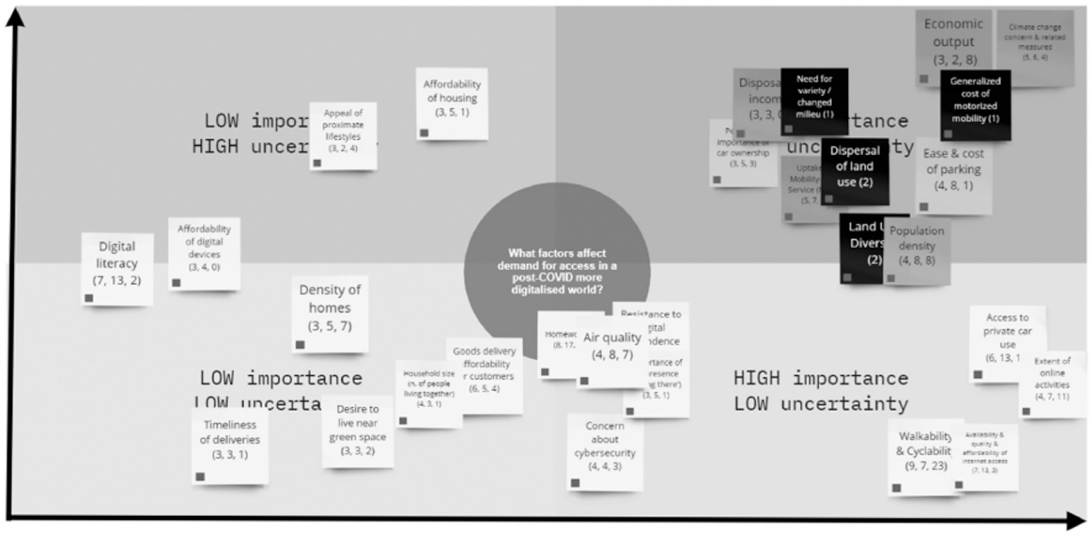


Fig. 4. Sorting variables (factors) according to the degree of importance and uncertainty concerning their effect on the future in relation to the focal question.

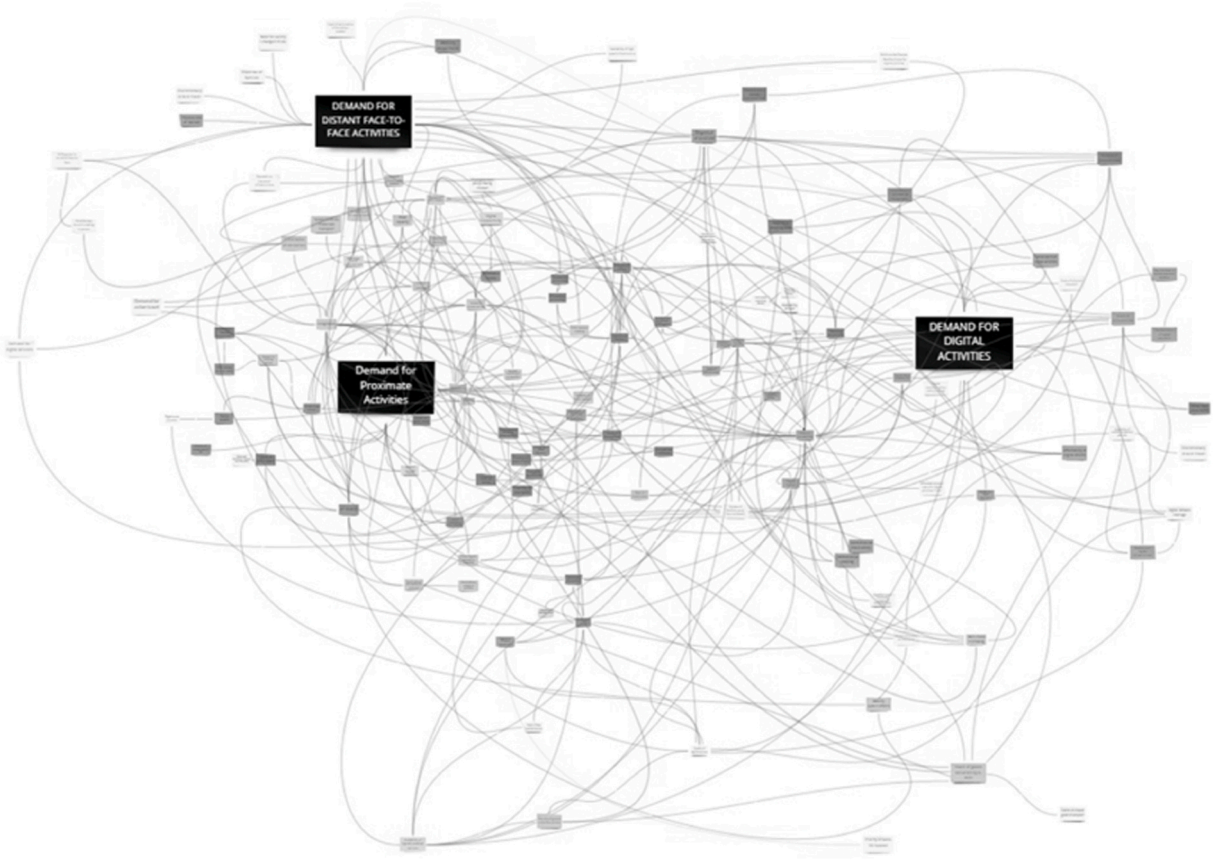


Fig. 5. Unmodified Triple Access System CLD.

individual CLDs it appeared in, number of links from it to other variables, number of links from other variables to it)'), 11 of these were judged to be of high importance and high uncertainty (see Fig. 4). As a result of Step 5, a single 'unrefined' shared mental model of the Triple Access System was produced (see Fig. 5). At the end of Step 7 a more simplified version of the shared mental model had been produced (see Fig. 6).

