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Scenario planning for transport practitioners

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ABSTRACT

Scenario planning helps in contemplating how the future may develop and can be especially important when needing to make sense of uncertainty – something now pertinent to the transport sector.

Accordingly, scenario planning is moving from the periphery of strategic transport planning towards becoming a more normalised and integral contribution. By examining rather than ignoring a range of uncertainties about the future, scenarios can be developed that enable an exploration of different futures, in turn improving transport planning. Scenarios can be narrative based, represented quantitatively, or combine 'storytelling and number crunching'. Both the process of creating them and of representing the scenarios, deepen an appreciation of uncertainty about the future. In turn this allows planners and policymakers to better understand potential outcomes and challenges and determine how to address these. Scenarios can also be used to identify and assess candidate measures for influencing the transport system, testing these against a range of uncertain future conditions. This helps to identify measures that together can help form a strategy that is more robust.

Drawing upon the combined experience of its authors, this paper provides insights into the development of scenarios and their use to improve decision making in transport planning. It offers advice on how to help ensure the scenario development process is credible, how to produce a coherent set of scenarios and how to ensure they are used to engage key stakeholders and to enable policymakers to confidently develop their strategic thinking and plans.

1. Introduction

Even before the Covid-19 pandemic, planning for future transport needs was complex, requiring an understanding of multiple interlinking social, economic, and technological issues. Where might people want to live, how and where might they work, shop and play in future? What means might be available to support how people, goods, jobs, services and opportunities are accessed in future, and how might they support a diverse population?

Past trends are a partial guide to addressing such questions. However, trends change, and can be changed. For example, changes in working from home, retail behaviour or how people feel about living in crowded cities may introduce unexpected future dynamics. New, as yet unencountered, technological innovations can further cloud any sense about what the future has in store. For example, if (fully) autonomous vehicles became mainstream (uncertain in itself), we simply do not know how this would change the transport system - from infrastructure supply, through the nature of demand and use, to impacts on different modes of travel and on where people live, shop, work and play. Thus, we are faced with a need to plan under deep uncertainty.

In its recently published Uncertainty Toolkit, the UK Department for Transport considers, in the context of decision making, uncertainty to be "the gap between available knowledge and the knowledge decision makers would need to make the best, most informed policy decision" (DfT, 2021: 8). Uncertainty is a state of mind and in that sense is subjective. The future is inherently uncertain. Each of us weigh up risks associated with decisions and outcomes. We judge probabilities in that risk assessment. However, if the probabilities are not known or knowable then we are faced with what is called deep uncertainty. For group decision making, this has been described as not knowing or agreeing

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upon: "(i) the external context of the system, (ii) how the system works and its boundaries, and/or (iii) the outcomes of interest from the system and/or their relative importance (Lempert et al. 2003)" (Marchau et al, 2019: 2).

As a result of a much greater sense of deep uncertainty prior to but amplified further by the pandemic, doubt has been cast over the ability of 'business as usual' transport planning to support robust decision making that can assure positive outcomes from investment decisions and interventions. Growing attention has been turning to approaches that can help 'open out', explore and accommodate ('close down') deep uncertainty in support of decision making (Lyons and Marsden, 2021). One such approach is scenario planning. This is notable for its now famous early use by the Shell Oil Company to "anticipate the various oil crises of the early 1970s and to come through those in better shape than did competitors" (Menzies and Middleton, 2020: 42).

With awareness of a growing interest in and use of scenario planning in transport, this paper aims to help transport practitioners by providing insight into what scenarios are, the process of developing them and the purpose they can serve. A single article cannot provide a complete 'how to' guide to developing and using scenarios, but the paper offers a basis for those already engaged with scenarios to reflect and for those curious about the possible merits of scenario analysis in transport planning to begin their journey of discovery. This is done through addressing a series of what we consider to be some central and commonly asked questions. As authors we have collective experience, over many years, in undertaking scenario development and planning in the transport sector (and beyond). There is also a rich literature to draw upon in terms of methodological insights and lessons from application. We draw together, from the literature and our own experience, what we hope is a useful point of reference to help others in their own (ongoing) engagement with scenario planning in the transport sector.

The next section builds upon this introduction to address what scenario planning is and why it is applied. This is followed by an examination of some of the history of scenario planning in the transport sector before moving to the ten questions we address. To conclude, we contemplate the future – of transport planning's handling of uncertainty in a changing world. Please note – in this paper our focus is principally upon explorative *possible* future scenarios as opposed to *preferred* future scenarios (visions).

2. The origins and rationale of scenario planning

The futurist Roy Amara distinguishes between "the art of the 'possible'", "the science of the 'probable'" and "the politics of the 'preferable'" (Amara, 1991: 646) in looking at futures. These three forms of futures reflect a history of futures work and define the space from which scenario development and scenario planning emerged.

The modern history of futures work goes back to the immediate post-war period, and – broadly - emerged from two different traditions (Curry, in press; see also Chermack et al, 2001). In the United States, the research organisations RAND and SRI (originally the Stanford Research Institute), both significantly funded by the US Department of Defense, built on wartime planning methods, and developed methods that used probabilistic and trends-based approaches to identifying *probable* futures. In Europe, people such as Fred Polak in the Netherlands and Gaston Berger in France evolved contrasting approaches that were designed to rebuild their societies. These can be thought of as *preferred* futures. Between these two is a gap, although it took some time before the idea of *possible* futures emerged.

