Embracing the Uncertain Future: Three Essays on Uncertainty in Analysis, Planning, and Policy Making

by

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Dissertation Abstract

Uncertainty is inseparable from long-range planning. In striving for just, equitable, and sustainable futures, we are always confronted with the limits of our own understanding. Looking far into the future, or even trying to properly assess the ground beneath our feet, often reveals much more about what we are unsure of than what we can predict with confidence. However, uncertainty is still largely treated as subordinate in urban planning, either not grappled with at all or applied as an addendum to mean trend forecasting. This dissertation seeks to invert the traditional approach by placing uncertainty at the center of planning within three stages of the planning process: simulation analysis, planning, and policy making. The objective of this three-paper dissertation is then to examine how uncertainty interacts with three stages in the urban planning and policy making process; and to suggest how centering uncertainty can improve planning. The first paper considers the analysis of policy options under uncertainty in land use and transportation simulation. This paper demonstrates the applicability of scenario discovery, a research design for decision making under deep uncertainty, in land use and transportation models. I find that scenario discovery performs marginally better in identifying robust strategies relative to more circumscribed approaches, but significantly enhances insights regarding adaptive policy making. The second, lead-authored paper asks what impact uncertainty has on the climate policy disposition of municipal elected officials. We sent a survey to elected officials in cities with greater than 100,000 people querying their degree of climate policy uncertainty as well as their propensity to support climate policies. Using a structural equation model with a novel latent variable measure of climate uncertainty, we demonstrate that uncertainty diminishes propensity for climate policy. My final paper delves into the use of scenario planning to support racial equity planning. From the literature on equity in scenario planning and my own experience, I develop a novel framework for using scenario planning to promote racial equity. This framework builds on the five types of racial equity, a six-stage hybrid scenario process, and the three outcomes of public sector scenario planning: organizational learning, organizational strategy, and community learning. Using this framework, I assess the inclusion of equity in the Delaware Valley Regional Planning Commissions Dispatches from Alternative Futures scenarios plan. This plan successfully raises racial equity as a concern for the future of the Philadelphia region. However, the stakeholder group was not sufficiently diverse for full deliberative justice and the scenario planners do not utilize tools that can assess the distributional outcomes of scenarios and policies. Neither epistemic nor restorative justice were a significant part of the scenario plan, leaving open the possibility for more radically co-designed scenarios for racial equity in the future.

Thesis Supervisor: P. Christopher Zegras

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1. Introduction

Uncertainty is inseparable from long-range planning. In striving for just, equitable, and sustainable futures, we are always confronted with the limits of our own understanding. Looking far into the future, or even trying to properly assess the ground beneath our feet, often reveals much more about what we are unsure of than what we can predict with confidence. However, uncertainty is still largely treated as subordinate in urban planning, either not grappled with at all or applied as an addendum on more central trend forecasting. This dissertation seeks to invert the traditional approach by placing uncertainty at the center of planning within three stages of the planning process: simulation analysis, planning, and policy making.

Planning is an activity that takes place when we don't know exactly what the future holds, which values we wish to promote, and what actions will be most effective in promoting those values (Christensen, 1985). It's then odd that so much long-range planning persists within a predict and prepare paradigm that projects the future with implausible precision (Marsden & McDonald, 2017). Transportation planning, a field that I consider to be my professional and academic home, is particularly guilty of such a mindset, often basing several billion dollars of infrastructural investments on population and facility use forecasts with single digit precision. Alternative forecasts or even error bounds are rare in official transportation planning documents. While such efforts have long demonstrated inappropriate technocratic hubris, the increasingly uncertain future readily also reminds the public and planners that we need a new approach. Climate change, pandemics, financial instability, political polarization, and social uprising remind us all that we cannot plan for a future calibrated to past experience.

In the three papers of this dissertation, I seek to demonstrate that uncertainty-centered urban planning does not just produce a different planning process, but also suggests entirely different strategies of intervention. Planning under uncertainty is not merely adding some error bounds around forecasts and optimizing the expected value. Rather, centering uncertainty encourages planners to determine the conditions under which our policy approaches perform best. Centering uncertainty also encourages planners to understand how the presentation of uncertainty impacts the choices of decision makers, so that uncertainties might be accommodated for and incorporated into planning. However, centering uncertainty is not an end unto itself, but rather a pathway towards promoting community values, such as racial equity. Current practices of uncertainty-centered planning must be expanded and rethought in order to incorporate such values.