From a post-workshop review of the 11 variables deemed to be of high importance and high uncertainty, seven prioritised critical factors were identified. The prioritised critical factors and their future projections used to create a set of possible triple access future scenarios are shown and explained in Table 1. Six combinations of factor projections were identified (see Table 2) to produce a set of divergent possible scenarios (summarised in Table 3 and set out in more detail in Annex 1).

5. Making use of the outputs from applying the methodology

The process of engaging in thinking, co-creating mental models of a system, and examining future possibilities for the system has value in its own right in terms of shared learning amongst those participating. Making use of the outputs from the methodology above to think together then provides further value in the planning process. We draw upon the example application for the Triple Access System to consider this further (Step 11 in Fig. 2).

5.1. Using the shared mental model of the present system to explore policy goals in planning

The Triple Access System CLD shown in Fig. 6 can be used to explore how possible urban mobility planning goals may be addressed as well as what possible effects may result in terms of influence within the system. This is illustrated below with an example policy goal: *To encourage more people to work from home and commute less.*

As a planning team, mentally walking around the Triple Access System in Fig. 6 enables two important questions concerning this candidate policy goal to be explored: (i) which aspects of the urban system may *influence* achieving this policy goal?; and (ii) what *consequences* could there be from achieving the goal?

From consulting Fig. 6, variables affecting and affected by homeworking are identifiable. Each of these can then be scrutinised in terms of wider understanding about them to help make sense of their relevance to the policy goal and what dynamics in the system would be affected by efforts to encourage more working from home. Such scrutiny provides a reminder of the simplified nature of the

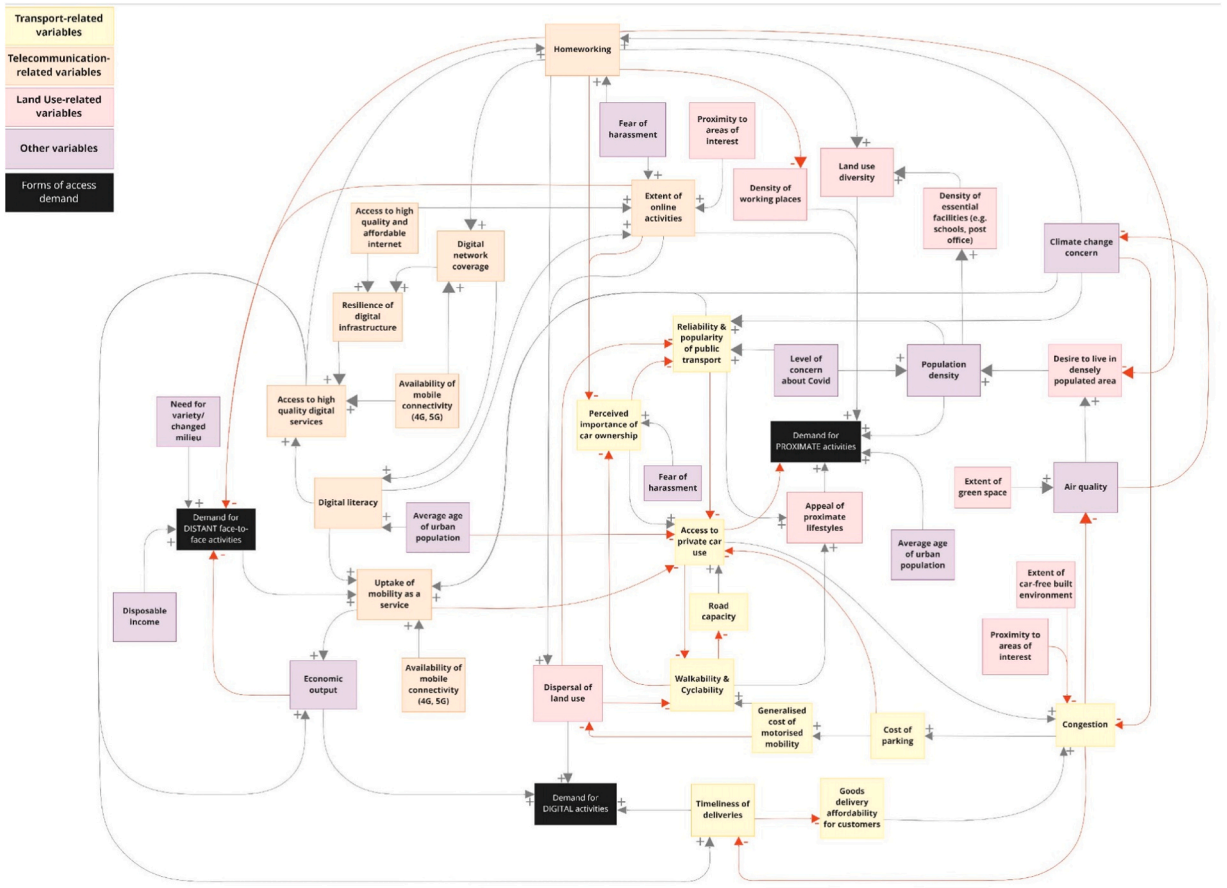


Fig. 6. Triple Access System shared mental model on a page.

Table 1
Critical factors (seven of which are critical uncertainties with two future projections, and two of which are considered more certain in terms of their future projection but nevertheless important and therefore brought into the definition and narrative of the scenarios).

Critical factor	Description	Future projection (s)
Climate change concern	People's concern towards (worry about) severe weather, including storms, floods, draught and desertification, global warming, all due to climate change. This includes political and public concern.	Very high or moderate
Economic performance	The size and health of the economy in terms of economic output, levels of employment and (disposable) income and state of public finances.	Strong or weak
Perceived importance of car ownership	Significance attached to sense of status, autonomy ('freedom') and assuring convenient access offered through car ownership.	High or low
Need for Variety / Changed milieu	The extent to which people crave difference rather than monotony in experience that may drive appetite for reaching beyond their immediate surroundings and may be affected by level of satisfaction with those surroundings in terms of richness of experience available.	High or low
Cost of motorised transport relative to income	The affordability of motorised transport as a measure of the attractiveness of a travel alternative, considering monetary costs (and time investment).	High or low
Urban land use diversity	The extent to which the makeup of land use reflects mixed purposes and opportunities for different needs and desires for access to people, goods, jobs, services, and opportunities to be met.	High or low
Population density	The number of people per unit of area.	High or low
Utility of online activities	*The extent to which digitally available activities will be useful, usable and used. This factor indicates how online activities will be used and useful in the future. A high level of this factor implies a high incidence of activities being carried out online, as there will be good availability and quality of internet access, and digital services, which will also be affordable.*	*High*
Attractiveness of walking and cycling	*The appeal of walking and cycling.*	*High*

Table 2
Wireframes for six possible triple access futures in 2040.