While at RAND, Herman Kahn had used game theoretic models to identify the *possible* outcomes of nuclear war, and he developed these when he left RAND to set up the Hudson Institute. The Hudson Institute, in turn, influenced a generation of planners through its corporate programme. Shell, famous for applying scenarios to the business challenges of the oil sector in the 1970 s (notably involving Pierre Wack (Wack, 1985a; Wack, 1985b; Kleiner, 1996; Wilkinson and Kupers, 2013), learnt from the Hudson Institute and combined this with the French La Prospective approach. SRI designed a four-scenario method that it called a "scenario parameter matrix" in the 1970s in which scenarios reflect "the expected future, the worst case, the best case, and a highly different alternative" (Bishop et al., 2007: 12). In a study costing $225,000 (1970s prices) the scenarios aside from the expected future were named "foul weather future", "disciplined society future" and "transformation future" and the SRI study was considered by Senator Proxmire to have squandered public money in the face of "a government that can barely decide transportation policy under current conditions" (Shapley, 1977: 1165) – a sign of how far scenario planning has come in the decades since. This method in turn influenced the 2x2 scenarios method (see later - Fig. 2, Section 4.1) popularised by Global Business Network in the 1990s (Curry, 2012).

In addition to *possible* futures, *plausible* futures are also discussed in scenario planning literature, although not well defined (see Section 4.6). From a transport perspective the DfT Uncertainty Toolkit emphasises the nuance of distinction between plausible and possible as follows. "Scenario analysis is a process of analysing future events by considering several alternative possible outcomes. Each scenario outcome and pathway should, however, be plausible" (DfT, 2021). Hines and Bishop (2013) emphasise that while it can be argued that "almost anything is possible", scenarios should have some foundation in the present for suggesting that they could come about, such as the existence of weak signals.

The Futures Cone shown in Fig. 1 is helpful, in our experience, in offering a reminder that given inherent uncertainty (of whatever degree) in looking to the future, *any* representation of the future is a subjective view based upon assumptions that determine where we look and what we see. We return in Section 4.6 to the matter of judging reasonable bounds of possibility. Bounds of possibility can include wildcard events (Pillkahn, 2008) – high impact events, such as a pandemic, which may (or may not) be unanticipated but which can be dramatic in terms of their effect upon the system under consideration.

Creating robust approaches to building "multiple types of hypothetical futures" (McBride et al., 2017: 6) has always been a challenge. Wendell Bell notes that "scenarios can be produced by any and all of the specific methods used by futurists" (Bell, 2004: 316). As a result, there are scores of methods (see Bishop et al., 2007), and some 400 attempts at defining what a scenario is (Spaniol and Rowland, 2019). This is because scenarios serve different purposes, and so are developed in different ways and take different forms.

However, what all the methods have in common is that they are designed to imagine multiple possible futures, and therefore to provide a framework to assess how to act in the present. The scenarios themselves are not the destination.

3. Scenario planning in the transport sector

The transport sector is no stranger to scenario planning, or at least to scenario development. In this section we briefly mention some examples with which we have been associated (there are plentiful further examples undertaken by others).

At the dawn of a new millennium it was in vogue to look to the future. In 2000 the Transport Visions Network explored the future of society and lifestyles through a set of six scenarios as a means to better appreciate the uncertainty and possibilities affecting derived travel demand (Lyons et al., 2002). In the very early 2000s, the UK Department for Transport commissioned work to review examples of scenario sets that had been developed internationally and choose a 2x2 set for 2030 that could be used in conjunction with the National Transport Model to explore uncertainty and travel demand implications (Chatterjee and Gordon, 2006). Shortly after this study, the UK Government's Foresight Unit undertook a very substantial piece of work looking out to 2050 at the future of transport and technology (OST, 2006). Not only did this create a 2x2 set of scenarios but this was preceded by state-of-science

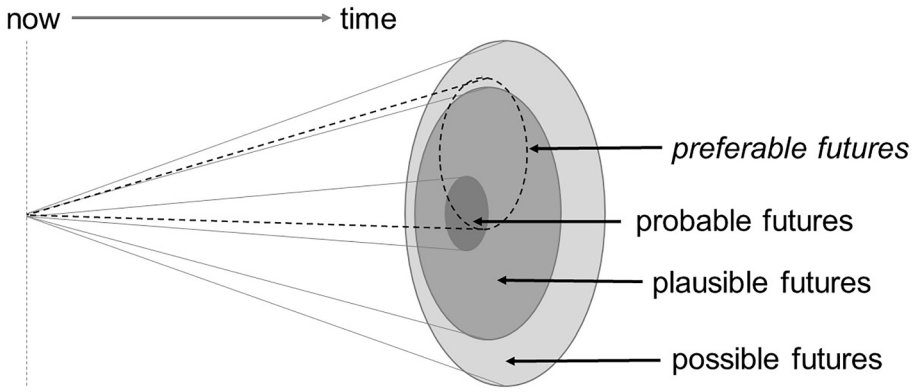

Fig. 1. Futures Cone (For the history of the futures cone see https://thevoroscope.com/2017/02/24/the-futures-cone-use-and-history/).

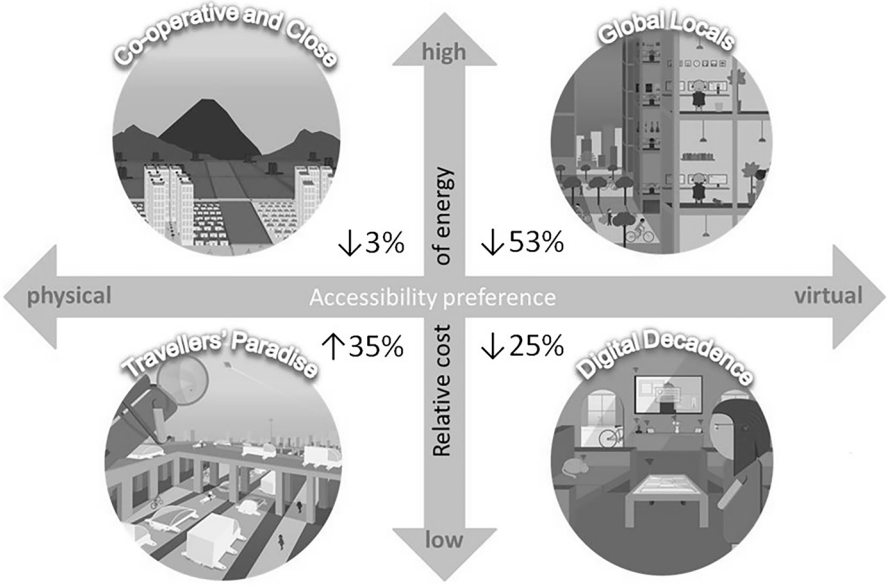

Fig. 2. Scenarios examining the future demand for car travel (based upon Lyons and Davidson, 2016: Fig. 1).

reviews and complemented by systems thinking.

