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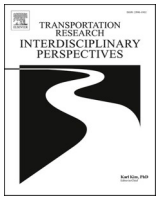

Planning for uncertain transportation futures: Metropolitan planning organizations, emerging technologies, and adaptive transport planning

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ABSTRACT

In the U.S., Metropolitan Planning Organizations (MPOs) play a pivotal role in regional transportation planning. Emerging transportation technologies present new challenges for transportation planning practice, which is experiencing growing uncertainty not only from these new technologies and other uncertainties, and MPOs must increasingly plan for the needs of new technologies and innovation. This study investigates how MPOs are currently planning for emerging technologies by analyzing regional transportation plans (RTPs) of the 50 largest MPOs and interviewing planning staff from 17 MPOs. We examine the extent to which *anticipatory governance* and *responsible innovation,* which come from science and technology studies (STS), are integrated into MPO planning efforts, shedding light on trends in transportation planning theory and practice. Findings reveal limited integration of anticipatory governance and responsible innovation into their planning processes. Some include aspects of foresight and engagement, but reflexivity, flexibility, and responsiveness are much less developed. Key actions being taken include more comprehensive thinking about region-specific impacts of technologies, developing policies, piloting technologies, building partnerships, and creating new tools and planning models. The extent to which these practices are creating adaptive capacities within MPOs is still limited. To address this, we propose an adaptive transportation planning model that combines anticipatory governance and responsible innovation with long-range transport planning. This integration is crucial for aiding MPOs and other planning agencies in developing robust governance systems, methodologies, and public policies to effectively manage technology within urban environments and navigate the increasingly complex challenges posed by emerging technologies and other uncertainties.

Introduction

Emerging transportation technology – including ride-hailing, shared micro-mobility, and autonomous vehicles (AVs) – has unknown and unrealized practical applications for land use and transportation systems. Across the United States, Metropolitan Planning Organizations (MPOs) engage in long-term planning that anticipates future growth and future transportation needs. As new technologies affect how, how much, and why people travel, MPOs face the challenge of planning for emerging technologies, including how to utilize and manage them, since investments made today will impact urban transportation for decades. Within this context, we argue there is a need for MPOs and other public agencies to plan for emerging technologies in a way that advances public policy goals related to public health, equity, economic development, accessibility, and sustainability. In this paper, we investigate how MPOs in the U.S. are planning for emerging technologies within the transportation sector, which has been subject to numerous 'disruptive' technologies and services in the last decade.

Our study analyzes MPO planning efforts through the lens of anticipatory governance and responsible innovation, looking for evidence of the applications of key aspects within MPO planning documents and work plans. Anticipatory governance and responsible innovation offer new theories, tools, and methods into how to manage new technologies (Guston, 2014; Stilgoe et al., 2013) and have not been directly applied in theory or practice within the transport sector. They offer valuable perspectives for MPOs needing to develop greater capacities for planning

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for new transportation technologies and the inherent uncertainties they introduce into urban and regional transportation planning. Certain aspects of anticipatory governance and responsible innovation are already being integrated into MPO planning efforts (and urban and transportation planning more generally), and further developing this is essential to ensure that new technologies meet the need of the publics that the transport and urban planning professions are tasked with serving, and that unintended consequences are proactively managed. There is a critical need to develop new ways of conceptualizing and conducting long-range transportation planning within the context of uncertain futures, technological and otherwise. To this end, we propose that integrating anticipatory governance and responsible innovation into long-range transportation planning is necessary to create adaptive planning capacities within MPOs.

To analyze emerging technology planning and a shift towards adaptive transport planning, we review planning documents from the 52 largest MPOs and conduct interviews with staff in 17 of these MPOs. Our results show that a majority are not thinking in new ways about emerging technology. Current efforts to plan for emerging technologies make it likely that their impacts will be poorly understood and have the potential to exacerbate the deleterious effects of new technologies. Flexibility and uncertainty emerge as two key issues. Some MPOs are taking on new roles, such as helping local communities plan for emerging technologies. In the discussion, we highlight innovative approaches used by local governments and suggest ways these approaches could be integrated into the work of MPOs within regional planning. We also develop the adaptive transportation planning triangle, which we develop as a new approach to transport planning that integrates anticipatory governance and responsible innovation into more traditional transport planning processes, while recognizing the 'conflicts' that arise between them, which must be actively managed. This paper highlights the critical need for MPOs to adapt to new circumstances, question the status quo of regional long-term transportation planning practice, and address issues of uncertainty and risk head on.

Background

Smart cities and emerging technologies

Smart cities increasingly drive urban development and are enabled by internet and communications technologies (ICT) which connect real-time data about urban systems to decision makers (Kitchin, 2014), aiming to improve sustainability (Ahvenniemi et al., 2017; Colding et al., 2020) and efficiency in delivering urban services (Chib et al., 2022; Lee et al., 2023). They are also used within the urban planning process to increase citizen engagement (Kayanan et al., 2022; Mancebo, 2020). Despite their potential benefits, numerous critiques highlight corporate-driven smart city models and commercialization of personal data (Clark, 2020; Hollands, 2015; Miller, 2020; Sadowski & Bendor, 2019) and concerns that that technology-driven decision making redefines urban challenges as technological problems, thus de-politicizing them (León & Rosen, 2020). Other scholars argue that increasing automation and use of technology could exacerbate existing societal (Eubanks, 2019) and spatial inequality (Clark, 2020).

While smart cities have captured attention as a concept, at their core they are about the development of new and emerging technologies to solve urban problems. Emerging technologies are characterized by their ability to disrupt the status quo and are defined by: (1) radical novelty, (2) relatively fast growth, (3) coherence (i.e., established identity versus being in a state of flux), (4) prominent impacts, and (5) uncertainty and ambiguity (Rotolo et al., 2015). These characteristics make planning for emerging technologies difficult since their emergence cannot be predicted, they quickly coalesce to have a specific function or purpose, and their impacts are not well understood within existing transport systems. In the transport context, on-demand ride-hailing is an example which has simultaneously been lauded as a sustainable mode of transportation that can reduce car ownership and derided as causing increased congestion and emissions (Clewlow & Mishra, 2017; Rodier, 2018). After more than a decade, the true impact and social value of ride hailing remains unknown, as is the size of a mature ride hailing market.

Due to their novelty, emerging technologies often emerge without clear regulatory frameworks and there is often little understanding about what type of regulation is needed (Hansson, 2020; Sprei, 2018; Stilgoe, 2018a). The past decade of ride-hailing exemplifies this, with cities and states regulating these services in a variety of ways. Autonomous vehicles (AVs) offer another example, with many urban planners aware of the opportunity to plan proactively (Freemark et al., 2019). Many cities are developing policies and regulations, and using pilot projects as ways to "experiment", but these happen in isolation from broader transportation planning efforts (Grindsted et al., 2022; McAslan et al., 2021b). Scholars who examine the introduction of AVs emphasize the necessity of rethinking planning strategies for such technologies (Cohen et al., 2018; Stilgoe, 2018a, 2018b).

Science and technology studies (STS) scholars view technology as both influenced by social systems and creating new social practices, with public policy and public values playing an important role (Cohen et al., 2018; Jasanoff, 2013; Muñoz-Erickson et al., 2017). Emerging technologies add a level of complexity to the issues involved because the technologies are in early stages of development and the full-scale societal impacts are unknown, raising new challenges about how to develop public policy for technologies we can anticipate, but which do not yet exist. Within urban planning, emerging transportation technologies warrant particular attention, and STS offers novel perspectives on their integration into urban and transportation systems. In this paper, we take a broad perspective of emerging technology that encompasses vehicle technologies, physical and digital infrastructures, multi-modal transport technologies, and emerging transport services.

Since the 1950s, transportation planning has been highly technocratic, and absent from significant public debates about values or alternative visions, perhaps notoriously exemplified by the planning and construction of the U.S. Interstate Highway System. With roots in 'high modernist' planning (Scott, 1998), the approach of applying technological solutions to solve complex societal issues permeates smart cities narratives. Techno-solutionism, 'big data', and urban science are used to address complex urban problems, placing them outside the realm of politics and public debate (Goodspeed, 2015; Kitchin, 2014). Within transport, challenges related to traffic management, congestion, pollution, and safety have been primarily addressed in highly technical ways, focusing on infrastructure and vehicle technologies. The modernist ideal of efficiency (of traffic) has shifted to discussions about the efficiency of moving people instead (e.g., compete streets (NACTO, 2013)). Critics of this 'mobility' paradigm advocate for a transition to an 'accessibility' paradigm (Cervero et al., 2017; Curtis & Scheurer, 2010; Levine et al., 2019). These critiques have significant implications for MPOs which are a product of the modernist era of urban and transportation planning.