Scenario	*Critical factors*								
	Climate Change Concern	Economic Performance	Perceived Importance of Car Ownership	Need for Variety / Changed Milieu	Cost of Motorised Transport Relative to Income	Urban Land Use Diversity	Population Density	*Utility of Online Activities*	*Attractiveness of Walking and Cycling*
Too Slowly Greener	⇧	⇧	⇩	⇧	⇩	⇧	⇧	⇧	⇧
Uneconomically Net-Zero	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇧	⇧
In a Fix	⇧	⇩	⇩	⇧	⇧	⇩	⇧	⇧	⇧
Bye Bye Car	⇧	⇧	⇩	⇩	⇧	⇧	⇧	⇧	⇧
Happy Green Dispersal	⇩	⇧	⇧	⇩	⇧	⇩	⇩	⇧	⇧
Tech Innovation Bonanza	⇩	⇧	⇩	⇩	⇩	⇧	⇧	⇧	⇧

Table 3
High-level narratives for six possible triple access futures in 2040.

Scenario	Narrative
Too Slowly Greener	Persistently high consumerism and slow-to-recede dependence upon car use, 'greener' though it is, are awkward reminders of past behaviours in a world in which climate change is still a major concern. This is despite an ever more depended-upon digital world of access, a richer urban mix of land use, and complementary appetite for active travel to compensate for sedentary, digital lifestyles. Motorised mobility is convenient, with increasing rates of electrification and shared mobility options.
Uneconomically Net-Zero	High taxes and restrictions have been imposed by governments to reduce carbon emissions, with a related decrease in people's level of consumption. Strong and effective efforts to tackle climate change in the 2020s and 2030s have come at some cost to economic performance and public finances and contributed to a reshaping of economic and social activity. Motorised multi-modal mobility is affordable and accessible but in a society in which digital activity dependence is much greater and urban land use less diverse.
In a Fix	Concerted global effort to tackle climate change has been ineffectual and economically costly. Climate anxiety has shaped attitudes and behaviours and dampened the role of motorised transport in access provision, driving a prudent live-local act global urban dynamic. There is a general appetite for variety, which is sought locally and digitally. Digital accessibility is more affordable than motorised mobility, and the online world plays a big part in supporting economic and social activities.
Bye Bye Car	There has been a marked shift in attitudes and lifestyles since the 2020s with a high level of consciousness concerning the environmental consequences of behaviours. Climate change remains a serious threat although the transition to a green economy is underway with appetite for local living, and 'responsible' access fulfilment, with car use moving into the shadows. Urban areas offer an increasingly wide range of different activities at a more granular scale. This, together with a reduction of congestion, have encouraged people to move from rural to urban areas, with a related significant increase in population density.
Happy Green Dispersal	Society is thriving in a green economy, with an environmental consciousness that accompanies greater optimism over climate change than was seen in the 2020s. Many people invest in having their own means of motorised mobility and digital connectivity at their disposal for access, as land use patterns have changed and urban density declined, but for travel itself there is an established modal hierarchy. Flexible working has had an impact on urban population density, as people progressively moved to greener rural areas. The digital economy is thriving.
Tech Innovation Bonanza	Concurrent successful diffusion of technological innovations in physical mobility and digital connectivity have shaped a society able to be quietly confident that decarbonisation is in check. People enjoy a richness of access choice that includes balanced and complementary patterns of access fulfilment in highly populated urban environments. Most activities have been subject to extensive digitalisation, including goods movements. People are taking advantage of virtual environments and digitally enhanced physical environments to participate in a diversity of urban activities.

CLD but also points to its ability to provide a starting point or framing for examining potential cause and effect in more detail, as illustrated in Table 4 in which the variables are set out.

This example demonstrates how creation of a shared, albeit simplified, mental model can help in critically examining: policy goals; planning considerations to help achieve such goals; and potential consequences (intended or unintended) of successfully pursuing the policy goals. As is apparent, the mental model can and must be built upon by turning to a wider knowledge base to help better understand potential causes and effects. However, in this way the planning process becomes more strongly grounded in an understanding of the system being addressed.

5.2. Using explorative scenarios in the planning process

Put simply, scenarios make us think when considering the future, as systems thinking does when considering the present. More specifically, not only do such explorative scenarios as those developed in this example help communicate how urban environments may change in future, they can be used as an important guide to planning how to shape future urban environments with a preferred future in mind. The scenarios reflect some of the different contexts (which are to a greater or lesser extent beyond the control of the planning authority or beyond its present gift to determine) into which the implementation of an urban mobility plan will play.

Candidate elements of such a plan can be 'stress tested' against these different scenarios to consider how they might perform in, and

Table 4
Variables affecting (- or +) and affected by (- or +) level of homeworking.