In 2014 the New Zealand Ministry of Transport explored uncertainty about the future of demand for car travel and developed a 2x2 set of scenarios (see Fig. 2 in Section 4.1) (Lyons et al, 2014). Social research at a similar time examined the future of mobility in an ageing society using a 2x2 scenario set (Shergold et al, 2015).

What is notable with all the examples above is that they sat on the periphery of transport planning practice. The scenarios developed were explorative in terms of uncertainty over the future and were developed with policy implications in mind. However, they were not used *directly* in the policymaking process or to directly consider the robustness of specific policies or interventions. Chermack and Coons (2012) argue that it is *use* of scenarios that matters most. As such it may be more appropriate to consider the studies above as examples of scenario *development* rather than scenario planning (Bishop et al. (2007) note the common confusion between, and inappropriate conflation of, scenario development and scenario planning). The scenarios helped those exposed to them to think, but not necessarily to make policy decisions. The prevalence of the classic 2x2 approach to the scenario development is also apparent.

More recently, this has changed. Scenarios are being developed and directly used in the policymaking process, as illustrated in the UK examples below. In 2015/2016, Innovate UK commissioned the development of a set of scenarios to explore the role of future technology for future transport, and be used to explore potential impacts on different stakeholders in society and consider policy interventions that were robust across a range of scenarios (Rohr et al., 2016). The scenario development process used the framework presented in Gausemeier et al. (1998), which combines expert opinion, gathered via in-person workshops, with cross-impact analysis, consistency analysis and cluster analysis using specialised computer support (see further in Section 4.8).

As authors we are all part of a team led by Mott MacDonald that has been providing futures support to the Department for Transport (DfT) since the start of 2019. The purpose of this engagement is to support DfT's wish to improve the robustness of its decision making in the face of uncertainty across its policymaking areas, using a range of futures methods (GOS, 2017), and scenario planning in particular. Scenarios are being used to help stress-test candidate policy measures or interventions in terms of how they may perform (in relation to preferred outcomes) in different plausible future contexts.

In 2020 Transport Scotland published its revised National Transport Strategy (Transport Scotland, 2020). Its underlying thinking and formulation have been informed by a scenario planning tool and process designed to expose the policymaking to stress-testing using eight plausible future contexts with qualitatively and quantitatively represented scenarios (Lyons et al, 2018; Ruscoe et al., 2019). In England, the subnational transport body Transport for the North adopted a similar approach in developing four future travel demand scenarios to be used

in its strategic transport planning and business case development (TfN, 2020). In the DfT's Uncertainty Toolkit (DfT, 2021) is an expectation that major scheme proposals will be appraised against a set of six 'off-the-shelf' Common Analytical Scenarios. This supplementary transport analysis guidance is testament to scenario planning becoming a permanent fixture of UK transport planning and policymaking.

With the preceding scene setting in mind, we now turn to a more detailed examination of the practice of scenario development and planning.

4. Lessons from scenario planning application

In this section we address ten central and commonly asked questions about scenario development and their use:

What is a scenario?
Why or when are scenarios worth developing?
Who should be involved in developing scenarios, how and why?
How is the scope of a set of scenarios clarified?
Do scenarios have to be tailored to a particular application?
How far should the bounds of future possibility be stretched?
How many variables are needed and how many scenarios?
How are the scenarios developed?
How is a scenario brought to life?
How much time and effort are needed for scenario development?

4.1. What is a scenario?

In broad terms a scenario can be considered an "intelligible description of a possible situation in the future based on a complex network of influence factors" (Gausemeier et al., 1998: 115). This description may be in terms of a distinct set of measures of interest or a richer socio-technical portrayal of the future that invites imagination and immersion.

A scenario can be a representation of aspects of the future ranging from those over which the party concerned has direct influence or control to those over which it has little or no control (the latter addressing the external environment within which the party wishes to operate or consider the operation of others).

Representation can be quantitative (e.g. DfT, 2018), qualitative (e.g. GOS, 2019) or one that combines narrative and numbers (e.g. Lyons and Davidson, 2016; TfN, 2020; Transport Scotland, 2020). Wider representations include vivid images, physical artefacts and theatrical improvisation (Curry and Schultz, 2009) (see further in Section 4.9). Scenarios are typically developed in sets when used to expose and explore uncertainty, thereby enabling contrast and possibility to be depicted and considered further. Fig. 2 shows an example of a 2x2 set of plausible scenarios in pictorial form. This depiction includes numerical estimates of percent change in total car traffic (vehicle distance travelled) between 2014 and each 2042 scenario as a means of fortification of the narrative. Numbers "characterise corporate cultures" (Wilkinson and Kupers, 2013) and can be powerful and grab attention when used alongside narrative. To quote Shell's Chief Economist (1993–1997), DeAnne Julius, "[e]ngineers are numbers people, and if you can't quantify what you are talking about, they tend to dismiss you as interesting (at best) mystics" (Wilkinson and Kupers, 2013).