Long-range transportation planning and metropolitan planning organizations

Long-range transportation planning is a planning process that identifies goals and policies at urban and regional scales and helps guide public investing in transport infrastructure and services. In the U.S., MPOs are primarily responsible for regional long-range transportation planning. MPOs were established under the Federal Aid Highway Act of 1962 to coordinate transportation investments, primarily for the planning and development of the U.S. Interstate Highway System. The Act requires MPOs be established in urbanized areas over 50,000 residents and today there are over 400 MPOs across the U.S. (AMPO, 2023). MPOs are typically governed by a board comprised of local elected officials and heads of local transportation departments and state agencies. MPO staff provide technical analysis and research support (AMPO, 2023). MPOs are federally mandated to engage in short- and long-term transport

planning (Table 1) and to address a range of planning requirements in their work (Table 2) (Title 23C.F.R. § 450.306, 2017).

The primary planning document is the Regional Transportation Plan (RTP), a 20-year plan that broadly sets the vision for the region's transportation system and outlines policies and actions to achieve that vision. The RTP informs the development of a Transportation Improvement Program (TIP), which lists strategies and projects (which must be included to receive federal funding), and the Unified Planning Work Program, which identifies planning priorities and activities for that year. While most MPOs are not policymaking bodies, their plans guide the development of a region's transportation system and infrastructural and technological investments that move the region towards its goals.

Emerging technologies challenge the ways MPOs have engaged in regional planning since their establishment. With limited land use planning authority and policy making power, many MPOs provide only advisory services about emerging technologies while helping direct funding towards local initiatives (Transportation for America, 2014). Additionally, MPOs rely heavily on regional travel demand modeling and are federally required to do so. These models are unable to capture the deep, complex uncertainty of the future due to their reliance on past and current travel trends to predict future travel patterns and use of models that do not (and cannot) account for emerging technologies (Abbott, 2005; Flyvbjerg et al., 2005; Hartgen, 2013; Rasouli & Timmermans, 2012; Zhao & Kockelman, 2002).

MPOs have begun to plan for emerging technologies in limited ways. Kuzio (2019) examines how MPOs plan for equity in emerging technologies and finds that 70 % of MPOs mention emerging technologies in their RTPs, but only four out of 20 plans consider their equity impacts. In an examination of AVs, McAslan et al. (2021a) find that most MPOs only mention key issues related to this emerging technology and only 23 % have developed policies, which focus on infrastructure, safety, public–private partnerships, data-sharing, and multimodal transportation. This shows improvement over Guerra's (2016) analysis that no MPOs had meaningfully begun planning for AVs. These studies highlight that MPOs are not currently planning in a way that is likely to be effective to adequately plan for the complexities and uncertainties inherent in emerging technologies.

As the primary agencies involved in long-range transportation in the U.S., MPOs have used and continue to rely on highly quantitative methods rooted in civil and transportation engineering to plan their transportation systems. These include travel demand modeling, traffic or environmental impact assessments, among others. Over the past two decades, there have been significant advancements in techniques, including complex spatial analysis, as well as the introduction of new methodologies like agent-based and activity-based modeling. Scenario planning (Abou Jaoude et al., 2022; Chakraborty et al., 2011; Chakraborty & McMillan, 2015; Goodspeed, 2017) has emerged as a crucial tool in urban and transport planning, especially for MPOs, and extensive guidance is available on its integration into the planning process (APA, 2024; Twaddell et al., 2016).

Table 2
Ten federally required factors that MPOs must consider in the planning and implementation of projects, strategies, and services (from Title 23 of the U.S. Code of Federal Regulations, Section 450.306).

Theme	Requirement (number refers to the order within Title 23)
Economic development	(1) Support the economic vitality of the metropolitan area, especially by enabling global competitiveness, productivity, and efficiency. (10) Enhance travel and tourism.
Safety and security	(2) Increase the safety of the transportation system for motorized and non-motorized users. (3) Increase the security of the transportation system for motorized and non-motorized users.
Mobility and connectivity	(4) Increase accessibility and mobility of people and freight. (6) Enhance the integration and connectivity of the transportation system, across and between modes, for people and freight.
Environment	(5) Protect and enhance the environment, promote energy conservation, improve the quality of life, and promote consistency between transportation improvements and State and local planned growth and economic development patterns. (9) Improve the resiliency and reliability of the transportation system and reduce or mitigate stormwater impacts of surface transportation.
Transport system	(7) Promote efficient system management and operation. (8) Emphasize the preservation of the existing transportation system.

Scenario planning sector relies heavily on quantitative modeling and forecasting, and within transport planning, relies mostly on normative scenarios which identify preferred futures, the key factors of which are analyzed, modelled and/or simulated to quantify the potential impacts of each scenario on the transport system. Additionally, exploratory scenarios, which present multiple plausible futures, are gaining traction (Avin & Goodspeed, 2020; Machiels et al., 2023). These tools enhance transport planning by enabling MPOs to assess investments more accurately, analyze various future scenarios, and target investments geographically to achieve environmental or equity objectives.

As extensions of an engineering-focused practice, new and existing methods often treat transport planning as a primarily technical process. However, as emerging technologies increasingly impact the transport sector, the complexity of uncertainties that much be understood are unable to fully be grasped in models or simulations. Recognizing this challenge, new adaptive planning processes are being developed to better anticipate and respond to new conditions (Ariza-Álvarez et al., 2022; Jittrapirom et al., 2023; Machiels et al., 2023). Furthermore, many issues related to the adoption and use of emerging technologies are not technical, but rather values-based and political choices, which quantitative methods cannot address. Anticipatory governance and responsible innovation offer valuable perspectives for long-range transport planning and can help aid MPOs in transitioning towards

Table 1
MPO planning products and purposes, adapted from "The Innovative MPO" (Transportation for America, 2014).

Plan name	Developed by	Approved by	Time frame	Content	Update requirements
Regional or Long-Range Transportation Plan (RTP or LRTP)	MPO (typically staff in consultation with Board)	MPO Board	20 years	Future goals, projects, performance measures; project travel demand; asset management, safety and system preservation; fiscally constrained budget	4–5 years (4 years for air-quality non-attainment areas)
Transportation Improvement Program (TIP)	MPO (typically staff in consultation with Board)	MPO Board and state governor	4 years	All projects receiving federal funding; must demonstrate alignment with RTP and State Transportation Plan	4 years (can be amended at any time)
Unified Planning Work Program (UPWP)	MPO (typically staff in consultation with Board)	MPO Board	1–2 years	MPO staff planning studies, research, modelling	Annually
Public Participation Plan	MPO	MPO	Not specified	MPO committees and subcommittees, engagement of people affected by transportation policy decisions	Not specified; FHWA and FTA review during MPO certification

more adaptive planning practices.

Anticipatory governance and responsible innovation in transport planning

Anticipatory governance and responsible innovation each provide valuable perspective for transportation planning amid the rise of emerging technologies. They advocate forward-thinking decision-making strategies to address the potential societal impacts of these technologies (Fuerth, 2009; Guston, 2014; Guston & Sarewitz, 2002). Anticipatory governance, with roots in science and technology studies (STS) and future studies, is a future-oriented framework involving identification of risks and opportunities associated with new technologies, and engaging stakeholders in the decision-making process (Barben et al., 2008; Guston, 2014; Institute for the Future, 2020; Sarewitz, 2011; Stilgoe et al., 2014). It aims to develop long-term policy perspectives (Quay, 2010) and to create new governance mechanisms to manage risks and uncertainties within institutions. Uncertainty, in this context, arises from inherent unpredictability and complexity of future events and outcomes, stemming from factors such as incomplete information, ambiguity, and the dynamic nature of social, environmental, and technological systems (Guston, 2014; Stilgoe et al., 2013).