Affecting variable	Affected variable
Fear of harassment (+) – Increased fear of harassment is not desirable, but there is potentially greater importance of homeworking to those who face fear of harassment outside their homes, with notable gender difference (Livingston et al., 2015). Fear of harassment could negatively impact women's willingness to commute and in turn employment inequality (Kondylis et al., 2020). ***Climate change concern*** *(+)* – As concern about climate change increases (Chen et al., 2020), people are more attracted to homeworking (particularly for car-based commuting) (Razif et al., 2020). Yet this can lead to increased energy consumption and related costs (Meinrenken et al., 2020). Managing energy's homeworking footprint becomes important both for emissions and addressing inequality of opportunity to work from home (Johnson, 2017). ***Access to high quality digital services*** (+) – This variable is itself affected positively by digital literacy, and by digital network coverage and resilience of digital infrastructure (as found by Savić, 2020). The importance and credibility of working from home has grown with the technological advancement surrounding it (Razif et al., 2020). ***Level of concern about Covid*** (+) – The level of concern about Covid was very strong during the pandemic, and homeworking became mandatory for periods of time in order to avoid the spread of the virus. The coronavirus has increased individual anxiety and risk perceptions of disease infection (Frutos et al., 2020), particularly among vulnerable groups (Meinrenken et al., 2020). It therefore becomes important to understand what can be done to make homeworking more accessible to all.	***Perceived importance of car ownership*** (-) – The mental model suggests an expectation of increased homeworking having an indirect negative effect on congestion (though reduced access to private car use). This is supported by Kalter et al. (2021), who also highlights the positive impact that homeworking might have on road safety, and air pollution. ***Density of working places*** (-) - This affect was seen during COVID-19, which accelerated the homeworking trend (Naor et al., 2021). The reduced demand for office space may in due course also result in a series of impacts on the real estate supply chain (Uchehara et al., 2020). ***Desire to live in a densely populated area*** (-) – The level of homeworking therefore has an indirect effect on population density, with a diminished need for living close to the workplace (Liu & Su, 2021). If population density goes down this reduces the demand for proximate activities. This suggests a need to try and lock-in the benefits of homeworking by trying to maintain population densities. ***Land use diversity*** (+) – An increase in land use diversity would (according to the mental model) increase demand for proximate activities with implications for businesses. ***Dispersal of land use*** (+) –Liu and Su (2021) found that homeworking generates a reduced need to live close to the work place, and therefore would support a strong spatial shift in housing demand affecting city structures (Delventhal et al., 2022; Althoff et al., 2022; and Gupta et al., 2021). ***Digital network coverage*** (+) – Increased homeworking is assumed to drive increased digital network coverage leading in turn to improved resilience of digital infrastructure and in turn access to high quality digital services thereby reinforcing homeworking, as seen in the evolution of homeworking (Watad & DiSanzo, 2000; Loia & Adinolfi, 2021). ***Demand for distant face to face activities*** (-) – Rafiq et al. (2022) highlighted, during the pandemic, how homeworking corresponds to a reduction in average person-miles travelled for both work and non-work activities.

exert influence over, that scenario and whether this will positively contribute towards shaping the preferred future as a result (Lyons et al., 2021). Elements that perform well in all the scenarios are indicative of greater confidence in their effectiveness in the face of uncertainty. Meanwhile, elements that perform poorly in some of the scenarios may suggest that they do not represent a robust contribution to the sustainable urban mobility plan and may need to be rethought – or have the timing of their introduction (and/or later removal) kept under review.

While a stress-testing exercise was not conducted with participants as part of this application of the methodology, such an exercise would typically involve participants (or other policymakers who are first familiarised with the scenarios) in a structured dialogue. This begins with ensuring a shared clarity of understanding of the element itself before then considering its performance in relation to the scenario in question. The participants also indicatively score the performance of the element and consideration of the scores across the set of scenarios offers a sense of how well, or not, the element copes in the face of uncertainty.

Consider the policy goal addressed above of encouraging more people to work from home and commute less. A candidate element of an urban mobility plan to bring this about could be workplace parking charges (targeted at car-based commuting). We illustrate briefly below how a workplace parking charges policy could perform in each scenario (with an indicative score ranging from −2 (problematic) to + 2 (compatible and positive)):

Too Slowly Greener (+1) – In a future where car ownership is not uncommon though with less dependence on car use and wider availability of car sharing, parking charges may be met with some objection but could encourage behaviour change, especially given the ever-improving appeal of online access.

Uneconomically Net Zero (0) – Mobility as a Service is widely available avoiding the need for car use though private (electric) motorised mobility is available and affordable so parking charges could be effective in influencing mode choice rather than degree of working from home which in this scenario may be affected for other reasons.

In a Fix (−1) – Cars are seen as emblematic of causes of climate anxiety in any case in this scenario but with increased desire for changed milieux to help alleviate anxiety already unable to be fulfilled by longer distance travel, parking charges could be seen as inequitable and a form of suppression met with objection in some quarters (as was seen in the early 2020s for the 15-minute neighbourhood concept).

Bye Bye Car (+2) – Car ownership is frowned upon coupled with high costs of motorised mobility with increased population density lessening the need for a car and with people increasingly content to live locally – all of which workplace parking charges would acceptably reinforce and promote homeworking.

Happy Green Dispersal (+1) – With high attachment to electric car ownership, workplace parking charges could discourage car commuting, and be compatible with general contentment to seek out changed milieux in local areas (allied to more working from home).

Tech Innovation Bonanza (0) – With a shift from ownership to usership of vehicles and general technology-enabled improvements in

choice for transport and digital accessibility, parking charges could be much less relevant in this scenario and have little or no influence on working from home.

Overall there is an impression that while parking charges may not be particularly effective in encouraging people to work from home in all scenarios, the policy does not seem problematic with the exception of the *In a Fix* scenario (suggesting some attention to how the policy is communicated and what concessions may be appropriate). In some scenarios the policy positively supports the goal of encouraging working from home. The policy also has the appeal of being inherently adaptable over time and hence able to respond to the unfolding future.

A planning authority in practice may wish to develop their own scenarios, tailored to their own urban area and their views on it. If the scenarios developed here were to be used instead (or used as an initial stimulus to thinking and planning) then a subset of the scenarios may be chosen if six were considered too many.

6. The value of systems thinking in the present and future

Having considered the process for developing mental models, the mental models themselves and how they can be used, we now reflect in this final section of the paper upon the processes and outputs concerning systems thinking and mental models and how these relate to planning in practice. This includes drawing on views from participants in application of the methodology to the Triple Access System, particularly those gleaned from Step 11.