4.2. Why or when are scenarios worth developing?

In essence, scenarios make you think (challenging current thinking and 'thinking about the unthinkable' (Kahn, 1962; Chermack et al, 2001)). They are able to help, through their development and use, in enabling decision makers to be "wise before the event", as opposed to being "wise after the event" (WRR, 1992). With such motivations in mind, we set out below three reasons for developing scenarios.

To better understand the future: the act of developing scenarios provides an opportunity to bring together a wide range of stakeholders to "broaden conventional thinking, enhance understanding and generate new insights relevant to taking meaningful action in complex dynamic systems" (McBride et al., 2017: 1). Further, Franco and Montibellar argue that participating in such exercises increases commitment for implementation (Wright et al., 2019).

To improve planning and policy making: a further aim of developing scenarios is to improve decision making by helping to identify and test shaping actions to support policy objectives and mitigation actions to counteract potential challenges to these objectives. In this regard, scenarios can help to: (i) explore different ways that the area of interest may develop in future; (ii) consider how key actors – governments, businesses, citizens - may be influenced and may behave under different future scenarios; (iii) identify policy and planning requirements under different future scenarios; and (iv) stress test policies using the scenarios (see next reason below) (GOS, 2017). They may also be used to explore and identify signals of how the future may be unfolding to help policymakers respond to change as it happens (Pillkahn, 2008).

To test the robustness of policies: scenarios can be used to 'stress test' policies, investment plans and interventions (courses of action), by indicating how well they perform across a range of future scenarios. Rather than identifying the optimum policy, investment or intervention in one scenario (the approach used in more traditional appraisal methods), the aim is to identify policies, investments and interventions that are 'robust' or 'resilient' across a range of scenarios. Such analysis is often undertaken qualitatively using 'wind-tunnelling' approaches where stakeholders discuss and rate how different courses of action perform in different scenarios or across different measures of success across scenarios (GOS, 2017)[1].

4.3. Who should be involved in developing scenarios, how and why?

Scenario planning processes can "change the way decision makers [see] the world" (Menzies and Middleton, 2020: 43). They can be particularly powerful when used by strategy makers to create new patterns of thinking across an organisation (Curry and Schultz, 2009). This can enable decisions to be based on "a wider, more informed point of view" (Menzies and Middleton, 2020: 43).

The primary actors involved should be those who will most likely use the outputs (GOS, 2017). This will ensure that relevant insight is generated and ultimately that the outputs will be owned and put into practice (McBride et al., 2017).

Scenario planning processes usually involve experts (those offering specific insight to the topic) and stakeholders (those who are affected by or who can affect a decision or action). Experts and stakeholders can have "competing needs, motivations, and cultures that must be balanced" (McBride et al., 2017: 4). Stakeholders may find it challenging to participate if their interests and strategic priorities conflict with the nature of the project or the emerging scenarios (Wright et al., 2019). Likewise, experts may make incorrect or biased assumptions based on their views and experience that could skew judgements made when creating scenarios (Wright et al., 2019). Scenario planning processes create a healthy environment within which to tackle these challenges - enabling the examination of whether strategic objectives are robust (GOS, 2017).

The diversity of participants has an impact on the quality of the participatory process. A diverse range of perspectives helps *open up* discussions on what is plausible in the future (Urueña, 2019). There is therefore great value in extending scenario planning processes beyond the usual subject experts to include those who are often excluded.

To design successful inclusive participatory scenario planning processes, the following is recommended:

[1] Such analysis can also be undertaken quantitatively (Marchau et al. 2019).

- have an appreciation of the value of participants' time, striking a balance between what can be expected of them and the quality of outputs sought;
- establish strong and clear links between the outputs of scenario development and decision making (McBride et al., 2017);
- carry out active and sustained engagement throughout the scenario planning process (McBride et al., 2017) – this is essential to develop ownership and confidence over the scenarios;
- ensure that the process enables participants to openly challenge and critique the emerging scenarios (Wright et al., 2019);
- undertake scenario orientation to familiarise participants fully with the scenarios themselves and the process undertaken to produce them (Wright et al., 2019); and
- design efficient, enjoyable, and fully collaborative participatory experiences – this is easier than ever using digital collaboration and communication tools.

4.4. How is the scope of a set of scenarios clarified?

What world should a set of scenarios describe? Typically, they can be described along three dimensions: time, space, and system (though note also van Notten et al. (2003) for distinction between issue-based, area-based and institution-based scenarios). They look forward over a period of time, typically between 10 and 50 years. They have a geographical range (city, region, country, continent, planet); and they define a system or a sector. This last element is the most difficult part of the framing process. Getting the scope (or domain) right at the outset of scenario development helps "avoid the explosion of the domain later" (Hines and Bishop, 2013: 33).

In terms of time, it is not necessary to be precise about the number of years into the future (though sometimes this is done to align with policymaking requirements) - the number of *decades* is often sufficient granularity. If the timeframe is too short, typically below 10 years, there is the risk of extrapolation (Pillkahn, 2008), and the risk, especially in organisational settings, that the process will be influenced by *current* strategic priorities; meanwhile "the probability of significant change and uncertainty increases as the time horizon gets longer" (Hines and Bishop, 2013: 34). In terms of engagement or communications, framing the project around a particular year (2030, 2040, 2050 etc.) can increase impact.

Geographical range tends to be a function of organisational span (McBride et al., 2017). A multinational company may prefer global scenarios; scenarios for a national agency will likely focus on its country. If there are questions about scale, it is better to go wider than narrower: it is possible to use a set of scenarios to interrogate a sub-system of the scenarios, but not to interrogate a super-system.