Anticipatory governance integrates foresight, flexibility, and adaptive management into decision-making processes. *Foresight* involves envisioning alternative futures, often using methods like scenario development (Fuerth, 2009). *Adaptive management*, originating from natural resources, promotes flexible decision-making through continuous learning and adaptation, incorporating new information to improve future-decision making (Månsson et al., 2023; Williams et al., 2009). By employing these approaches, anticipatory governance helps decision-makers in identifying and managing uncertainties, anticipating challenges, and developing strategies to proactively address issues as they arise. It emphasizes the development of long-term reflective capacity building and encourages increased interaction between experts and the public (Guston, 2014). Particularly crucial for transportation planning, which is rooted in modernist planning and infrastructure provision (Scott, 1998), anticipatory governance broadens the definition of expertise.

Responsible innovation, drawing from various fields, primarily focuses on ethical and social dimensions of technology and innovation processes. Responsible innovation emphasizes balancing the potential benefits and risks of emerging technologies by integrating ethical considerations (Monsonís-Payá et al., 2017; Stilgoe, 2018b; Stilgoe et al., 2013). Key aspects of responsible innovation include anticipation, inclusion, reflexivity, and responsiveness (Stilgoe et al., 2013). *Anticipation* aligns with broader concepts in anticipatory governance, while *inclusion* involves engaging diverse publics in science, technology, and innovation processes through public dialogues and robust engagement (Stilgoe et al., 2013). *Reflexivity* prompts institutions to question their activities and assumptions, acknowledging the limits of their knowledge and challenging underlying theories and assumptions (Stilgoe et al., 2013). *Responsiveness* entails building the capacity to adapt to changing stakeholder perspectives, public values, and circumstances (Stilgoe et al., 2013).

Anticipatory governance and responsible innovation share similarities in their focus on decision-making regarding new technologies, governance, and responsiveness or flexibility. However, crucial distinctions exist, shaping how these concepts can influence long-range transportation planning. Responsible innovation, unlike anticipatory governance, emphasizes present-focused processes rather than future-oriented approaches, prioritizing technologies with public value and benefits (Bozeman, 2007). Anticipatory governance focuses more on developing new governance mechanisms to manage future uncertainty. Moreover, responsible innovation typically involves a broader range of stakeholders addressing societal concerns, whereas anticipatory governance is often led by policymakers and experts to manage risks and uncertainties of emerging technology. Despite these differences, both concepts highlight the importance of engagement, reflecting a historical lack of involvement in technology and innovation issues. While citizen participation is a standard practice in urban planning and long-range planning by MPOs, specific engagement regarding technology deployment and its implications remains less common.

Anticipatory governance and responsible innovation offer valuable contributions to transport planning practice. Table 3 outlines key concepts, approaches, and tools of long-range transport planning alongside anticipatory governance and responsible innovation, facilitating comparison and analysis. Integrating these frameworks into long-range transportation planning can advance adaptive planning practices. Given the uncertainties posed by emerging technologies, this integration becomes crucial for MPOs to address. In the following sections, we assess the extent to which MPOs have begun to incorporate anticipatory governance and responsible innovation into their planning efforts for emerging technologies, and then consider the extent to which this progress moves urban and transport planning towards more adaptive models.

Methods: evaluating MPO planning approaches for emerging technology

This paper examines approaches used by MPOs to plan for emerging transportation technologies in order to evaluate the current state of long-range transportation planning. We combine document analysis and interviews to analyze MPOs. The methods used included an initial scoping review of MPOs in metropolitan areas with a population over 1 million. We then identified 35 MPOs for which to include in a document analysis, which was then followed up with interviews with staff of 17 MPOs. These three methods are detailed below.

Scoping review of MPOs

In order to identify MPOs which include emerging technology in their planning efforts, we conducted a scoping review of all MPOs in metropolitan areas over 1 million people, based on 2019 U.S. Census estimates. After accounting for multiple MSAs in a single MPO and multiple MPOs in a single MSA, we are left with 52 MPOs in our sample. We searched the regional transportation plans (RTPs) of these MPOs for keywords, including ‘emerging technology’, ‘smart mobility’, ‘technology’, ‘innovation’, and ‘new mobility’. In addition, each RTP was manually searched by the research team to identify any part of the plan that addressed transportation technology. We also searched MPO websites for additional content and stand-alone plans or reports on emerging technology, smart regions, or smart mobility. In this study, we refer to ‘policies’ as both internal policies an MPO may have and policy recommendations they make to local governments in their regions. This is important since most MPOs do not have direct policymaking power since implementation of regional plans happens at the local level. We also do not set limitations on what is an emerging technology, and instead aim to gain a sense of how MPOs define this for themselves. The range of what is an emerging technology is quite broad and includes everything from vehicle electrification and next generation ITS to hyperloops, drones and flying taxis.

Our initial assessment of MPOs in MSAs over 1 million considered two dimensions – RTP year and integration of emerging technology into the RTP – which is shown in Table 4. Five categories were identified: (1) those with no mention of emerging technologies; (2) those with only a brief mention, such as a few sentences or paragraphs; (3) those with a section on emerging technologies within a chapter of the RTP; (4) those with a dedicated chapter on emerging technology; and lastly (5) those with emerging technology, and technology more broadly, discussed throughout the RTP.

Table 3
Core concepts, approaches and tools within long-range transport planning, anticipatory governance and responsible innovation.

	Long-Range Transportation Planning	Anticipatory Governance	Responsible Innovation
Key Concepts	• Forecasting • Infrastructure planning • Public participation • Multi-modal planning • Demand analysis & management • Policy development • Sustainability & resilience • Social equity • Economic development	• Foresight • Adaptive management • Stakeholder engagement • Risk assessment and management • Precautionary principle • Capacity building • Collaboration • Policy experimentation & flexibility • Resilience building	• Ethics by design • Co-creation & co-design • Stakeholder engagement • Impact & risk assessment • Open science & innovation • Responsible research & innovation framework • Equity & accessibility • Technological literacy
Methods & Tools	• Scenario planning • Transport modeling & demand forecasting • Multi-criteria decision analysis • Network optimization • Cost-benefit analysis • Environmental impact assessment • Economic impact assessment	• Scenario planning • Foresight techniques • Horizon scanning • Early warning systems • Vulnerability assessment • Regulatory impact assessment • Policy mapping	• Ethical impact assessment • Public deliberation • Regulatory sandboxes • Life cycle analysis • Technology assessment • Inclusive design • Social impact assessment • Environmental impact assessment • Ethical guidelines & frameworks

Table 4
MPO RTP by plan year and integration of emerging technology into the RTP. MPOs bolded with an asterisk indicates those included in the detailed document analysis, generally those plans with at least an emerging technology section and adopted in 2017 or later.

Emerging Tech in RTP	Plan Year						
	2014	2015	2016	2017	2018	2019	2020
No Mention	**Orlando***^[1]		Rochester	Providence			Louisville
Brief Mention			Oklahoma City Nashville Tucson Virginia Beach	Indianapolis Phoenix **San Francisco***[2]	Raleigh	New Orleans	
Section		Kansas City	Richmond	**Newark***	Charlotte **Washington, DC***	**Detroit*** **Memphis*** **Salt Lake City***^	**Atlanta***^ **Austin*** **Denver***^ **Grand Rapids*** **Houston*** **Jacksonville*** Milwaukee
Chapter				Cleveland **New York***	**Dallas-Ft. Worth***^	**Baltimore*** **Birmingham*** **Hartford*** **Miami*** **San Antonio***	
Throughout				**Las Vegas***^ **Philadelphia***^	**Buffalo***^ **Chicago***^ **Minneapolis-St. Paul***^ **Portland***^ **Seattle***^	**Boston***^ **Pittsburgh***^ **Sacramento***^ **San Diego*** **St. Louis*** **Tampa***	Cincinnati[3] **Columbus***^ **Los Angeles***^

Notes:
* MPOs included in document analysis.
^MPO staff interviewed.
1. Orlando was included in the sample due to known planning activities for emerging technologies.
2. San Francisco was included in the sample due to the development of a stand-alone document/plan on emerging technologies.
3. Cincinnati was excluded from the sample due to its RTP only being available in an online web format and not a downloadable PDF document.

MPO document analysis

The scoping review analysis served as a method to filter MPOs for further study in the document analysis. MPOs whose RTPs included only a brief mention of emerging technology or were adopted prior to 2017 were excluded from further analysis. We also excluded Cincinnati, OH which, although had a plan adopted in 2020 and integrated technology throughout, the plan was only available in an online format and not a downloadable PDF. Orlando, FL and San Francisco, CA were added into our sample since they had stand-alone documents on emerging technologies. Lastly, three smaller sized MPOs – Cleveland, Charlotte, and Milwaukee – were excluded since the emerging technology components in their RTPs were less developed. A sample of 35 MPOs advanced to the document analysis.