"The Value of Scenario Discovery in Land Use and Transportation Modeling: An Automated Vehicle Test Case", considers scenario discovery, a type of decision making under deep uncertainty (DMDU) analysis, in land use and transportation interaction (LUTI) modeling. DMDU approaches deploy novel research designs in simulation experiments in order to inform policy when uncertainty cannot be well characterized statistically. In this experiment, I examine the added information gained from utilizing scenario discovery relative to more limited simulation approaches. As a test case, I simulate policy options for managing the land use impacts of automated vehicles (AVs) in the Baltimore-Washington region. Methodologically, I determine that scenario discovery performs better than current scenario approaches in determining contingent policies, though more limited scenarios can be helpful in determining robustness. Substantively, I find that automated vehicles have the potential to blunt current policy tools for compact development and enhance the popularity of already high demand areas.

"The Pernicious Effects of Uncertainty on Long-Range Planning", examines how uncertainty influences the decisions of elected officials. In this paper, climate uncertainty is accepted as the inevitable background in which elected officials make policies. We sent a survey to all elected officials in cities with greater than 100,000 people, querying their degree of climate policy uncertainty as well as their propensity to support climate policies. Using a structural equation model with a novel latent variable measure of climate uncertainty, we demonstrate that uncertainty diminishes propensity to support climate policy. We additionally tested for

potential for whether gain or loss framing in the presentation of that uncertainty impact the propensity to support climate policy, but our sample size prevented conclusive results.

"A Framework for Implementing Racial Equity in Scenario Planning in Regional Scenario Planning" then examines how regional planning organizations can use scenario planning, the leading approach for incorporating scenarios into long-range planning, to promote racial equity. Though regional planners increasingly desire to incorporate equity into their practice, they lack guidance on how to use scenarios to advance equity planning. Likewise, equity planning may benefit from scenario planning's deep analysis of driving forces and creative opening up of multiple futures. This paper attempts to reconcile these two planning approaches so that scenario planning can gain new relevance in supporting equity-oriented planning, and planning for equity can develop policy approaches that are robust to outside driving forces. I develop a framework from the scenario planning literature and personal experience that builds on five types of racial equity, a six-stage hybrid scenario process, and three outcomes of public sector scenario planning: organizational learning, organizational strategy, and community learning. As a paradigmatic case, I utilize interviews, document analysis, and participant observation to assess the use of the Delaware Valley Regional Planning Commission (DVRPC) *Dispatches from Alternative Futures* for equity planning. I find that the plan successfully raises racial equity as a concern for the future of the Philadelphia region, but the planning approach at DVRPC does use scenarios to support epistemic or restorative equity.

The papers on scenario discovery and exploratory scenarios are part of an answer to the challenge raised by my paper on climate uncertainty. If uncertainty is undermining the decision making of elected officials, planners are justified in their wariness toward presenting uncertainties to the public. Including error bounds and contingencies could simply confuse the public or supply arguments for oppositional groups. But such trepidation is less sensible when we have processes and analyses to help grapple with that uncertainty. In fact, a planning proposal should have more legitimacy if it is tested through multiple futures and analyzed for vulnerabilities. And these uncertainty-incorporating approaches will certainly be most legitimate and powerful when they incorporate community members in a community-driven planning process supporting more equitable outcomes.

In planning the long-range future, planners should consider, and potentially center, the role of uncertainty in all planning actions, from setting a vision through the implementation of policy. A thorough theory of planning under uncertainty must address how what we don't know influences all moments in the process. This dissertation, then, does not attempt a thorough theory of planning under uncertainty but moves in that direction by examining uncertainty in three essential areas of analysis. This leaves much ground to be explored more thoroughly in later work.

This dissertation is organized as follows. The introduction defines uncertainty and subsequently introduces how each paper fits within a larger discussion of uncertainty in the planning process. The next three sections are the full manuscripts of each of the papers.

What is uncertainty

I use Abbot's definition of uncertainty in planning: "Uncertainty is a perceived lack of knowledge, by an individual or group, that is relevant to the purpose or action being undertaken" (2005, p. 238). Uncertainty is a perception, not a fact about the outside world. Natural processes may be random, chaotic, or indeterminant but they are not uncertain until they are perceived as such. One can be certain about that which is unknowable, such as what becomes of our souls after we pass. One can also be quite uncertain about established fact, such as the winner of the 2020 election. In the second part of his definition, Abbot acknowledges Dewey who argues that uncertainty is only relevant when we seek to act (Dewey, 1929). This pragmatic definition aligns well with urban planning and policy making.

Uncertainty possesses several dimensions relevant to its interpretation. Friend and Jessop (1977) introduce a tripartite division: uncertainty of knowledge, uncertainty of related decision fields, and uncertainty of values. For the authors, knowledge is resolved through research, decision fields are brought together via coordination, and values are the province of political decision makers. While they do not believe that uncertainty can be fully eliminated, they are optimistic that strategic planning can identify the most relevant uncertainties and dedicate resources to their diminution. Christensen theorized two intersecting dimensions of uncertainty in planning: technology – knowledge of how to act – and goals (1985). Similar to Friend and Jessop, Christensen suggests the planner's role is to apply appropriate processes toward reducing uncertainty. Unlike her predecessors, Christensen introduces a space of "chaos" – unknown technology and unagreed goals – for which she offers only charismatic leadership as a solution.