One of the main advantages of using system thinking is to enhance a more in-depth understanding of the system, its components and their relationships, in order to explore how an action in one part of the system might trigger unexpected effects elsewhere. System thinking can clarify the origin of present practices and policies, while helping to establish choices for the future, exploring uncertainty and variation in systems (Schiere et al., 2004). Futures thinking is particularly effective when transformative actions are needed to cope with future challenges (e.g., climate change) (Coulter et al., 2019). System thinking is therefore a very powerful tool to think about the present and the future, and a valuable tool to support planners who work on uncertain futures. Combining mental models of the present (represented by CLDs in this work) and the future (represented by explorative scenarios in this work) helps us to understand if we are able to imagine a future differing from the perceived present (Schöll & Binder, 2010).

A series of more specific aspects are now highlighted below.

6.1. *What's going on in your head?*

A co-created shared mental model reflects how a group of participants collectively perceive the system of interest. The way it is perceived and the thoughts behind the design process may play a key role in the way a group of actors would then proceed with the planning process intended to influence the system. For this reason, even though a shared mental model is not empirically based (or validated), its value is in 'exposing' the mental models which individuals carry around in their heads and bringing them together into a shared and enriched whole to understand what is influencing our minds and hence our planning (Doyle et al., 1996). In our application of the methodology to the Triple Access System we learned that having a diverse group involved makes a big difference in terms of the resulting shared mental model. For example, the variable "fear of harassment" was suggested by a female participant, which underlines how the system might be perceived (and designed in our minds) in different ways depending on different participants' viewpoints and priorities.

6.2. *Think together before you plan*

The 'think before you plan' approach we suggest becomes therefore a key step in any planning. In fact, if actors in the planning process do not have some sharing of their own mental models with others (through this process) then this can lead to blind spots and misunderstandings. It can potentially lead to differences of opinion because of an unrecognised partial view of the system and some of its key variables (Penn et al., 2022). In the case of our example of the Triple Access System, a lack of understanding of the urban system that the planning process seeks to influence can give rise to unintended and unanticipated consequences (Doyle et al., 1996). Thinking together can also help in better appreciating the interplay between supply and demand in a system (as discussed in Section 4.1) and recognising that while change in demand can suggest a signal for change in supply in response, change in supply is able to influence change in demand. Thinking before planning guides how co-evolution of supply and demand is understood and indeed treated in the planning process.

6.3. *Making it your own*

It is important to make clear that the mental models produced using the methodology are a product of a particular set of actors at a particular point in time. Once produced (as done for the application example in this paper) they can also be used 'second hand' by others to help with their thinking and planning. However, when 'made your own', the mental models are likely to become more informative and easier to understand/use. It should also be stressed that one cannot expect simply to quickly scan them to derive enriched understanding and value. Value can only come from investing time to more carefully study and discuss them (as one of our participants put it: a mental model expressed through a CLD cannot be treated like fast food).

6.4. Governing the silos

'Joined up thinking and practice' may be hard to realise. For instance, with respect to our application example, responsibility and expertise relating to transport, land use and telecommunications may reside in different parts of an urban authority (even assuming all such component parts exist at all). Indeed we found it particularly hard to identify digital planners to take part. This being the case, there is an importance to using the processes and mental models produced to help teams in different silos come together periodically to at least blur the boundaries of thinking and understanding between them and help establish a common appreciation of the system of interest and its significance to the planning process. In this sense – for our example - Triple Access Planning may not be a replacement for transport planning, land-use planning and telecommunications planning, but rather a lens through which to view and better apply each of them – a triple access *mindset* to help advance urban mobility planning, including thinking differently about what forms of modelling, analysis and appraisal are needed to inform policy and investment decisions.

6.5. The importance of being able to address uncertainty

Planning for uncertain events and having contingencies has contributed to the survival of the human species (Suddendorf, 2017), and futures thinking can take account of ongoing issues and system implications to reimagine what might happen in the future (Szpunar et al., 2014; Merck et al., 2016). While futures thinking has often not been well represented or considered in planning (Sardar, 2015), the COVID-19 pandemic reminds us of how systems that are in any case evolving can be shocked in ways that bring about amplifications of trends, trend breaks and new forms of change. In short, a reminder of the importance of accommodating uncertainty in our planning for the future.

6.6. Limitations

Developing and demonstrating the application of the shared mental models methodology has been challenging. Engaging participants who were not familiar with the approach (system thinking and scenario development) was demanding as they found it difficult to understand and contribute at the outset. In turn it was important for them to be engaged throughout the whole process across different workshops, as this allowed them to deeply understand the importance and value of the methodology. However, this did involve a substantial contribution of time from those taking part. It is therefore necessary to be able to make a clear case for the merits of the approach to secure buy-in from those concerned as a precursor for embarking on the process – especially given what may be a lack of familiarity. Where dealing with a system of systems consideration, it can be challenging to secure a group of participants in the process that bring together both knowledge of the different systems of concern and a diversity of perspective on how they might interact. Since the shared mental models are a product of those taking part, this is key. However, this applies to planning in general.

7. Concluding remarks

This paper presents a methodology to enable participants with different knowledge and background to co-design mental models of the present system(s) to better understand and plan for the future system(s), taking into consideration uncertainty. The methodology we suggest lends itself to multiple planning contexts involving complex systems. In terms of our specific application, the paper has set out an approach that develops both a mental model of the presently understood Triple Access System and depictions of possible triple access futures in 2040. The use of the resulting models in terms of the wider planning process have then been considered. This methodology and its outputs are intended to facilitate reflective thinking on important and uncertain issues related to planning and to support policy development and testing at a time of deep uncertainty. The limitations of orthodox transport planning seem well recognised, and change is needed. The intention of this paper is to contribute to such change and to an ongoing process of learning by doing to bring that change about.

Declaration of Competing Interest

None.

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Annex 1. – Scenario narratives

Scenario 1 - Too Slowly Greener

Persistently high consumerism and slow-to-recede dependence upon car use, 'greener' though it is, are awkward reminders of past behaviours in a world in which climate change is still a major concern. This is despite an ever more depended-upon digital world of access, a richer urban mix of land use, and complementary appetite for active travel to compensate for sedentary, digital lifestyles.