The question of defining sector or system is the most difficult decision to make in the scoping or framing phase. Much of the intuitive logics[2] literature refers to understanding the "decision focus" at the start of the scenarios process (for example, Schwartz and Ogilvy, 1998; and Wilson, 1998). This is based on approaches developed initially by SRI and built on by Global Business Network. Schwartz states that "[w]hen developing scenarios… *begin with a specific decision or issue* [emphasis added], then build out towards the environment" (Schwartz, 1996: 241). In the experience of the present authors, this focus leads to scenarios that are too narrow to produce useful outcomes. Who knows, after all, if that decision will still be meaningful when set in a larger or longer-term context? Following Donald Schon (1983), the purpose of scenarios should be *problem-setting*, not problem-solving.

Defining the system is a challenge; it often takes time. One rule of thumb is that it needs to be larger than the immediate system of concern. Two of this paper's authors were involved in defining the scope for the UK Foresight project on Intelligent Infrastructure Systems (OST, 2006), which developed scenarios for transport five decades into the future. The obvious system was "the future of *mobility*", which covered multiple modes, individual and group, personal and commercial, private and public. In discussion with the advisory group, this was up-framed to "the future of *access*", which included both digital and physical access, and also transport deliveries to the home.

Such wider framing can cause anxiety among project sponsors that the project will take them to a set of futures but fail to bring them back to what they need to do *now*. But as Pierre Wack (Kahane, 2012: 45) notes, scenario development and planning processes involve "breathing in" and "breathing out". Breathing in develops a rich understanding of the possible future landscape, breathing out identifies the implications. One way to make this visible, and allay anxiety, is to break the overall project question into two parts, addressing these two phases separately.

4.5. Do scenarios have to be tailored to a particular application?

As identified in Section 3, there are many examples of sets of scenarios that have been developed specifically for the application of concern. Yet there are also examples where previously prepared scenarios are used instead (e.g. Chatterjee and Gordon, 2006, also mentioned in Section 3).

The DfT's Uncertainty Toolkit identifies six draft Common Analytical Scenarios (CASs): *High Economy*; *Low Economy*; *Regional*; *Behaviour Change*; *Technology*; and *Decarbonisation* (DfT, 2021). These are intended (once published in final form) to be 'off-the-shelf' scenarios to be used in different applications and by different authorities. In so doing: (i) the resource requirements for applying scenario planning are lowered; and (ii) greater consistency is possible in the treatment of uncertainty in appraisal of major schemes and the development of transport policies and strategies. While set to be required for major schemes; a local authority developing a small transport scheme may also wish to use the CASs (or another generic set of scenarios) as a basis for its exploratory work. The CASs are designed for modelling purposes in quantitative form but narrative representations of them could also be introduced and used.

Proportionality is key when considering the extent to which scenario planning should: (i) (only) use pre-prepared scenarios; (ii) tailor pre-prepared scenarios further to a particular application; or (iii) develop a new set of scenarios tailored to a particular purpose. A key benefit of developing tailored scenarios (whether from pre-prepared scenarios or as a new set of scenarios) is the richness and quality of conversation and discussion that can be generated by them and therefore the subsequent improvements in robust decision-making. Also, as noted in Section 4.4, time, space and system dimensions of scope should be considered in determining the scenarios needed.

The DfT's Uncertainty Toolkit states the following. "Due to the variety of uncertainty which may be relevant to individual investment proposals, it may be proportionate for schemes to develop their own analytical scenarios. These would focus around the additional uncertainties that may be important to their scheme. These should be in addition to the Common Analytical Scenarios, and depend on the impact level of the scheme" (DfT, 2021: 26). A cautionary note, perhaps pertinent to the CASs, is sounded by Wilkinson and Kupers (2013), as follows. "Scenarios have a limited shelf life. As they become familiar, the temptation arises to cling to them—which risks thinking within, rather than looking beyond, the box. Generating new scenarios on an ongoing basis counters the tendency to hold on to familiar ones".

[2] The term 'intuitive logics' is used to describe "a plausibility-based approach that enables participants, usually within a workshop setting, to create narratives that describe unfolding chains of causation, which resolve themselves into sets of distinct future outcomes, usually four" (Derbyshire and Wright, 2017: 255). The intuitive logics approach is the most commonly applied approach to scenario development.

4.6. How far should the bounds of future possibility be stretched?

The futures literature, as noted earlier, makes a distinction between *probable*, *possible* and *preferred* scenarios. Scenarios lie in the category of the possible: they travel in sets of multiple futures. The literature also refers extensively to *plausible* futures (Spaniol and Rowland, 2019) although 'plausible' is rarely defined (which may explain the communicative appeal of Fig. 1's conceptual distinction between probable, plausible and possible futures). Voros described, rather expansively, plausible futures as "those [futures] which "could happen" (i.e. they are not excluded) according to our current knowledge (as opposed to future knowledge) of how things work" (Voros, 2003: 17).

However, Schultz (2015), who contests the value of 'plausibility' as an assessment criterion, traces the term's use to futures practice. As Schultz notes, the notion of plausibility limits the range of scenarios to "the subjective capability and state of knowledge of the viewer" (Schultz, 2015); it becomes a criterion that is bounded by the cultural constraints of the organisation or sector, and restricts the ability of participants to challenge their own world views.

As McBride et al. (2017, 7) note, "[t]he tendency of people to perceive the future as being largely like the past (Bryson et al. 2016), however, means that relying on preconceptions of what is plausible can be problematic (Ramírez and Selin 2014)". In such circumstances, "plausibility becomes a socially-negotiated framing of what is seen as broadly reasonable". In turn, this becomes a barrier to the process of "re-perceiving" (Wack, 1985a; Wack, 1985b) - yet this is one of the desired outcomes of scenarios work.

Testing possible scenarios against notions of plausibility can also prevent the work from stretching thinking and widening the sense of what might be considered plausible in the future (McBride et al., 2017). A scenario from the 2010s about 2020 in which countries closed down swathes of their economies for health reasons would have failed a typical 'plausibility' test.