Both these frameworks align with the ends/means division in rational planning (Banfield, 1959), an approach that was already on its way out by the time that Friend and Jessop, and Christensen developed their frameworks (Dalton, 1986; Rittel & Webber, 1973). The underlying assumption is that uncertainties can be systematically reduced through analysis. Christensen chips away at this by recognizing that plural politics often leads to conflicts in goals that cannot be resolved by consulting the political class. However, her framework relies on the insistence that the best approach to uncertainty is always to reduce it. In this view it primarily views uncertainty as the unyielding context of planning, rather than an opportunity for strategic and adaptive decision making.

For my own research, the classification of uncertainty in modeling, as developed by Kwakkel et al. (2010), is a more clear guide for understanding types of uncertainty. The authors introduce three dimensions of uncertainty: location, level, and nature. The location refers to the point uncertainty enters the planning process – data collection, analysis, decision making, modeling, etc. Each of the essays in this dissertation reflect uncertainty in one location. The level of uncertainty indicates the scale used to describe the uncertainty. Level 1 (shallow) uncertainties are probabilistic. Level 2 (medium) uncertainties can be ordered in likelihood. Level 3 (deep) uncertainties can have possibilities enumerated but relative likelihood cannot be judged. Finally, level 4 (recognized ignorance) uncertainty acknowledges that surprises happen. This dissertation is primarily interested in deep uncertainties.

The 'nature' of uncertainty refers to whether uncertainty is due to imperfections in our knowledge, inherent variability, or interpersonal ambiguity. The three natures are epistemic, ontic/variability, and ambiguity. Epistemic uncertainties can be known but are not yet available. Transportation planners might not know the current ridership on a transit line but they could determine this with high precision. Resolving epistemic uncertainty, however, costs time, money, energy, political capital, and/or privacy. Ontic uncertainties are inherently probabilistic or deeply uncertain – they cannot be presently resolved. Future ridership on a transit line cannot be perfectly estimated even with appropriate variables specified. Complexity theory explains how even deterministic processes can produce irreducibly uncertain outcomes (Skrimizea et al., 2019; Urry, 2005). Ambiguity refers to differences in frame and values. Frames are different ways in which participants understand and make meaning of the same phenomena.

Uncertainty in Three Phases of the Policy Making Process

For practitioners, grappling with uncertainty means locating it within the planning process and deploying specific planning tools according to that location. One of the objectives of this dissertation is then to provide that guidance with respect to three phases of the long-range planning process: decision making, strategic analysis, and in scenario planning.

Figure 1.1 presents an idealized long-range planning cycle developed by the Delaware Valley Regional Planning Commission (DVRPC). I look to the DVRPC example because my third paper returns to DVRPC as a case of long-range scenario planning. Reading clockwise, long-range planning begins with the analysis of

trends and forces and, potentially, scenario planning to better understand the implications of those trends and forces. This feeds to the community vision and strategies, and eventually decisions made by elected and appointed bodies. Implementation tails off the right, indicating responsibility outside of long-range planning. Meanwhile, the long-range planning team evaluates the performance of the previous plan in order to inform the next planning cycle.

Figure 1.1 The Delaware Valley Regional Planning Commission Long-Range Planning Process

Though these moments are often presented cyclically, they often interact idiosyncratically and most planning processes do not follow this idealized model. A sudden change in the environment might support new policy without additional analysis or planning. Analysts may churn out new documents according to the standards and requirements without much connection to decisions. Plans are made, shelved, dusted off, and repurposed. Each of these moments uniquely encounters uncertainty. Each moment within the planning must be examined individually to understand and work with uncertainty in that moment.

The reader will also note that this dissertation does not cover all phases in the above planning process. It does not include visioning, implementation, or evaluation. It also does not cover planning processes outside of the DVRPC long-range model including negotiation and urban design. Even within the phases included, there is a rich trove of methods and approaches unaddressed. This dissertation is not meant to be a comprehensive guide to or unified theory of uncertainty throughout the planning process. Rather, I seek to cover three core phases in the planning process where uncertainty has been most visible and vexing. Nonetheless, the results of these three studies demonstrate the value of this starting point.