Climate Change Concern	⇧	While global CO_2 emissions are now on a downwards trajectory, change has been too slow and the 1.5 °C **threshold of global warming was exceeded** in the early 2030s with signs of things getting worse. **Public concern is at a record high** internationally with mounting **tensions between those who emit less and those who emit more**. Voting behaviour now more strongly reflects concern over climate change with **expectations for governments nationally and at city levels to do more**.
Economic Performance	⇧	The **global economy is healthy** which is benefitting from some green growth but also from **persistently high consumerism attributable to exponential growth in e-commerce** in the last 20 years which is generating substantial **uncontrolled and un-optimised freight flows** in urban areas. Employment rates are high.
Perceived Importance of Car Ownership	⇩	A high proportion of the urban population has held onto the **convenience of *access* to a car.** While car ownership is not uncommon, its importance has declined in the face of heightened **importance of households' green credentials**, **less frequent need for car use** and **more widely available car sharing schemes**. A **substantial and growing proportion of vehicles are electric**.
Need for Variety / Changed Milieu	⇧	In spite of an increasingly rich and immersive digital world for work and play, people are **hungry for 'real world' escapism for leisure**, that helps ease anxiety levels over climate change. Many feel they **need a change from their immediate everyday environment** where they live and work and yet in which they are less invested.
Cost of Motorised Transport Relative to Income	⇩	Economic buoyancy coupled with electrification of the vehicle fleet (including public transport) makes **motorised mobility affordable and seemingly convenient**, even for shorter journeys and is often the preferred choice for access, when transport systems are not disrupted by extreme weather.
Urban Land Use Diversity	⇧	The **urban environment offers a variety of amenities which has intensified** in response to market demand for changed milieu. While for some this means that many/most of the trips originating from an area end in the same area, others are **drawn to exploring within and between cities**, taking advantage of affordable and often seemingly 'green' motorised mobility.
Population Density	⇧	The high land use diversity offers a range of job opportunities, with a related **increase of population density**. Such density has **constrained availability of green spaces** which is adversely affecting quality of life for those who cannot afford to explore further afield and for whom digital immersion is less fulfilling.
Utility of Online Activities	⇧	Since the early 2020s, further **breakthroughs in digital innovation have drawn many people deeper into a strongly online existence, especially for work and shopping** but also for aspects of social engagement. Digital dependence is strong such that **'always on' spills over into expectations in the 'real' world**, favouring travel environments that allow multitasking.
Attractiveness of Walking and Cycling	⇧	Augmented reality, coupled with a **need to counter sedentary lifestyles** has made walking and cycling an attractive option for leisure activity (when weather conditions allow), even if the destination area concerned has first been reached by motorised transport. **Assistive technologies have enhanced what are still considered to be 'active' travel modes**.

Scenario 2 - Uneconomically Net-Zero

Strong and effective efforts to tackle climate change in the 2020s and 2030s have come at some cost to economic performance and public finances and contributed to a reshaping of economic and social activity. Motorised multi-modal mobility is affordable and accessible but in a society in which digital activity dependence is much greater and urban land use less diverse.

Climate Change Concern	⇩	While the world continues to wrestle with onward reductions in CO_2 emissions and adverse climate change effects, **co-operation and transitioning into a green global economy have made great strides**. People remain moderately concerned after 20 years of intensive efforts but **there is quiet confidence that disaster is being averted** and a net zero 2050 is within reach.
Economic Performance	⇩	**High taxes and restrictions imposed by governments** to reduce carbon emissions have had an impact on people's levels of consumption. **Individuals have become more responsible and buy less** or rely more on second-hand products. This has had a **negative impact on economic performance**, in spite of its much greener credentials, as sales decreased, and many companies closed. There are high rates of unemployment, but the **collective public mood demands 'greener over richer'**.
Perceived Importance of Car Ownership	⇩	Co-operative behaviour to address climate change has influenced the role of the car in society. While it still symbolises convenience for fulfilling access needs, **it is use of a car not ownership of the car that matters more** and this has led to its **incorporation into a 'mobility system beyond the private car' reflective of the MaaS aspirations** of the early 2020s
Need for Variety / Changed Milieu	⇩	Whereas at the turn of the millennium, pursuit of new horizons was part of consumerism, this is now **fulfilled increasingly in the digital world with a richness of experience** in some ways unrecognisable to life in the 2020s. As such a **need for variety in the 'real' world has been dampened** with movement of people significantly substituted for by movement of technology-based goods to people's homes to enrich their online existences.
Cost of Motorised Transport Relative to Income	⇩	The **subsidised transition towards electric vehicles has been substantial** and this has happened in tandem with the rise in shared mobility services. Across the population **motorised mobility is affordable and accessible to many in private and public forms** though **level of use in terms of vehicle distance travelled remains moderated** by overall environmental awareness.
Urban Land Use Diversity	⇩	**Many shopping and leisure facilities closed**, due to the economic downturn and land use diversity is poor. There are some attractors localised in specific areas, though **many areas have become progressively more residential**.
Population Density	⇩	**High proportions of working from or near to home have seen demand for larger residential properties** in cities which has absorbed land-use change away from more mixed use. Beyond this, with relaxed locational requirements

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		for work, coupled with affordability problems for those unemployed or in low paid work, there has been **some outward migration from urban cores and an overall decline in population density**.
Utility of Online Activities	⇧	The spread of activities from a land use perspective has made journey distances longer, and people prefer to do activities online as physical activities have become "unaffordable" both from an economic and logistical/accessibility perspective. **Digital service providers have innovated and thrived as a result of their lower-carbon credentials**.
Attractiveness of Walking and Cycling	⇧	**Sedentary lifestyles fostered by the digital world**, coupled with **environmental awareness and less intrusion of motorised traffic** into urban environments has seen **strengthened and sustained attractiveness of active travel** as a means of access, with advantage taken of power-assistive technologies to help overcome longer distance.

Scenario 3 – In a Fix

Concerted global effort to tackle climate change has been ineffectual and economically costly. Climate anxiety has shaped attitudes and behaviours and dampened the role of motorised transport in access provision, driving a prudent live-local act global urban dynamic.