However, it is important that a given scenario is coherent - that the world it describes hangs together as a system. Some practitioners recommend the use of reinforcing and balancing loops from systems thinking as a method to test for coherence (Hodgson and Sharpe, 2007). It is also important that within the overall set of scenarios the individual scenarios are distinctively different from one another. One of the attractions of the 2x2 approach is that the double uncertainties create this distinctiveness through the underlying structure.

The desired outcome, then, is a set of collectively distinctive and individually coherent scenarios that *stretch* thinking about a system or sector and open up new insights about its *possible* evolution, along with new questions about opportunities and risks. As with much futures work, this becomes a question of judgment - judgment that improves with practice.

4.7. How many scenarios and how many variables are needed to create scenarios?

Amer et al. (2013) undertook a review of several scenario studies and specifically addressed the question of the appropriate number of scenarios, and approaches for developing scenarios. They found that most futurists and researchers recommend the use of three or more scenarios, but not more than five. Fewer than three scenarios are not advised because one single scenario does not allow for alternative options and two scenarios will usually reflect extreme situations. On the other hand, more than five scenarios will increase costs (of designing, drafting narratives, communication of the scenarios etc.) and will increase the complexity of their use in terms of evaluating policies. Cognitive overload can be a real problem, with consideration of too many scenarios feeling "unnecessarily complicated and the impacts difficult to untangle" which can result "in a large volume of analysis that is difficult to absorb" (ITF, Thompson and Jamotta, 2015: 20).

The number of scenarios used can also be affected by whether they are considered quantitatively instead of, or as well as, qualitatively (see Section 4.5 for reference to DfT's six scenarios (intended for quantitative representation and modelling (DfT, 2021)); and Section 3 for reference to Transport for the North's four scenarios (TfN, 2020) and Transport Scotland's eight scenarios (Ruscoe et al., 2019), both represented qualitative and quantitatively).

There is more variation in terms of how many variables should be considered in scenarios, and indeed in how such variables are described. Terms such as 'drivers', 'drivers of change', 'factors' and 'critical uncertainties' are often used. The number of variables is very much linked to the scenario development approach (see Section 4.8) and the complexity of the system under consideration.

The 2x2 approach focuses on what are deemed to be the two most important and most uncertain variables (called critical uncertainties) to define the scenarios (for an example see Fig. 2). The approach is often criticised on the basis that it is difficult to describe complex environments using only two variables, that the approach may oversimplify the situation or environment, and that researchers may miss critical system variables (Amer et al., 2013). Nevertheless, it is also emphasised that many of these variables can be built into the resulting scenario narratives (i.e. the two critical uncertainties are used to define the 'wire frames' for the scenarios and further variables then provide additional colour in the 'storytelling'). The 2x2 approach can be more appropriate for exploring specific questions or less complex environments. It can also appeal in terms of ease of use in thinking and planning because of the (a) symmetry of representation of uncertainty.

Alternative approaches may use 3–8, or even more, framing variables. These approaches may be more appropriate in more complex environments - such as exploring future transport - incorporating demographic and economic factors, as well as a range of new technologies and behaviours. In such approaches, tools like morphological analysis, cross impact analysis and consistency analysis may be used in scenarios development (Amer et al., 2013). Approaches that use more variables may require software support (Gausemeier et al., 1998). These tools are discussed in further detail in the next Section.

4.8. How are the scenarios developed?

Creation of explorative scenarios can involve an inductive process to develop scenarios organically. This starts from plot or systemic elements relevant to the particular subject of study. The approach that is much more commonly seen and recognisable across many transport examples is a deductive process (McBride et al., 2017). In this, the scenario structure shapes the content.

In the deductive approach, drivers of change (variables) affecting the future area of interest are typically identified. The PESTLE framework – see Fig. 3 – is often used to guide identification of variables of interest (for subsequent prioritisation). Alternatively, STEEP is used (wherein 'Legal' is, if considered relevant, addressed through the lens of 'Political'). The number of variables identified can be substantial.

Variables are then prioritised according to their importance (impact) as well as according to the degree of uncertainty regarding their future state. For example, if the future of interest is public transport provision, then variables such as attitudes to climate change, prevalence of flexible working and of driverless cars (that affect passenger demand) may be considered both highly important (impactful) and uncertain.

Determination of relative importance of variables is often done initially in a workshop setting (and may be informed by cross-impact analysis, as discussed below). A manageable number of chosen variables must be decided upon to form the basis for defining scenarios. This can be dealt with through the 2x2 approach (described earlier) or a morphological approach (Börjeson et al., 2006) can be used that caters for three or more key variables. The morphological approach is "a structured method for ensuring consistency and relevance in scenario development" (Johansen, 2018: 116). It involves most or all of the following steps (also benefitting from substantial interaction with