"The Value of Scenario Discovery in Land Use and Transportation Modeling: An Automated Vehicle Test Case" examines uncertainty in strategic choice. In particular, I look at simulation modeling analysis and how DMDU can aid the selection of both robust and contingent policy options. Simulation has long played a central role in transportation project selection but the practice has long persisted with single point (Marsden & McDonald, 2017), often biased, forecasts (Flyvbjerg et al., 2002; Voulgaris, 2020). Fortunately, DMDU tools are on the horizon for these practices (Lempert et al., 2020), and this paper seeks to assess the value that such computationally intensive practices add.

"The Pernicious Effects of Uncertainty on Long-Range Planning" focuses on uncertainty in the decision-making stage. Long-range uncertainty is a persistent and irreconcilable challenge of municipal climate policy (Bulkeley et al., 2019). And though research has attempted to uncover the impacts of climate uncertainty on individuals (Gustafson & Rice, 2019; Howe et al., 2019), no one has examined how uncertainty impacts elected officials. Persistence campaigns of climate doubt raise the stakes for such research (Oreskes & Conway, 2011). The paper highlights the importance of boldly facing uncertainty for policy makers, their advisors, and community members seeking to influence them.

"Equity in Scenario Planning: A Framework and Test Case" considers scenario planning, a planning approach that is designed to identify uncertainties and address their implications. In the case of DVRPC, it is a regular stage in their long-range planning process. Equity planning perspectives could renew the relevance of scenarios for stakeholders (Avin, 2007), engage a broader citizenry (Zapata & Kaza, 2015), and increase their ability to aid in addressing regional equity planning mandates (Martens & Golub, 2021). Scenario planning could also help equity planners to discover the more expansive imagination that will be required for necessary change (Inch, 2021; Zapata, 2021). Instead of focusing on how to include uncertainty, this paper focuses on how we might do it in service of more equitable outcomes.

Contributions

I intend for this dissertation to contribute to several literatures. Centrally, I am interested in contributing to the discussion of planning under uncertainty and futures planning. This includes the exploratory scenario planning more familiar to the urban planning field and newer DMDU approaches. With respect to the latter, I am interested in both introducing these approaches as additional strategic options for urban planners as well as developing relationships with the interdisciplinary DMDU community. I often view futures from a complex systems perspective that is informs DMDU approaches, and I hope that fellow planners that view regions as complex, dynamic systems will find value in this work.

This dissertation will also contribute to critical substantive conversation on climate change policy and equity planning. "The Pernicious Effects of Uncertainty on Long-Range Planning" demonstrate the value of examining how municipal elected officials think and act on climate change. It extends beyond the current discussions in the climate communications literature, which has tended to look at the behaviors of the general population. Similarly, "Can the Uncertain Future be an Equitable Future? A Study of Equity in Regional Scenario Planning" addresses the challenge of regional equity planning. As my career progresses, I intend for these themes to increasingly intertwine. I seek to ask questions regarding the impact of uncertainty on efforts for climate justice, and how communities might embrace uncertainty to seize strategic opportunities for more just futures.

Finally, I seek these papers to directly influence professional planning and policy making practice. The questions set forth in this dissertation are inspired, in part, by the unease with which professional planners have approached uncertainty. The research in this dissertation should provide practitioners with the confidence that they need not ignore nor get lost in uncertainty. Even as I demonstrate that uncertainty can hold back important policy advances, I demonstrate two tools that planners can use to work with uncertainty. Scenario discovery is still very novel in North American planning practice. The Transportation Model Improvement Program at the US Department of Transportation has started to promote its use (Milkovits et al., 2019), but I am not yet aware of practitioners utilizing exploratory modeling approaches for land use or other urban systems. My work will aid in these new applications. I am particularly interested in how scenario discovery with microsimulation can inform robust strategies for equity. The final paper should provide a useful framework for practitioners interested in scenarios but concerned that they are too value neutral to support equity goals. Seeing professional planners attempt to apply the framework would be the greatest reward for the time I put into refining it.

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2. The Value of Scenario Discovery in Land Use and Transportation Modeling: An Automated Vehicle Test Case

Abstract

Long-range planning is an uncertain endeavor. This is especially true for urban regions, small ships in a global urban storm: too small to influence macro policies, but without the land use powers of local governments. Exploratory scenarios, the established practice for planning under deep uncertainty has inspired stakeholders to consider multiple futures but fallen short of identifying robust and contingent policies. We need new tools to plan under conditions of deep uncertainty. Scenario discovery is a simulation modeling approach designed to explore maximally unlike scenarios for policy making under deep uncertainty. This paper presents an application of scenario discovery in land use modeling and asks what this computationally intensive approach offers relative to more circumscribed exploration of uncertainty space. The introduction of autonomous vehicles (AVs), and their associated impacts on land use provide a test case demonstrating this method, as well as a topic of substantive concern. This research concludes that scenario discovery is particularly valuable for identifying the conditions under which contingent policies are likely to succeed. In terms of AV policy this research establishes that forward thinking transit oriented-development strategies can mitigate spatial dispersion while also reducing overall housing costs. Additionally, I find that AVs may blunt the impacts of some current policy tools if they extend the distance individuals are willing to travel to work.