Climate Change Concern	⇧	**Concerted efforts by governments around the world that emerged following COVID-19 to address climate change** have been sustained including intense education campaigns and initiatives to change technology and behaviour. However, **heightened public consciousness** has coupled with **disappointing outturn effects on actual emissions** and climate change effects are now very much part of people's lives and a **source of anxiety and concern**.
Economic Performance	⇩	Huge post-pandemic **investment that gambled on a transformational economic green recovery failed to create the momentum hoped** for and **crippled public finances** across many parts of the globe brought about prolonged poor economic performance which while dampening emissions from consumption volume has also **dampened progress on greening consumption** that is still occurring.
Perceived Importance of Car Ownership	⇩	**Car ownership is associated with economic prosperity and profligacy** and while electric cars have been a growing part of the car fleet, new vehicle sales have slumped. **Cars are seen in urban areas as emblematic of causes of climate anxiety unless they are shared and have high occupancy levels**. With poor economic performance, **efficiency has driven goods movement in urban areas** which now relies heavily on consolidation and use of cargo bikes.
Need for Variety / Changed Milieu	⇧	The depressive effects of climate change concern and poor economic performance have heightened **society's appetite for the alleviating influence of changed milieu**. Efforts to kerb emissions stifle fulfilment of desire for variety through longer distance travel and **variety is sought locally and digitally**.
Cost of Motorised Transport Relative to Income	⇧	Motorised transport for many is turned to only for essential travel in cities and **low demand compounds the problem of delivering affordable supply**, creating **stagnation in the role of motorised mobility for access**, aside from those who are more affluent and who ease their climate guilt through use of electric vehicles. Access is instead supplemented through use of active travel and digital connectivity.
Urban Land Use Diversity	⇩	The 15-minute city concept championed by Paris as it emerged from the COVID-19 pandemic stimulated many national governments to incentivise their cities to follow suit, but **economic fragility and uncertainty worked against many smaller businesses and community ventures in urban areas, stifling an increase in land-use diversity**.
Population Density	⇧	**Economies of scale and concentration have nevertheless worked to incentivise people to remain in urban environments** in large numbers and precarious employment and scarce resources have **driven an increase in average household sizes** in urban areas.
Utility of Online Activities	⇧	The **relative affordability of digital access compared to motorised mobility**, coupled with an entrenchment of digital dependence in society that has built up since the 2020s, now go hand-in-hand with **an established online world of digital connectivity that plays a big part in supporting economic and social activity**. There is also the **appeal of escaping the unpredictable and disruptive weather patterns of the 'real' world**.
Attractiveness of Walking and Cycling	⇧	Active travel plays a significant part in urban life for work and leisure as **an accompaniment to digital dependence** in relation both to movement of goods and people, **encouraged by a weak economic picture, otherwise sedentary lifestyles and climate concern**.

Scenario 4 - Bye Bye Car

There has been a marked shift in attitudes and lifestyles since the 2020s with a high level of consciousness concerning the environmental consequences of behaviours. Climate change remains a serious threat although the transition to a green economy is underway with appetite for local living, and 'responsible' access fulfilment, with car use moving into the shadows.

Climate Change Concern	⇧	Climate change concern grew in the 2020s and is still high, because despite many measures that were put in place **it took longer than expected to achieve the technological and behaviour change now being seen**. People feel **unsure whether enough has been achieved soon enough to arrest the still worsening news from scientists**. Consequently, **social norms now strongly reflect expectation of sustainable behaviours**.
Economic Performance	⇧	While global regime transition towards a green economy has been slower than hoped for, **the fruits of the efforts to transition are now being born economically**. New activities, mainly related to **digitalisation and sustainable consumption** have intensified in recent years lending themselves to **urban environments where people are able to live, work and play locally while remaining 'globally' connected**.
Perceived Importance of Car Ownership	⇩	**Owning a car in urban environments is frowned upon**, as this is strongly associated with unsustainability of the past. **Use of motorised vehicles in urban areas in general is seen by many as profligate – whether for movement of people or goods** - unless done so in a highly efficient way. Urban freight systems have evolved accordingly and **alternatives to cars and vans are enjoying ever-increasing popularity**.
Need for Variety / Changed Milieu	⇩	The **sense of need for variety, fuelled by market influences on consumption of the past, has abated** - people are increasingly content to live locally and invest in enriching their neighbourhoods and urban environments in place of looking elsewhere for changed milieu.

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Cost of Motorised Transport Relative to Income	⇑	Demand for motorised transport overall has gone down as walking and cycling are favoured for shorter journeys while digital connectivity consistently serves as the access means of preference. Consequently, **the cost of providing motorised transport has increased costs for its remaining consumers**. There is also **a high cost to social standing in terms of depending upon motorised transport where alternatives exist**.
Urban Land Use Diversity	⇑	**Urban areas offer an increasingly wide range of different activities at a more granular scale** which aligns with appetite for local living and reinforces and is reinforced by reluctance to travel longer distances (across urban areas) where this can be avoided.
Population Density	⇑	**Due to high land use diversity and the significant reduction of congestion, an increasing number of people have moved from rural to urban areas**, and population density is quite high. Despite the high population density, there is a high number of green spaces, and fewer cars, so cities are very liveable.
Utility of Online Activities	⇑	**Digital services have proved to be highly complementary to local living and help offer people an overall sense of access fulfilment** that might previously have been perceived to need greater amounts of physical mobility to reach more remote destinations. **Digital connectivity also suffers less disruption from extreme weather than physical mobility**.
Attractiveness of Walking and Cycling	⇑	During the 2020s and 2030s **the pendulum continued to swing away from car dependence towards active travel in urban areas** and power-assisted active travel modes moved from niche into mainstream use. Demand for activity travel has prompted greater public confidence and **led to ever greater demand in what is now recognised to be a virtuous circle**, though this is periodically exacerbated by weather effects.

Scenario 5 - Happy Green Dispersal

Society is thriving in a green economy, with an environmental consciousness that accompanies greater optimism over climate change than was seen in the 2020s. Many people invest in having their own means of motorised mobility and digital connectivity at their disposal for access, as land use patterns have changed and urban density declined, but for travel itself there is an established modal hierarchy.