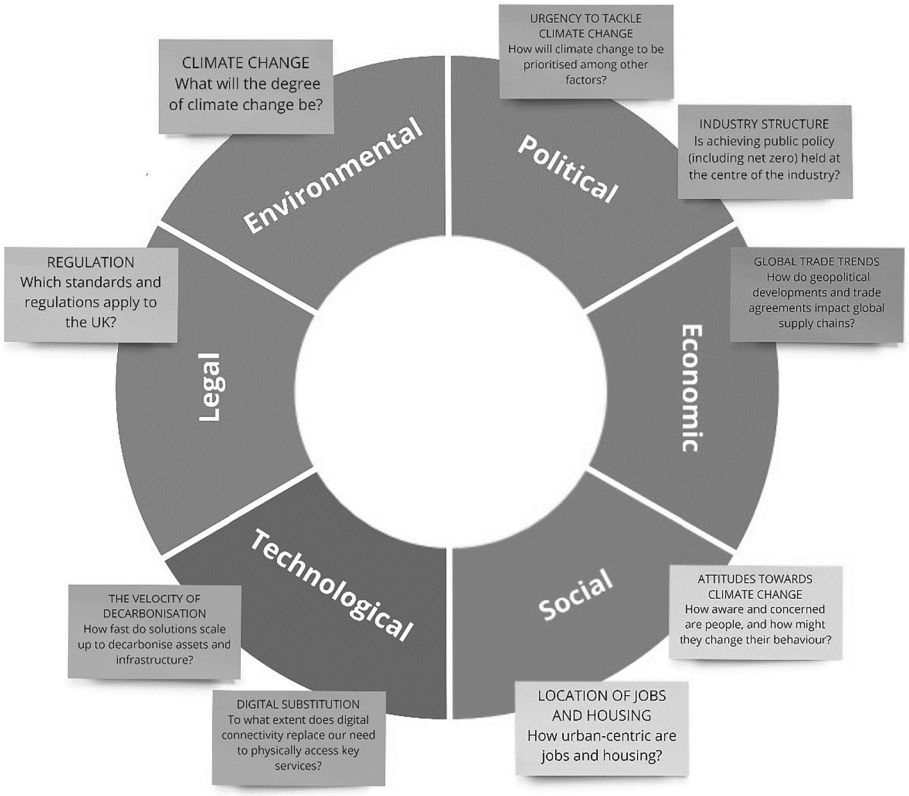

Fig. 3. Illustrative drivers of change (variables) using PESTLE framework.

stakeholders and experts):

1. *Cross-impact analysis* – This involves identifying those variables that have the highest shaping potential in the system of interest. It is undertaken by specifying the assumed impact of each variable on all of the other variables being considered in the scenario assessment (in a pairwise fashion). The result of this analysis is an influence matrix (Gausemeier et al., 1998) which allows a variable's importance to be considered according to the extent to which it impacts upon and is impacted by the other variables. This information can be used to develop a short-list of the most impactful variables in the system.
2. *Variable projections* – Each variable, by virtue of its uncertainty, will have a range of possible future states (high/medium/low; dispersed/concentrated; growth/stagnation/decline etc.). A matter of judgement, the number of future states will be at least two but may be three or even four or five (depending on views about how the future may unfold).
3. *Consistency analysis* – For a scenario to be credible, the combination of variable projections of which it is to be comprised must be able to reasonably coexist. For example, it is reasonable that high demand for public transport could sit alongside low fares, but high demand for public transport may not be consistent with high growth in driverless cars. Consistency analysis takes each pairing of variables and judges the relative consistency of each possible pair of projections.
4. *Cluster analysis* – In studies with large numbers of variables, computer software is available to use the outputs from the consistency analyses to identify bundles of consistent projections across all variables (eliminating bundles with inconsistent projections) (Gausemeier et al., 1998). However, there can be a very large number of consistent bundles across all the variables and therefore cluster analysis is undertaken to identify clusters of bundles with similar projections. The different clusters become the basis of the scenarios. The number of scenarios will depend on how different the different projection bundles are and the complexity of the future situation; and is less influenced by the "habits of the scenario team" (Gausemeier et al., 1998).

These then become the outline scenarios that can then be fleshed out (see Section 4.9 below).

Such morphological analysis can enhance the quality of and confidence in the scenario development. It is time consuming and mentally demanding. The 'spirit' of this approach can be applied more rapidly and less systematically. If this is done, the resulting projection bundles are still likely to represent credible scenarios, though they may not reflect as well the extent of uncertainty that exists or support as much divergence of thinking.

4.9. How is a scenario brought to life?

Having determined the outline scenarios, there is a need to add colour and bring them to life. This is an art as much as a science (as we reiterate further below). For a recent example of what is produced, please see TfN (2020). Before embarking on this it is important to consider the following questions:

1. Who will ultimately find these scenarios useful and therefore who is your audience?
2. How can you make them useful and usable for this audience?
3. How can you help make sure that your audience uses them in practice?
4. What are the critical issues and messages each scenario must communicate to your audience?

Ultimately the scenarios will help their audience to consider how they might "thrive and survive, or wilt and die" (Wright et al., 2019:10) within each future. While some scenarios can appear more dystopian and others more utopian, it is important to recognise that there are

winners and losers likely in most if not all scenarios and that different beholders of the scenarios will view their relative appeal differently. For explorative purposes, scenarios should reflect "tales of possibility" (Chermack and Coons, 2012: 238). Scenario names should capture the essence of each future in a few words without implying prior judgement on each scenario in terms of appeal: the task in crafting and using such scenarios is not to identify preference but to explore future contexts for present-day decision making.

Scenarios may have either a quantitative or qualitative nature, or both (as discussed earlier in the paper). Qualitative scenarios provide an accessible format for a range of audiences. They also provide an outlet for creative expression that can really help to describe the elements of a complex system in play – most commonly this is done within a scenario narrative, but could also be in the form of a visualisation or other forms of multimedia (such as a video).

Writing a narrative is not always a straightforward process due to the wealth of input, content and ideas generated from the participatory process. A degree of imagination is required to create insightful and meaningful scenario narratives. As Einstein noted "Fantasy is more important than knowledge. Knowledge is limited, while fantasy encompasses the entire world." (Pillkahn, 2008: 185). When we tap into our imagination, we can open our minds to what is possible in the future rather than being restricted to thinking only about the present. Our imaginations allow us to write scenarios from a future perspective, supported by information generated from workshops to reflect the plausible theory of change for how the future developed in this manner.