The documents included both regional transportation plans (RTPs) and supplemental planning documents, reports, and online materials. RTPs and supplemental documents were downloaded from MPO websites in June 2020 and draft RTPs were re-checked in September 2020 to ensure we used the most recently adopted plan. The documents used in our analysis are shown in Table 5.

The document analysis centered on three central themes. First, we assessed how MPOs are organizing emerging technology in planning documents, what technologies are 'emerging', and what key issues are being addressed. Second, we identify planning tools and policies being used by MPOs to plan for emerging technologies, considering public engagement, policies, pilot projects, and partnerships or new planning

Table 5
Planning documents of the 35 MPOs included in the document analysis.

Region	MPO	Documents
Atlanta	ARC	The Atlanta Region's Plan
		The Atlanta Region's Plan Policy Framework (2015)
		Regional Transportation Technology Policy Document: Overview of Trends and Policy Implications (2016)
		Winning the Future: Sharpening Our Focus Volumes 1–4 (2017)
		Regional Transportation Systems Management and Operations (TSMO)
Austin	CAMPO	2045 Regional Transportation Plan
Baltimore	BRTB	Maximize 2045: A Performance-Based Transportation Plan
Birmingham	RPCGB	2045 Regional Transportation Plan
		2045 Regional Transportation Plan Appendix E: Emerging Technologies
Boston	BRMPO	Destination 2040
		Connected and Autonomous Vehicles and the Boston MPO (2017)
Buffalo	GBNRTC	Moving Forward 2050
		Smart Mobility: A Framework for Local Governments in the Buffalo Niagara Region
Chicago	CMAP	On To 2050
		Emerging Transportation Technology Strategy Paper (2017)
Columbus	MORPC	2020–2050 Columbus Area Metropolitan Transportation Plan
		MORPC Smart Streets Policy (2019)
Dallas-Ft. Worth	NCTCOG	Mobility 2045
Denver	DRCOG	2040 Metro Vision Regional Transportation Plan
		Mobility Choice Blueprint
Detroit	SEMCOG	2045 Regional Transportation Plan for Southeast Michigan
Grand Rapids	GVMC	2045 Metropolitan Transportation Plan
Hartford	CRCOG	Connect 2045: Metropolitan Transportation Plan
Houston	HGAC	2045 Regional Transportation Plan
Jacksonville	NFTPO	Path Forward 2045
		NFTPO Smart Region Master Plan (2017)
Las Vegas	RTCSNV	Access 2040
Los Angeles	SCAG	Connect SoCal 2020–2045 Regional Transportation Plan / Sustainable Communities Strategies
		Emerging Technology Technical Report (2020)
Memphis	MMPO	Livability 2050
Miami	MDTPO	Miami-Dade 2045 LRTP
		Impact of Future Technology in the 2045 LRTP (2017)
Minneapolis-St. Paul	MC	Thrive MSP 2040
New York	NYMTC	Plan 2045: Maintaining the Vision for a Sustainable Region
Newark	NJTPA	Plan 2045: Connecting North Jersey
Orlando	MO	Blueprint 2040
Philadelphia	DVRPC	Connections 2045 Plan for Greater Philadelphia
Pittsburgh	SPC	Smart Moves for a Changing Region
Portland	Metro	2018 Regional Transportation Plan
		Metro RTP Emerging Technology Strategy (2018)
Sacramento	SACOG	2020 Metropolitan Transportation Plan/Sustainable Communities Strategy
Salt Lake City	WFRC	Regional Transportation Plan 2019–2050
San Antonio	AAMPO	Mobility 2045
San Diego	SANDAG	San Diego Forward
		San Diego Forward Appendix E: Transportation System and Demand Management Programs, and Emerging Technologies
		San Diego Emerging Technologies White Paper (2018)
San Francisco	MTC	Plan Bay Area 2040
		Autonomous Vehicles Perspective Paper (2018)
Seattle	PSRC	The Regional Transportation Plan 2018
		The Regional Transportation Plan 2018 – Appendix N: Technology
		Vision 2050 Technology Briefing Paper (2019)
St. Louis	EWGCOG	Connected 2045
		St. Louis Region Emerging Transportation Technology Strategic Plan
Tampa	HMPO	It's Time Hillsborough: 2045 Long Range Transportation Plan
Washington, DC	NCRTP	Visualize 2045

tools. Lastly, was to identify how MPOs choose technology projects, evaluate their effectiveness in meeting the region's goals, and how they fund emerging technology projects.

Conceptually, moving from the first theme to the third can also be understood as an increasingly complex engagement in how MPOs plan for emerging technologies. In the first stage, MPOs present a broad overview of emerging technologies (alternatively called 'new mobility', 'advanced technology', or just 'technology'). In the second stage, MPOs identify key actions they plan to take to actively plan for and/or deploy emerging technologies. In the final stage, MPOs develop decision-making tools to help them decide how emerging technologies could be adopted, how to select technologies and invest in infrastructure, and how to assess technology projects once deployed.

MPOs vary significantly in terms of the degree to which they integrate emerging technology into their RTPs. Through the analysis, a number of approaches were identified using a thematic analysis (Nowell et al., 2017) and a multi-stage reflective approach. First MPO documents were analyzed, and several common approaches were identified regarding how MPOs work with emerging technologies. Next, these were compared against some of the core concepts of anticipatory governance and responsible innovation, mainly foresight, engagement, integration, reflexivity, and responsiveness. From these, we again searched for evidence of these concepts in the documents. Ultimately, this process yielded 15 specific approaches or actions across the, which we discuss below.

MPO interviews

Semi-structured interviews with MPO staff were used to gain a detailed and up-to-date assessment of how MPOs are integrating emerging technology into their planning activities, outside of official planning documents. Interviews were conducted between September

Table 6
MPOs by how many elements are included in RTPs and emerging technology plans.

0–3 elements	4–6 elements	7–9 elements	10–12 elements	13–15 elements
Austin	Baltimore	Birmingham	Boston	Atlanta*
Washington DC	Detroit	Columbus	Jacksonville	Buffalo*
	Grand Rapids	Dallas-Ft. Worth	Los Angeles	Chicago
	Houston	Hartford	Minneapolis-St. Paul	Denver
	Memphis	Las Vegas		Pittsburgh
	Miami	Philadelphia		Portland
	New York	Sacramento		St. Louis
	Newark	Salt Lake City		
	Orlando	San Antonio		
	Tampa	San Diego		
		San Francisco		
		Seattle		
2	10	12	4	7
6 %	29 %	34 %	11 %	20 %

*Atlanta and Buffalo contain all 15 elements identified and analyzed in this chapter.

and November 2020. A total of 28 MPOs were contacted for interviews and 17 interviews were conducted. Participants were identified through online staff directories of those in positions most likely to be engaged in planning for emerging technology. The final participant list included dedicated smart mobility staff, technology strategists, and mid- and director level transportation planners and engineers, as well as a handful of MPO executive staff. Table 3 indicates the 17 MPOs interviewed. Research team members took extensive notes during the interviews which were used in a thematic analysis to identify key issues that emerged. The questionnaire itself included questions on the (1) general landscape and focus of emerging technologies in the MPOs, (2) decision making and assessment of emerging technologies, and (3) processes and tools used in planning efforts, such as policies, pilot projects, and partnerships and collaborations.

Findings: How MPOs are planning for emerging technologies

Our results show that many MPOs have begun making progress towards building their capacity to plan for emerging technology. Table 6 shows how many of the 15 approaches or actions areas are included for each of the 35 MPOs analyzed. A total of 63 % of the MPO show evidence of using between 4 and 9 of the elements or actions we identify, and 20 % contain 13 to 15 elements/actions. We expected the plan year to have some impact on this, with newer plans incorporating more elements/action, but we see little relationship here. The integration of emerging tech within MPO plans (as a percent of plans adopted that year) peaked in 2018, with half of the plans that year including emerging technology in their plans.

Regional transportation plan analysis

In examining more closely the 15 distinct elements, we can draw several key observations about how MPOs are planning for emerging technologies. The 15 elements/actions are shown in the tables below. Table 7 shows the five organizational elements of MPO plans. Table 8 shows the five planning tools and policies being used by MPOs. And

Table 7
Overview of emerging technology landscape components.