Climate Change Concern	⇩	There is a political and public **air of optimism regarding global efforts to tackle climate change** over the past two decades. There is now a **healthy lock-in to political and public attitudes and behaviours** that are ever-more reinforcing of the green economy. **Climate change concern is always present but is moderate given the path society has taken**.
Economic Performance	⇑	Economies are doing well, with **many people employed in ever more familiar roles to improve environmental sustainability**. Global infrastructure investment has seen a significant reorientation away from large capital projects for longer distance travel towards **greening existing infrastructures and supporting local travel**. E-commerce sales are still high but **growing numbers of people are buying organic/sustainable products** and are willing to wait longer to **enable logistics operators to optimise delivery efficiencies**. Free return, 'immediate' deliveries are commonly no longer available options.
Perceived Importance of Car Ownership	⇑	Strong environmental awareness and its influence on the economy has not diminished **people's attachment to having their own (electric) car**. However, the **nature and extent of car use is in marked contrast to that seen in the 2020s**. Car use finds itself in the context of **a modal hierarch that has finally moved from principle into practice**.
Need for Variety / Changed Milieu	⇩	The co-operative drive to tackle climate change has helped avert a mounting global mental health crisis as people come together to address a common cause. **Contentment of people to dwell and use disposable incomes within the areas that they live** has diminished appetite to seek out changed milieu, at some cost to the aviation sector in particular.
Cost of Motorised Transport Relative to Income	⇑	Governments moved during the late 2020s and early 2030s to **strongly internalise the external costs of motorised mobility and as a consequence such costs are higher relative to income**. This has driven more sustainable behaviours as people are drawn to higher occupancy shared mobility and goods movement has been forced to drive up efficiencies. While vehicle fleet electrification is moving closer towards completion in several parts of the world, total cost of motorised transport remains high.
Urban Land Use Diversity	⇩	**Urban areas have seen a decline in land-use diversity following a period of de-population caused by the revolution in flexible working behaviours** at the start of the 2020s. Many **businesses reliant upon weekday trade in urban areas closed**, while some have diversified to serve residents and in particular their weekend leisure demand.
Population Density	⇩	Population density in urban areas has declined since the early 2020s, triggered by **irreversible longer-term effects caused by COVID-19 which has seen a weakened hold of urban areas on knowledge workers** and an ongoing redistribution of population.
Utility of Online Activities	⇑	Society's dependence on digital connectivity during COVID-19 proved to be a sustained step change in demand for digital services, and **the digital economy is thriving as a result with household expenditure on digital equipment and connectivity at an all-time high**.
Attractiveness of Walking and Cycling	⇑	**Most people can walk or cycle within urban areas very easy** thanks to the infrastructure improvements and reduced motorised traffic and can reach mobility hubs for less-frequent longer-distance multi-modal trips.

Scenario 6 - Tech Innovation Bonanza

Concurrent successful diffusion of technological innovations in physical mobility and digital connectivity have shaped a society able to be quietly confident that decarbonisation is in check. People enjoy a richness of access choice that includes balanced and complementary patterns of access fulfilment in highly populated urban environments.

Climate Change Concern	⇩	Governments, while reluctant to be seen to interfere unduly with consumer behaviours, placed **great emphasis in the 2020s and 2030s on technological innovations to reduce CO_2 emissions**. This brought forward to market maturity several developments in the early 2020s both in relation to transport and digital technologies that have

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		consequently had effects on consumer behaviour. **While the pursuit of decarbonisation continues, people's concerns are now more modest**.[1]
Economic Performance	⇧	Industry, academia and governments have been working hard to reach net zero. This has had a positive impact on economic performance, as **new jobs related to sustainable businesses and especially high-tech industries have been created**. Standards of living are high, and **most activities have been subject to extensive digitalisation** (including goods movement). People buy products online and urgent/important deliveries are now typically made by flying drones. Other deliveries are efficiently designed to make optimal use of vehicles and resources, in order to reduce congestion due to urban freight.
Perceived Importance of Car Ownership	⇩	For the affluent, flying e-taxis have entered the modal repertoire alongside a now mature ride-hailing industry. The **transition towards an electrified and ever more autonomous vehicle fleet** has also started to see a **long-awaited shift from ownership to usership** in terms of the car's status in society.
Need for Variety / Changed Milieu	⇩	The **maturity of a repertoire of technological innovations has satiated the appetite for variety** of many as they go about their daily lives, seemingly enriched in both their digital connectivity and physical mobility and sometimes both together. The need for longer distance changed milieu is diminished though there are **worrying early signs that this trend could reverse**.
Cost of Motorised Transport Relative to Income	⇩	**Motorised transport is affordable either in private or shared public forms** when needed or desired. However, innovations in digital connectivity continued to out-strip what transport innovation could achieve, and **many people regularly substitute fully motorised mobility** for digital connectivity or (power assisted) active travel to fulfil their accessibility requirements.
Urban Land Use Diversity	⇧	The rich repertoire of technological innovations facilitating access has stimulated creative industries and augmented reality amenities and services in urban areas. Across the socio-economic spectrum **people are taking advantage of virtual environments and digitally enhanced physical environments to participate in a diversity of urban activities**.
Population Density	⇧	Urbanisation followed an increasing trend and **population density in urban areas is very high**. People understood, and were attracted by the notion, that **cities were the places where a real impact on decarbonisation could actually happen** (due to the high volume of human activities), thanks to everyone's contribution to sustainability while continuing to enjoy prosperity.
Utility of Online Activities (Useful, Usable and Used)	⇧	Digital connectivity still shows no signs of reaching a plateau of creativity in terms of the quality and diversity of services available and this is now **fully embedded into people's physical and virtual lives such that flexibility of access form for given functions is high**.
Attractiveness of Walking and Cycling	⇧	Many people enjoy active travel for short-to-medium distance trips. There are **several bike sharing and other micro-mobility options (increasingly benefitting from augmented reality)** that make active travel very easy and convenient.

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