Introduction

The analytic processes deployed in long-range planning have long aided in masking uncertainty. Land Use Transportation Interaction (LUTI) models, a tool utilized by Metropolitan Planning Organizations (MPOs) the predict and prepare paradigm that has dominated long-range planning approaches. Modelers and planners often rely on point forecasts whose basic assumption is that the future will be largely similar to the present – just with more people (Marsden & McDonald, 2019). Planning professionals are just beginning to develop analytic frameworks that acknowledge future uncertainty in the application of these models. I thus examine *scenario discovery and robust decision making*, a novel research design for decision making under deep uncertainty (R. J. Lempert et al., 2006). Scenario discovery has limited deployment in the regional planning context, including a handful of transportation applications (R. Lempert et al., 2020; Milkovits et al., 2019), and even fewer in Land Use Transportation Integrated (LUTI) (Swartz & Zegras, 2013).

The primary goal of this paper is to demonstrate the application of scenario discovery for land use modeling to the urban planning community. In doing so, I assess the usefulness of this approach relative to more circumscribed approaches to incorporating uncertainty into modeling. I compare the information gained for a large number of futures to two more limited sampling of uncertainty space. In focusing on only the outer edges of the uncertainty space, the more limited sampling is designed to resemble the results of an exploratory scenario exercise which develops and examines scenarios at the edges of plausibility. I demonstrate scenario discovery by modeling the impacts of automated vehicles (AV) on land use decisions. In doing so, I demonstrate how scenario discovery can allow us to draw policy insights regarding a topic that is deeply uncertain. I also draw conclusions regarding the potential land use impacts of automated vehicles and policies to support desirable outcomes.

My research seeks to provide insight on the following questions:

- Q1: How well does scenario discovery within LUTI modeling perform in identifying robust and contingent planning strategies relative to exploratory scenarios?

- Q2: What are the potential land use outcomes from autonomous vehicle adoption and what policies can be put in place to support desirable outcomes?

For the research questions I hypothesize as follows:

- H1A: Scenario discovery within LUTI modeling will be more *precise* in identifying robust strategies than exploratory modeling because additional scenarios will support a finer grain measure of robustness. Scenario discovery within LUTI modeling will be more *accurate* in identifying robust strategies because the sampling technique ensures more even coverage of the uncertainty space.
- H1B: Scenario discovery will determine contingent policies, where more limited samples will be insufficient.
- H2A: Automated vehicles will contribute to more dispersed land use patterns, as was the case with previous transportation technologies that increased mobility speed and comfort (Wegener & Fuerst, 2004). The dispersal encouraging effects of decreased value of accessibility in residential location choice will be stronger than the concentration effect of opening up newly developable central land on former parking lots.
- H2B: Policies that encourage more concentrated land use will be less impactful if automated vehicles change how people value accessibility in location choice.

In answering these questions, I seek to contribute to the literatures on the application on uncertainty analysis in planning, LUTI applications, and the impacts of new transportation technologies.

Uncertainty in Planning

A primary tool for planning under uncertain conditions is "exploratory scenarios," which are defined by asking *What can Happen* (Börjeson et al., 2006)*?* In this type of scenario planning, conveners work with stakeholders to tell several unlike stories about the future in order to prepare for whatever comes.(Schwartz, 1991). This form of scenario adapted approaches that Herman Kahn developed for Cold War strategy to the business world (Wack, 1985), but has rapidly gained purchase within urban planning in the past two decades (Avin & Dembner, 2000; Chakraborty & McMillan, 2015; Zegras et al., 2004).

Deep uncertainty can be defined as a condition under which individuals know the potential outcomes but cannot define the distribution of key parameters (Kwakkel et al., 2010). Exploratory scenarios have been preferred for deep uncertainty because of its focus on the conditions under which policies should be advanced, rather than determining the most likely or preferable outcome. One objective of such exercises is to select policies that are *robust* to a variety of futures and identify other, *contingent*, policies that should be implemented in limited circumstances (Avin, 2007). Depending on the goals and models available to planners, scenarios may also be run through urban systems models to understand potential impacts (Knaap et al., 2020). For narrative intelligibility, scenario planners recommend 3-5 scenarios. However, from the modeling standpoint, this is insufficient to consider policy robustness (R. J. Lempert et al., 2006). This does not necessarily obviate the organizational learning and collaborative action potential of scenarios (Bootz, 2010; Wack, 1985; Xiang & Clarke, 2003), though those outcomes have been tested elsewhere (Zegras & Rayle, 2012).