Component	Definition	Number	Regions (by major city)	General approach
Visioning	Inclusion of emerging technology in the MPOs broad vision for the region or statements related to the expectations of emerging technologies.	22	Atlanta; Boston; Buffalo; Chicago; Columbus; Denver; Detroit; Jacksonville; Los Angeles; Memphis; Newark; Orlando; Philadelphia; Pittsburgh; Portland; Sacramento; San Antonio; San Diego; San Francisco; Seattle; St. Louis; Tampa	In addition to typical regional goals, many MPOs use the 'vision' component of the RTP to describe where emerging technology fits in. In most of these 22 plans, this includes putting forth a transformative vision where technology becomes a key characteristic of the transportation system.
Mapping technology trends	Listing of the technology trends that the region is paying attention to or the types of technologies included as 'emerging technology'.	30	Atlanta; Austin; Baltimore; Birmingham; Boston; Buffalo; Chicago; Dallas-Ft. Worth; Denver; Detroit; Grand Rapids; Hartford; Houston; Jacksonville; Las Vegas; Los Angeles; Memphis; Miami; Minneapolis-St. Paul; New York; Newark; Philadelphia; Pittsburgh; Portland; Salt Lake City; San Antonio; San Diego; San Francisco; Seattle; St. Louis	This is the most common approach in RTPs to include emerging technology. The RTPs range from including simple lists to more detailed discussions of what different technologies are.
Impact of emerging technology	Broad consideration of the positive and/or negative impacts of emerging technologies.	29	Atlanta; Baltimore; Birmingham; Boston; Buffalo; Chicago; Dallas-Ft. Worth; Denver; Grand Rapids; Hartford; Houston; Jacksonville; Las Vegas; Los Angeles; Memphis; Miami; Minneapolis-St. Paul; New York; Newark; Philadelphia; Pittsburgh; Portland; Salt Lake City; San Antonio; San Diego; San Francisco; Seattle; St. Louis; Washington DC	As the second most common approach to including emerging technology in RTPS, this element goes deeper than just listing the technologies. Across the 29 MPOs that include this, the benefits of technology are included more so than the possible negative aspects.
Emerging technology goals	Inclusion of specific goal(s) for emerging technology, as part of regional goals or technology specific goals.	21	Atlanta; Austin; Buffalo; Chicago; Columbus; Dallas-Ft. Worth; Denver; Hartford; Houston; Jacksonville; Las Vegas; Los Angeles; Newark; Pittsburgh; Portland; Sacramento; Salt Lake City; San Diego; San Francisco; Seattle; St. Louis	Many of the goals for emerging technology remain very general. Many of the goals relate to various ways of using technology to better manage the existing transportation system. Fewer MPOs develop technology specific goals, like for CAVs.
Uncertainty	Discussion or consideration of uncertainty as an inherent principle in emerging technology.	16	Atlanta; Baltimore; Boston; Buffalo; Chicago; Dallas-Ft. Worth; Denver; Detroit; Minneapolis-St. Paul; New York; Pittsburgh; Portland; Salt Lake City; Seattle; St. Louis; Washington DC	Uncertainty in RTPs is common, but in these plans, uncertainty is directly related to emerging technology and in many MPOs acts as a general framing for their thinking about technology.

Table 8
Overview table of key action areas and tools that MPOs are using to plan for emerging technologies.

Component	Definition	Number	Regions (by major city)	General approach
Public engagement	Public engagement for the RTP included emerging technologies; or separate engagement for one or more emerging technologies.	16	Atlanta; Birmingham; Boston; Buffalo; Denver; Detroit; Hartford; Miami; Minneapolis-St. Paul; Newark; Orlando; Pittsburgh; Portland; San Antonio; St. Louis; Tampa	MPOs doing public engagement around emerging technologies generally get public input on how important it is to invest in new technologies.
Policies or policy considerations	Policy implications for emerging technologies, either creating new policies or specifying policy impacts.	24	Atlanta; Baltimore; Birmingham; Boston; Buffalo; Chicago; Columbus; Dallas-Ft. Worth; Denver; Detroit; Hartford; Jacksonville; Las Vegas; Los Angeles; Minneapolis-St. Paul; Pittsburgh; Portland; Sacramento; Salt Lake City; San Antonio; San Diego; San Francisco; St. Louis; Washington DC	The policies being developed are broad. Most common policies include building capacity for emerging tech., data collection and sharing, and how emerging tech. should promote equity.
Partnerships	Mention of public–private partnerships (PPP), institutional, interagency, or industry partnerships.	21	Atlanta; Baltimore; Boston; Buffalo; Chicago; Denver; Grand Rapids; Hartford; Houston; Jacksonville; Los Angeles; Minneapolis-St. Paul; Orlando; Philadelphia; Pittsburgh; Portland; Sacramento; San Antonio; San Diego; Seattle; St. Louis	Partnerships in this element are often inter-jurisdictional. A smaller number of MPOs are pursuing partnerships with industry or universities. Generally, these partnerships do not yet exist as they pertain to emerging technology.
Pilots	Mention of pilot projects to plan for emerging technology; can be completed, ongoing, or planned.	24	Atlanta; Birmingham; Boston; Buffalo; Chicago; Columbus; Dallas-Ft. Worth; Denver; Grand Rapids; Hartford; Houston; Jacksonville; Los Angeles; Miami; New York; Portland; Sacramento; Salt Lake City; San Antonio; San Diego; San Francisco; Seattle; St. Louis; Tampa	Two thirds of the MPOs are included in this element because they plan to use pilot projects for emerging technology. The others actively use pilots and have done so for technologies like AV shuttles.
New planning approaches and methods	Discussion of new planning methods and approaches used in RTP process.	12	Atlanta; Boston; Buffalo; Chicago; Denver; Jacksonville; Las Vegas; Minneapolis-St. Paul; Pittsburgh; Salt Lake City; St. Louis; Tampa	These MPOs outline their use of scenario planning and the inclusion of emerging technologies in those scenarios; 3–4 MPOs detail other methods or frameworks, like adaptive planning.

Table 9
Overview table for decision making approaches for emerging technologies.

Component	Definition	Number	Regions (by major city)	General approach
Anticipation of benefits and risks to regional goals	Consideration or discussion of how emerging technology will help or hurt the region meet its stated RTP goals.	17	Atlanta; Buffalo; Chicago; Dallas-Ft. Worth; Denver; Detroit; Hartford; Los Angeles; Memphis; Minneapolis-St. Paul; Philadelphia; Pittsburgh; Portland; San Antonio; San Francisco; Seattle; St. Louis	One of the key characteristics of this element is the uncertainty of the impacts of emerging tech. In general, MPOs have considered the impact of emerging tech. in stand-alone planning documents and not in RTPs.
Flexibility and/or adaptability	Mention of flexible planning approaches; or a recognition of the need to be more flexible in a variety of ways.	12	Atlanta; Austin; Baltimore; Buffalo; Columbus; Denver; Los Angeles; Minneapolis-St. Paul; Pittsburgh; Portland; Sacramento; St. Louis	Half of the MPOs talking about flexibility discuss this need in the context of what projects get funded. The other half discuss the need for flexible funding sources.
Technology selection	Mention of or discussion of how the MPO selects technologies; also, the need to develop this capacity.	18	Atlanta; Birmingham; Boston; Buffalo; Chicago; Columbus; Dallas-Ft. Worth; Denver; Hartford; Jacksonville; Las Vegas; Los Angeles; Minneapolis-St. Paul; Philadelphia; Pittsburgh; Portland; Sacramento; St. Louis	Most MPOs have not developed ways to select emerging technology projects that are different from how they select other projects. The biggest trend here is for several MPOs to prioritize general projects that will enable or catalyze deployment of emerging tech.
Technology assessment	Mention of existing approaches or the future need to assess technology, specifically in relation to regional goals.	10	Atlanta; Boston; Buffalo; Chicago; Jacksonville; Las Vegas; Los Angeles; Minneapolis-St. Paul; Pittsburgh; Sacramento	This is the least common element that was analyzed. In general, MPOs are adapting existing approaches to assessing projects to work for emerging technology. These include several plans that use performance measures to assess their goals.
Funding and investment considerations	Mention of need to fund emerging technologies; also dedicated emerging technology funding streams	22	Atlanta; Birmingham; Boston; Buffalo; Chicago; Columbus; Dallas-Ft. Worth; Denver; Jacksonville; Las Vegas; Los Angeles; Miami; Minneapolis-St. Paul; Orlando; Philadelphia; Pittsburgh; Portland; Sacramento; San Antonio; San Diego; St. Louis; Tampa	Most of the MPOs that discuss technology as it extends to impacting funding. A lesser number of MPOs detail actual funding of emerging technology projects, typically with dedicated funds for pilot projects.