Chermack and Coons provide an example of an article devoted to elaborating on how to "write the scenario stories" (Chermack and Coons, 2012: 234), having noted the paucity of such available guidance. They note how "[s]cenario planning is part art, part craft, part science, and part process" (Chermack and Coons, 2012: 235) before setting out advice on crafting scenarios. Importantly, a considerable part of the effort comes from the preceding steps and assessment of insights from these steps that form part of the 'breathing in' stage of preparation for crafting. In then creating narratives, the author must guard against bias from their own mental models by seeking feedback from other participants. A key challenge is to be able to generate "believable ideas about things that have not happened" (Chermack and Coons, 2012: 245). Learning ultimately comes from doing.

In the creation and communication of scenarios and their narratives, there is benefit increasingly available through digital tools. We have found the use of the digital collaboration tool Miro[3] very effective for exploring and communicating the entire process and culmination of scenario development (and in turn scenario planning). Within the digital space tools such as role-play and voting can be creatively used to allow people to let their guard down and really connect with others when thinking about the future worlds that they are co-creating or making sense of. It is often valuable to remind participants themselves that scenario development is as much an art as a science, and that judging credibility and consistency is more relevant than notions of right or wrong.

4.10. How much time and effort are needed for scenario development?

There is no absolute answer to the scale of resource input to scenario development and planning. Part of the appeal of using scenarios is how flexible their development can be in terms of time and resource requirements.

As previously mentioned, it is possible to use already published scenarios as the context for a conversation about the uncertainty surrounding a small transport scheme. This approach is undoubtedly time and resource efficient but may diminish the credibility of the scenarios work and its potential to support and influence thinking and decision making around the specific issues for a project.

Overall, judgement is needed when deciding whether pre-prepared (published) scenarios, rather than tailored scenarios are sufficient for robust decision making. Schemes with higher impacts, greater revenue risk and more uncertain outcomes require more tailoring of scenarios to ensure uncertainty is considered sufficiently (DfT, 2021).

As a guide to time requirements, the GO-Science Futures Toolkit describes a process of scenario development that takes approximately one day of face-to-face workshops (GOS, 2017). Yet, in practice, time requirements for activities can vary considerably (Dator, 2009). For large and complex systems and schemes, there are a multitude of tasks and activities involved in the scenario planning process. As a result, projects can be conducted across multiple workshops with some workshops running over consecutive days or scheduled over a period of weeks or months (McBride et al., 2017).

The authors of this paper have found that online workshops using digital whiteboard approaches have optimised scenario development in terms of time and quality. "[O]nline offers the potential to increase the volume and diversity of participation" and improvements have been observed in participant interaction (Wright et al., 2019: 14).

In summary, "[d]eveloping plausible and nuanced scenarios is time-consuming" (McBride et al., 2017: 4) but, the use of already published scenarios offers opportunity to save time whilst still helping to accommodate uncertainty in decision making. The amount of time and effort that should be expended on scenario development should be proportionate to the purpose for which the scenarios are being developed.

5. Contemplating the future

The exploration of the ten questions above is intended to help demystify what lies within the field of scenario development and planning as applied in the transport sector. At the same time, it illustrates how many important considerations need to be addressed if application is to be fruitful. We hope this serves to support the ongoing and shared endeavour of learning by doing as we face the need for decision making under deep uncertainty in transport planning, policymaking and investment.

In contemplating the future it is important to be honest about how well we understand and acknowledge uncertainty. We are living in a world that is in a state of flux – shaken by the global shock of COVID-19 but in any case subject to a multiplicity of political, economic, social, technological, legal and environmental dynamics. Feeling deeply uncertain is legitimate. As the French Philosopher Voltaire (1694–1778) reportedly said, "uncertainty is an uncomfortable position, but certainty is an absurd one". Ignorance of the challenges surrounding transport planning, and continuing with business as usual approaches to policymaking and investment is increasingly untenable.

The fact that futures-based tools and processes such as scenario planning are available should be welcomed and embraced and it is indeed grounds for encouragement that they are moving from the periphery into becoming more normalised contributions to mainstream transport planning. The DfT's recent publication of its Uncertainty Toolkit presents the latest example of readily available and open source tools designed for transport practitioners.

Much as we would caution use of the word 'revolution' to describe change in the transport system over time, so too can we expect to see a more evolutionary rather than revolutionary change in the practice of transport planning when it comes to scenario planning. Awareness, knowledge and experience are growing and may continue to do so over time. We advocate a learning by doing philosophy and this is apparent in national and international networks of academics and practitioners who are sharing insights and experience with mutual interest in improving the application of scenario planning. The Decision Making Under

[3] http://www.miro.com

Uncertainty Society[4] is an example (not limited to the transport sector) of a network set up with this in mind. The International Transport Forum, at the time of writing, has a working group examining decision making under uncertainty (within which this paper's first author is involved) and is reporting on this in 2021.

Perhaps one of the greatest challenges in handling uncertainty remains engagement and communication. Scenario planning must be able to deliver decision making support to which decision makers themselves are receptive. Scenarios can be powerful for communicating a range of challenges and opportunities, but how can we improve their appeal to wider audiences, thus increasing their impact? We are keen to explore more of the potential to visualise scenarios through illustrations and animations as well as the relationship between narrative and numbers in depicting futures.

We are also keen to share in future more of our evolving insights into the experience of *using* scenarios directly in support of transport policymaking (scenario planning) as distinct from the process of creating and representing the scenarios themselves (scenario development).

With such unprecedented grand challenges as the climate emergency it is crucial that transport planning is able to connect with the policymakers and transport users it ultimately supports, and to communicate an understanding of future possibilities.

We hope this paper helps inspire and encourage others to become ever more actively involved in the transport planning evolution in which thinking about the future using scenario planning is set to be increasingly significant.

CRediT authorship contribution statement

Glenn Lyons: Writing - original draft, Writing - review & editing. **Charlene Rohr:** Writing - original draft, Writing - review & editing. **Annette Smith:** Writing - original draft, Writing - review & editing. **Anna Rothnie:** Writing - original draft, Writing - review & editing. **Andrew Curry:** Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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