Robust decision-making using *scenario discovery* could provide an analytics approach for considering deep uncertainties within LUTI models. In this approach, policies are modeled in an ensemble of hundreds or thousands of futures. Instead of asking which policies are likely to produce the highest expected value, scenario discovery asks what are the conditions under which policies perform well or poorly (Hall et al., 2012; Walker et al., 2013). However, no previous research has attempted to assess the additional information

gleaned from running such an ensemble of LUTI modeling runs relative to more limited exploratory scenario approaches.

Modeling Automated Vehicles and Land Use

As AVs approach the marketplace, there is great uncertainty regarding their impacts on household location choice and associated land use patterns. AVs may exacerbate sprawl by making longer commutes more comfortable or facilitate infill by making near-to-destination parking obsolete. Though researchers have extensively modeled the travel demand impacts of AVs, few studies have utilized LUTI models or estimated second-order impacts on land use (Papa & Ferreira, 2018; Soteropoulos et al., 2019), even though previous changes in transportation technology profoundly altered large-scale urban form (Wegener & Fuerst, 2004).

Meyer, Becker, Bösch, & Axhausen (2017), using the Swiss national transport model, found accessibility declines in urban areas associated with increased congestion but accessibility gains in suburban areas. The Swiss national transport model is a macroscopic travel demand model. This study used only the personal transport changes and no changes to freight. Because they only ran a transport model, the findings are gravity-based accessibility scores based on travel times on the network. They do not calculate resultant changes in land use.

Two other studies found inner urban population decreased between 1-4% while outer suburbs in nonurban and rural regions increased between 1-3% (Gelauff et al., 2017; Thakur et al., 2016). Gelauff et al. (2017) use the Dutch spatial equilibrium model (LUCA). LUCA microscopically models four types of agents: three different educational attainment consumer groups and land owners. The consumers choose location and size of their dwelling, their job location, and commute mode by considering locational characteristics and commuting cost. The simulation experiments consider the impacts of ACs on lower perceived cost of travel and additional roadway capacity. Thakur et al. (2016) use a bespoke LUTI model for the Melbourne area. This model has thirty-one radiating zones and is integrated with the Victoria Integrated Transportation Model. Population is redistributed according to a discrete choice model in which accessibility to employment is a key variable in location choice. The scenarios they consider examine changes to real and perceived in-vehicle and out-of-vehicle time.

Distance to work could increase between 7-10% in Atlanta though retired households may move in closer (Zhang, 2017). The author develops an AV operations and dispatching model that they integrate with UrbanSim discrete choice residential and firm location model. The simulation experiments primarily consider behavioral adjustments associated with decreased disamenity of in-vehicle time and policies related to parking. Development may leapfrog the greenbelt in Seoul, South Korea and become less clustered (Kim et al., 2015). Kim also uses an agent-based discrete choice framework. They present a single automated vehicle scenario, which they model by increasing accessibility of faraway regions and decreased preferences for proximity to goods and amenities. Several authors noted the increasing importance of amenity in location choice (Meyer et al., 2017; Thakur et al., 2016). Specific results are difficult to compare because of the different context, models, and assumptions in each simulation.

Basu and Ferreira (2020) utilized the SimMobility long-term model to examine the deployment of automated mobility in association with a car lite pilot in Singapore. SimMobility is a state-of-the-art transportation model with three modular components: long-term land use decisions, mid-term travel demand, and short-term network simulation. The long-term model simulates daily behaviors in the housing market, including the decision to search for housing, bidding, and developer behavior. Utilizing accessibility and property values as variables, they determine that car lite policies, in conjunction with automated vehicles, have the potential to increase the incomes of in movers. In a different study, SimMobility is also used to simulate the impacts of

automated mobility on demand (MoD) on vehicle ownership and residential choices in Singapore. They examine a partial automation scenario, in which automated MoD is introduced into only a specific study area of central Singapore, and a full automation scenario, in which only automated MoD and public transit are allowed to operate, while private cars are banned from the study area. In their full automation scenario, the already high-demand study area has increased demand relative to the baseline.

The SILO model, which I use in this research, is used in two previous studies. SILO is a microscopic discrete choice model that simulates each household, person, and dwelling unit in a modeling region. The model is designed primarily to determine location choice decisions and associated land use patterns, and can be readily integrated with existing transportation models. Relying in part of some behavioral heuristics, such as maintaining a relatively fixed distance to work distribution, it is simpler to set up and calibrate than other microscopic land use models, Looking at two scenarios which decrease value of time and increase vehicle occupancy in Austin, AVs decrease core population between 5.3% and increase growth outside the core by 5.6% (Wellik & Kockelman, 2020). In Munich, six scenarios examine reduced value of time, the decision to purchase an AV, and lower parking penalty in the core. The additional urban sprawl induced by less burdensome commuting is largely compensated by increased attractiveness of the already popular urban core (Llorca et al., 2022).