Table 9 shows the decision-making processes being used by MPOs for emerging technology. Below, we summarize the key findings, without focusing on each of these action areas individually, but providing a synthesis of the themes that emerging from our analysis of all 15 elements and action areas.

Most MPOs include only a cursory look at emerging technologies, as represented by the fact that mapping technology trends and identifying the broad impacts of emerging technology are the two most commonly included elements across all the RTPs and planning documents that were analyzed (Table 7). There is a general awareness that technology will change transportation and we see a general consensus on the technologies likely to drive this change including connected and/or autonomous vehicles and shared mobility (e.g., ACES, CAVES, etc.). MPOs also recognize that technologies will interact with each other and with existing technologies. Finally, most MPOs anticipate emerging technologies will have a large impact on the way residents travel and nearly all MPOs recognize the need to proactively plan for emerging technologies.

The role of emerging technology is somewhat mixed when we examine how they fit into regional transportation goals. On the one

Goal	Automated vehicles	Connected vehicles	Electric vehicles	Ridehailing	Coordinated microtransit	Luxury microtransit	Stationary / free-floating car share	Conventional bike share	Dockless bike and scooter share	Travel information and payment
Vibrant communities	+/-	+/-					+		+/-	
Economic prosperity	-			-				+		
Transportation choices	+/-	+/-		+/-	+/-	-	+	+	+	+/-
Reliability	+/-	+/-		+/-	+	+	+			
Safety and security	+	+		-						
Environment	-	-	+				+	+	+	
Health			+					+	+	
Equity	+/-	+/-	+/-	+/-	+	-	+/-	+/-	+/-	+/-
Transparency	-	+		+/-	+	-	+	+/-	-	-
Fiscal stewardship		+	-		+	-				

+: Generally positive impact
+/-: Mixed impact
-: Generally negative impact
(blank): Neutral / not enough information to assess impacts

Fig. 1. Portland Metro matrix of RTP goals and how different emerging technologies may impact those goals. (Source: Metro, 2018)

Fig. 2. EWGCOG graphic showing the scale of possible impacts of technology for each of its 10 guiding principles. (Source: EWGCOG, 2019).

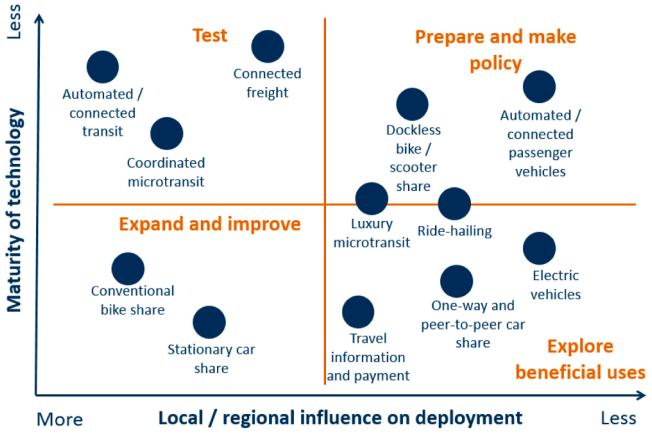

Fig. 3. Portland Metro's assessment of how public agencies can respond to different technologies based on maturity and public influence. (Source: Metro, 2018).

hand, many MPOs have developed broad goals for emerging technology, but they lack clear direction and application. A smaller number of MPOs have developed more specific goals centered on emerging technology.

Fig. 4. *Robo Ride* AV shuttle pilot project in Peoria, Arizona, pictured in March 2020. (Source: Devon McAslan).

Additionally, MPOs that seem to be further along in the planning efforts for emerging technology have done more in-depth assessments of how different emerging technologies could impact their existing transportation goals around safety, congestion, air quality, and others. Portland's Metro provides a strong example of this (Fig. 1), although it also highlights that there is a lot of missing information about a lot of anticipated emerging technologies (Metro, 2018). Another example is EWGCOG in St. Louis (Fig. 2), which focuses on linking the region's guiding principles to positive and negative impacts (EWGCOG, 2019). In general, emerging technologies are presented as solutions to problems, or a tool the MPO can use to help achieve their goals. However, MPOs have not shown a strong understanding of how this might be accomplished. Most of the MPOs only scratch the surface of how emerging technologies can help them address region specific challenges or goals.

A total of 24 MPOs are developing their own internal policies for emerging technology. However, these tend to focus on a few key issues, that are tangential to actual emerging technologies, but highly relevant for building anticipatory capacities. The polices address issues of building staff capacity; addressing data competencies (e.g., data collection, management, analysis and security and privacy concerns); monitoring trends in emerging technology; creating working groups or committees for emerging technology; or deploying pilot projects. Only about one third of MPOs, including Metro (Portland), CMAP (Chicago), and SCAG (Los Angeles), take a more proactive approach to first identify what they want emerging technology to accomplish and then investigate ways to enable that happening as new technologies are deployed. In this process, Metro also evaluates the maturity level of a technology in relation to its potential regional impacts and then identifies different actions it can take, such as testing, developing policy, expanding a service, or explore beneficial uses (Fig. 3) (Metro, 2018).

Pilot projects, such as the AV pilot project in Peoria, Arizona (Fig. 4) are a key tool MPOs identify to deploy different kinds of emerging technologies, with 24 MPOs citing them in the RTPs. Despite the intent to use pilot projects to evaluate the degree to which technology advances their goals, the RTPs do not elaborate on how MPOs are assessing and learning (or plan to learn) about emerging technologies through pilot projects or otherwise. While pilot projects can provide quick feedback about emerging technologies, the capacities to be responsive to advances in technology or policy are not being developed. The MPOs that do address assessment of technology projects indicate they will use the same performance measures as they do for all other projects. The RTPs do not detail what these measures are, as these are housed outside of the RTP and are often more dynamic and more frequently updated. A small number of MPOs have indicated their intention to include

emerging technology as a factor in overall project selection, including 'extra points' for projects that incorporate emerging technology and help prepare the region for future technologies.

Interviews with MPO planning staff

The interviews with MPO staff provided additional information not revealed during the document analysis and show that many acknowledge they have a long way to go and are still 'figuring it out'. Many MPOs were still working out how to include emerging technology in their RTPs, which is attributable to a lack of immediate need, particularly in regions where there were no emerging technologies. Regions like Seattle and Chicago indicated that certain emerging technologies, like AVs, were many years away from being deployed, and thus not an immediate concern. Uncertainty was important here, as MPOs cited continued uncertainty about what they should actually be investing in.

When asked specifically about flexibility (or responsiveness), all interviewees noted it was something they had thought about but had not yet figured out how to accomplish. Some MPOs did note that the regular legal requirement to update the RTP every four years provided them with a certain degree of flexibility. However, this time frame is likely too long to adequately respond to emerging technologies in a meaningful way within an anticipatory governance framework.

Most MPOs highlighted the importance of equity in emerging technologies. Equity was identified in the document analysis as an important goal for emerging technology. However, discussions of equity in the interviews revealed different definitions among MPOs. In some cases, it meant equity among people in the region. In other cases, it meant regional equity in terms of investments between communities. This particularly came out in discussing the role of the MPO in regard to emerging technology, where one of the functions of the MPO is ensure that small cities, suburban communities, and rural areas are not "left behind" and benefit from emerging technologies in the same way central cities might.

Interviews also revealed that MPOs are evolving their core functions in different three different ways: (1) regional leaders; (2) data leaders; and (3) convenors and catalyzers. In the first group, MPOs such as Dallas-Ft. Worth, Las Vegas, and Minneapolis-St. Paul take a leading role in determining what the region will address in terms of emerging technology. In the second group, MPOs such as Denver, Seattle and Portland emphasize their ability to collect, manage and share data regionally and use this as a way to learn about emerging technologies. In the third group, MPOs like Sacramento and Chicago are working more as facilitators and making sure that everyone that needs to be at the table is present and able to participate in the planning efforts for emerging technology.

The interviews also confirmed what was evident in the document analysis – that most MPOs see planning for emerging technology as distinct from their 'regular' planning activities. There is a general sense that emerging technologies present unique challenges that require new ways of planning, thus require special plans or attention. In only two of the MPOs interviewed was there a clear sense that emerging technology is an extension of what they already do to integrate technology into their transportation infrastructure.

Discussion: towards adaptive transportation planning in MPOs

Anticipatory governance and responsible innovation bring distinct perspectives to modern transport planning, particularly in the context of emerging technologies. We propose that adaptive transportation planning is achieved through the combination of these multifaceted strategies, depicted in Fig. 5 as a triangle with adaptive planning at its core. While the specific methods of adaptive planning are not explicitly delineated, it is envisioned as a combination of all three planning approaches. However, in combining these, MPOs and other planning agencies must navigate the potential conflicts that arise between them, as shown in Fig. 5. We discuss each of these conflicts and examine how MPOs are integrating elements of anticipatory governance and responsible innovation into their transport planning processes and how they address these different conflicts.

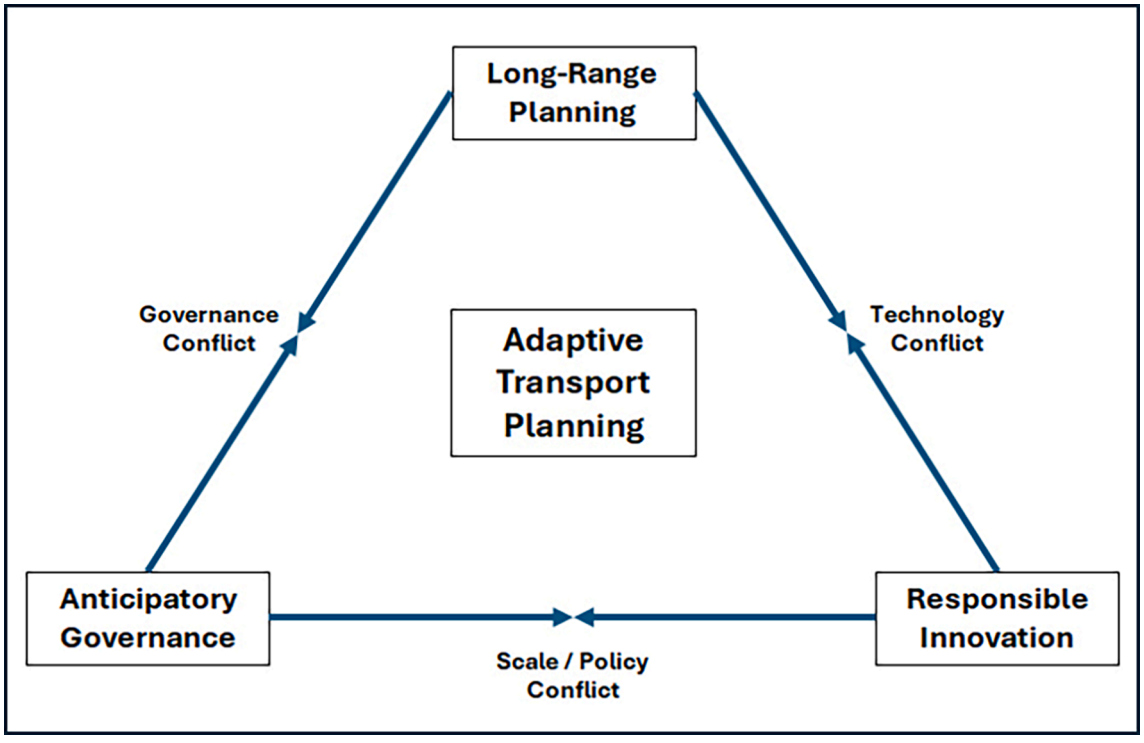

Fig. 5. Adaptive Transport Planning triangle is the integration of anticipatory governance, responsible innovation, and long-range planning process. These three points on the triangle also have associated conflicts between them, which must be managed to build adaptive planning capacities.

The first conflict we identify is the *governance conflict* between long-range planning and anticipatory governance. This tension primarily revolved around *what* is being governed and *the methodologies employed*. Anticipatory governance requires the development of new governance structures, potentially conflicting with federal and state requirements for transport planning. Further, questions arise concerning the jurisdiction over technology and innovation governance, historically centralized within federal agencies. This is exemplified by tension between states seeking to regulate emerging technologies like AVs and federal agencies granting exemptions for testing. Additionally, this conflict underscores the disparities between traditional transport planning tools, which focus on forecasting the future, and the anticipatory governance methods that prioritize managing risk and uncertainty in a more flexible and responsive way.

The second tension arises from the technology conflict, where long-range planning and responsible innovation intersect in determining the suitability of technologies for the transport sector. A focus on safety and efficiency, for example, may result in policies that focus on adoption of AVs to reduce human error in driving and increase roadway capacities. However, responsible innovation introduces ethical and values-based processes into transport planning that may influence the selection criteria for technologies. Additional factors such as equity or privacy may become more important. Responsible innovation offers novel stakeholder engagement methodologies to assist MPOs in making informed decisions about technology investments that address both transportation issues and provide broader public value.

Lastly, the scale (or policy) conflict between anticipatory governance and responsible innovation reflects the dichotomy between present-focused innovation and future-oriented governance. This tension influences policy development, stakeholder engagement, and the scale at which policies are implemented. Adaptive planning necessitates the integration of both the short-term perspective of responsible innovation and the long-term vision of anticipatory governance to effectively address future challenges in transport planning.

The synthesis of anticipatory governance, responsible innovation, and long-range planning into adaptive planning offers a robust framework for addressing the complexities of transport planning in the era of emerging technologies. MPOs must navigate the conflicts inherent in these approaches while incorporating elements of each to effectively shape the future of transport infrastructure. Developing a comprehensive strategy that encompasses foresight, stakeholder engagement, and adaptability will be critical for successfully navigating the evolving landscape of transport planning in an era of rapid technological advancement.

Our findings show that over half of the examined MPOs are integrating some aspects of anticipatory governance and responsible innovation into their planning efforts, with 20 percent incorporating nearly all elements (Tables 7–9). However, these integrations are currently rudimentary, highlighting the need to expand these capacities to foster adaptive planning for U.S. regions. This entails incorporating foresight, engagement, reflexivity, and responsiveness. Such integration will enable MPOs to further develop adaptive transportation planning, combining traditional transportation planning approaches with anticipatory governance and responsible innovation. This holistic approach is vital for maintaining a focus on transport systems while simultaneously developing anticipatory capabilities and more ethics- and values-based perspectives on technology and innovation in the transport sector.

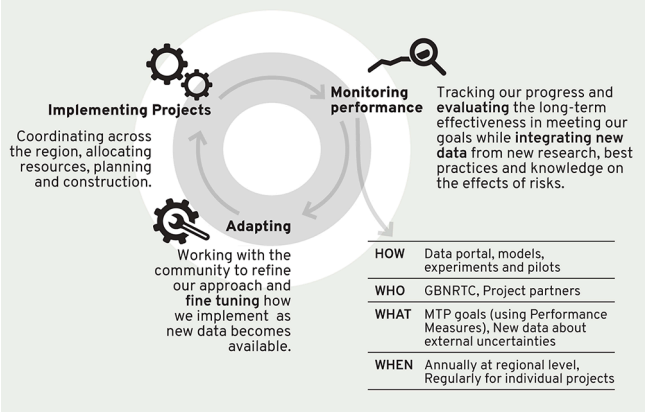

Fig. 6. GBNRTC adaptive planning framework. (Source: GBNRTC 2018).

Anticipatory governance involves three key steps, which includes (1) the development and analysis of a range of possible scenarios, (2) creation of flexible adaptation strategies, and (3) ongoing monitor and respond to change (Quay, 2010). While many MPOs acknowledge the importance of these steps, implementing them remains a challenge for most. For example, Buffalo's GBNRTC, has developed an 'adaptive planning framework' (Fig. 6), which emphasizes monitoring and evaluation. Similarly, Chicago's CMAP has developed a robust decision-making process rooted in scenario planning. This will enable CMAP to develop plans that perform well and address the region's goals no matter the technological developments that occur, thus increasing their capacity to adapt to different technology futures. Many MPOs still grapple with the need for greater flexible and adaptability in response to evolving needs and remain unsure how to develop these capabilities. The struggle to achieve this flexibility underscores the governance conflict inherent in MPOs, as these new approaches clash with the more rigid long-range transportation planning process. Despite these challenges, a few MPOs are making significant strides in this direction.