Finally, the TRANSPACE model is used to examine the impact of roadway capacity and induced demand in the Bay of Santander (Cantabria, Spain). If AVs create new capacity without inducing demand, population growth increases 2.1% outside the city, but if the capacity is consumed, growth could increase up to .7% in the central zone. Employment grows 1.6% in the core with increased core capacity, but decreased -.85% with the assumed behavioral changed (Cordera et al., 2021)

Generally, these simulation experiments have estimated decentralizing behavior to have larger impacts on land use outcomes than the reallocation of central land, however that balance is not universal. Comparison across the current literature is difficult because the cases lack consistency in the selected models and variables. Even within individual experiments, the number of runs remains small and it's difficult to determine whether their results are truly robust beyond their specific parameterization, with the exception of some sensitivity testing. None of these modeling efforts examined more than six scenarios or systematically explored the uncertainty space – something that this paper seeks to introduce.

Exploratory Modeling in Land Use and Transportation Simulation

Exploratory modeling is a variety of computational approaches to assist reasoning regarding a system when there is uncertainty. When modelers cannot take system dynamics for granted because of these uncertainties, exploratory modeling approaches perform hundreds, thousands, or even more runs to rapidly test how those uncertainties impact model dynamics (Bankes, 1993). In the past two decades, exploratory modeling approaches have increased in variety and application, as led by decision making under deep uncertainty scholars in Europe (Kwakkel et al., 2016) and at RAND (Groves & Lempert, 2007). This paper utilizes one of those approaches, scenario discovery for robust decision making (Bryant & Lempert, 2010; R. J. Lempert et al., 2006).

Scenario discovery has found very limited application in LUTI modeling. Lempert et al. (2020) demonstrate robust decision making using scenario discovery in travel demand modeling. Working with the Sacramento Area Council of Government, they demonstrate that the region's ability to meet mobility and climate goals depend on external uncertainties. Milkovits (2019) developed the Travel Model Improvement Program Exploratory Modeling and Analysis Tool (TMIP-EMAT), a travel demand model-oriented extension of the original Exploratory Modeling and Workbench (Kwakkel, 2017), and deployed TMIP-EMAT using the

Greater Buffalo-Niagara Regional Transportation Council regional travel demand. With respect to land use, Swartz & Zegras (2013) provided a demonstration of concept for land use modeling using UrbanSim to examine future growth in Lisbon, Portugal. This paper is just the second instance, to my knowledge, of exploratory modeling of land use outcomes, and the first to compare scenario discovery results to more limited sampling approaches.

Research Design and Methods

Scenario discovery is a simulation research design with two phases: sampling and data mining. Given that an exploration of all future states is impossible, Latin hypercube sampling (LHS) – which ensures the maximum difference between runs – is preferable to intuition-based approaches, which might ignore regions of uncertainty (Groves & Lempert, 2007). Scenario discovery then utilizes data mining to explore the broader uncertainty space for regions in which a policy performs particularly well or poorly. I employ the Patient Rule Induction Method (PRIM), an algorithm that searches for lower dimensional boxes of concentration within higher dimensional space (Friedman & Fisher, 1998). Because each box edge is defined by a single variable, PRIM is easier to interpret than comparable methodologies (R. J. Lempert & Groves, 2010).

Each uncertainty parameterization is a *scenario*. Each scenario is modeled without policy and with each policy intervention. For each completed run, or *future*, the simulation model generates select indicators. The indicators of each future are translated into *regret* – i.e. the difference between the highest performing future for each scenario and the performance of the selected future. Regret allows for comparison across unlike scenarios. A *failed* future refers to one with greater-than-median regret amongst policies with regret greater than 0.[1] Let *robustness* be the percentage of scenarios that succeed for any given policy. For any indicator robustness is calculated as the $r = 1 - \frac{N_f}{N}$ where r is the robustness, N the total number of futures, and N_f the number of failed futures. We can also call $\frac{N_f}{N}$ the failure rate. Finally, the PRIM algorithm is deployed to search for the conditions under which policies tend to outperform others (Gross, 2018).