Since we conducted our analysis, MPOs have continued developing the capacities we study in this paper. For instance, San Franciso's MTC has further developed adaptive planning capacities in the update of their RTP, *Plan Bay Area 2050*, as detailed in Machiels et al. (2023). They emphasize how the new exploratory scenario planning process used by MTC aligns with their adaptive planning framework, which incorporates real option theory. Real option theory embeds options into plans, allowing for changes along the way, and removing the need to make all decisions early in the planning process (Coppens et al., 2021; Machiels et al., 2023). The adaptive planning framework is an extension of exploratory scenario planning (Avin & Goodspeed, 2020; Goodspeed, 2020) consists three stages: scenario development, strategy development, and adaptive plan-making and monitoring (Machiels et al., 2023). This framework, like GBNRTC's framework, requires ongoing monitoring and adapting, with input from data collection and analysis on changing conditions.

Scenario planning is a useful tool to address issues related to emerging technologies, aiding in managing risks, designing robust strategies, and enhancing transparency of uncertainties by developing and visualizing multiple possible futures (Avin et al., 2022; Goodspeed, 2020; Sherman & Chakraborty, 2022). While many MPOs use scenario planning, many fewer incorporate emerging technologies into their scenarios, despite their significant role in shaping future transportation systems. However, among our sample, MPOs in Buffalo, Philadelphia and Salt Lake City have more thoroughly integrated emerging technology into their scenarios. Given its importance in transport planning and anticipatory governance, further development of scenario planning within MPOs is crucial for enhancing foresight capabilities and managing uncertainties in adaptive planning processes.

While some MPOs incorporate emerging technology into their scenario planning, others recognize the need to better integrate it into transportation models. One promising method is TMIP-EMAT (Travel Model Improvement Program Exploratory Modeling and Analysis Tool) (FHWA, 2023). TMIP works alongside various transportation models to incorporate uncertainties like the penetration rate of AVs, changes in land use, and demographic shifts. Rather than producing a single output, TMIP runs multiple scenarios to analyze risk probabilities and provide best and worst-case scenarios (Milkovits et al., 2019). Methods like TMIP allow planners to deviate from the standard travel modeling

process to better incorporate uncertainties inherent in emerging technology through 'robust decision making under deep uncertainty' (Lempert et al., 2022).

While scenario planning and new methods are beneficial for building anticipatory capacities, they alone cannot establish an adaptive transport planning process. Machiels et al. (2023) provide a broad adaptive planning framework, yet it lacks integration of responsible innovation crucial for new technology planning. Given the growing impact of technological innovations in transportation, any adaptive planning framework must incorporate ethical considerations and values-oriented approaches. Moreover, it necessitates robust public participation that encompasses emerging technologies alongside other objectives.

Portland's Metro serves as a leading example of an MPO integrating responsible innovation dimensions. In their RTP, they outline various methods for assessing and prioritizing technologies aligned with their transportation objectives. While Metro's approach primarily involves internal deliberations, incorporating stakeholder engagement into this would be a positive advancement. Several MPOs are adopting new deliberative and multi-stakeholder methods to engage in dialogues about emerging technologies. GBNRTC (Buffalo) and MAG (Phoenix) were part of the global *Our Driverless Futures* citizen dialogues, which aimed to understand public sentiments about AVs and inform recommendations to policymakers and industry (Chng et al., 2021). These citizen dialogues contribute to reflexive participatory technology assessment (pTA) methods to engage stakeholders about emerging technologies (Kaplan et al., 2021). While this example focuses on AVs, other MPOs could adopt similar strategies to focus on specific technologies or broader technology considerations.

Increased stakeholder collaboration can also be interpreted as increasing exchanges between the public sector and industry. MPOs are forging partnerships and initiating pilot projects with technology firms, facilitating mutual learning about emerging technologies and their potential to address public challenges. The learning capacity of technology pilot projects – which contributes to the need for continued monitoring and analysis (Machiels et al., 2023) – is crucial for deciding how to allocate public resources and identifying the most effective uses of emerging technologies for public benefit. Many technology pilot project fail to incorporate this, reducing their effectiveness as planning tools (McAslan et al., 2021b).

Conclusion

In this paper, we assess how MPOs integrate anticipatory governance and responsible innovation into their planning for emerging technologies. While many MPOs have incorporated several dimensions, it remains an ongoing process. Most MPOs demonstrate a basic awareness of emerging technologies and are planning in varying ways, with a wide range, from rudimentary to more advanced approaches. Only seven of the 50 MPOs examined show significant progress in aligning with anticipatory governance and responsible innovation principles, evident in actions such as foresight, adaptive management, stakeholder engagement, flexibility, and responsiveness. In practice, actions like comprehensive consideration of region-specific impacts of emerging technologies, policy development, technology piloting, partnership building, and exploration of adaptable planning methods to address evolving circumstances and uncertainties are signs of emerging anticipatory governance within MPOs.

Drawing from prior research, we propose that the combination of long-range transport planning, anticipatory governance and responsible innovation is necessary for creating adaptive transportation planning capacities to address the uncertainties inherent in emerging technologies. While our focus is on transportation, these adaptive planning capacities will enable MPOs to manage a wide range of uncertainties associated with increased technological diffusion in urban areas. Our proposed approach contributes to the advancement of theories in adaptive planning, anticipatory governance, and responsible innovation, offering a relevant framework for addressing multifaceted challenges across diverse domains.

Long-range planning, anticipatory governance and responsible innovation form the foundation of a new adaptive planning paradigm. We identify conflicts that arise between each pair, which need to be addressed to effectively develop adaptive capacities. The apparent lack of integration evident in many MPOs may stem from a failure to acknowledge these conflicting interests. Addressing these conflicts – governance, technology, and policy – enables MPOs to better navigate the complexities surrounding emerging transportation technologies. Integrating anticipatory governance and responsible innovation into transport planning will not reduce or eliminate uncertainty in urban and transportation futures. Instead, it equips MPOs and other agencies with a broader toolkit to manage uncertainties and mitigate risks more effectively.

A main limitation of this study lies in its reliance on MPO planning documents to analyze emerging technology, which are typically updated every four years. Consequently, many of the plans analyzed have been revised since our analysis, potentially incorporating more robust strategies for emerging technologies and adaptive planning. Just as MPOs require prompt feedback on new technologies' impacts, enhanced monitoring of MPO planning work could facilitate more rapid assessment of the current planning landscape. Future research might also explore emerging technology efforts within planning agencies not bound by the same federal and state regulatory constraints as MPOs, offering insights into innovative planning approaches.

How MPOs approach emerging technology planning today will shape the future deployment of transportation technologies. Developing tools, methods, and policies now is crucial for MPOs to effectively leverage emerging technologies in advancing regional transportation and urban development goals. MPOs face important decisions about what technologies to fund, how to implement regionally significant technology projects, and how to enable member jurisdictions to pursue emerging technology projects in a way that is compatible with other jurisdictions. Enhanced regional planning can facilitate coordination in planning, deployment, and maintenance of transportation technologies. While new methods and tools aid in adapting to evolving regional planning needs, institutional changes are also necessary to incentivize MPO innovation in long-range transportation planning. Given the transformative potential of emerging transportation technologies, rethinking traditional transportation planning approaches is imperative.

This study offers valuable insights for planners by identifying best practices across the U.S., which can then be adapted to local and regional contexts. The frameworks introduced can help urban planners navigate technology integration within the constraints of federal and state planning regulations. Moreover, this study emphasizes the evolving role of MPOs in areas such as data management, partnerships, and risk management, which extend beyond traditional regional transportation planning responsibilities. This expanded scope underscores the importance of regional coordination as MPOs evolve to meet the diverse needs of their regions.

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CRediT authorship contribution statement

Devon McAslan: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. **Lisa Kenney:** Formal analysis, Writing – original draft, Writing – review & editing, Visualization. **Farah Najar Arevalo:** Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. **David A. King:** Conceptualization, Methodology, Investigation, Formal analysis, Writing – review

& editing. **Thaddeus R. Miller:** Conceptualization, Methodology, 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.

Data availability

Data will be made available on request.

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