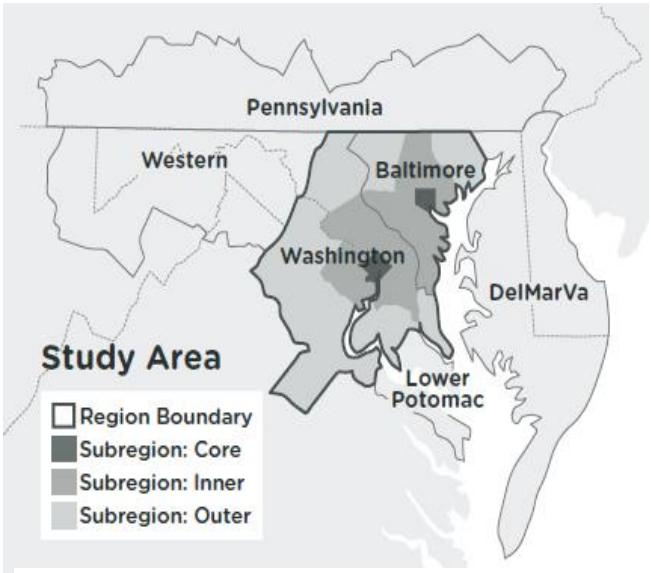

Figure 2.1: The SILO Modeling Region

In this experiment, I run scenarios on the Simple Integrated Land Use Orchestrator (SILO), an agent-based land use model microsimulation that stochastically simulates household location choice decisions, designed to integrate with existing transportation models (Moeckel, 2016). SILO is used to simulate the 2015-2030 time-frame in one-year increments. The model consists of four modules: synthetic population generation, demographic changes, real estate development, and household relocation. Household relocation is determined by three logit models that determine whether to move or stay, which region to move into, and which dwelling to move into within that region. Location choice factors include accessibility to jobs, travel time to work for working household members, and housing costs.

[1] Other rules can be used for determining regret including policy responsive tools where such a threshold officially exists.

In calibration of the application of SILO to Maryland and reflect decision making of actual households in the region, the modelers added racial segregation preferences, as well as measures of crime and school quality (Knaap et al., 2020). The weight of individual factors in the logit model depends on household size, income, and race.

SILO maintains a synthetic population of all individuals and dwelling as well as households. The demographic model is essential in determining realistic location choice behaviors. Every annual simulation each individual ages one year. Markov transition rates determine life events – such as marriage, parenthood, and death – for individuals of a given their gender and ages. This is crucial because the residential location choice model accounts for the home and work locations of both workers in married households and school quality for households with children. The development model increases home values where units are highly occupied and decreases home values where many units remain vacant. Developers respond to these signals by preferring to add units where prices are high. A development capacity layer acts as a hard cap on total units. This layer was developed from an analysis of zoned capacity in each Maryland jurisdiction and estimates based on projected growth locations in other states.

A couple of the limitations of this experiment accompany my selection of the SILO model. First, the SILO model takes the future employment distribution as a given. Our instantiation used employment projections from the Maryland Statewide Transportation Model (MSTM). These projections include the metropolitan planning organization employment forecasts for the Baltimore and Washington region expanded with forecasts from state agencies in rural areas (Tadayon & Shemer, 2013). Second, I was unable to integrate SILO with a transportation model at this time, so this experiment does not directly model feedback between land use and transportation. I thus treat travel times on the network as an uncertainty, as explained further below

This instantiation simulates the Baltimore-Washington region (Figure 1), where SILO has already been exercised in exploratory scenarios and AV modeling (Knaap et al., 2020). The Baltimore-Washington region is an older US region with two downtowns and several major suburban job centers. Many central areas and inner suburbs possess limited capacity to absorb new development under current land use regulations, something that SILO accounts for. In order to track regional growth, all counties are either assigned as core, inner, outer, or beyond the region. Core jurisdictions are Baltimore and Washington, DC. Inner suburbs are those adjacent to the core jurisdictions and Howard County, which is well suburbanized at this point. Outer jurisdictions include the remaining jurisdictions within the two metropolitan planning organizations. Beyond the region is largely rural but does include smaller populations centers in Wilmington, DE, York and Lancaster PA, and Ocean City, MD. SILO does not model beach home development in Maryland and Delmarva.

I selected uncertain parameters within the SILO model that best align with those uncertainties elevated in the literature on AVs and in previous modeling (Llorca et al., 2022; Soteropoulos et al., 2019; Sperling, 2018). My use of "uncertain parameters" reflects that what is now uncertain in the model are fixed or stochastic parameters, such as the value of access or distance to work constraints. It is also consistent with the previous literature (Groves & Lempert, 2007). Uncertainty parameters include the auto operating cost, increased infill capacity due to lower parking demand, travel times, and three parameters reflecting changing values of accessibility: value of access in location decisions, zonal accessibility score, and distance to work constraints (Table 2.1). The ranges were determined from estimates in the literature and previous AV modeling (Litman, 2018; Soteropoulos et al., 2019).

Because this experiment was not integrated with a travel demand model, all the parameters are within the SILO location choice module. My uncertain parameter in this case then selects from two zone to zone travel time scenarios rather than modeling the full impact of vehicle automation and household relocation on travel

times. In the first case, AVs use the road space as efficiently as human driven cars – I use the 2030 baseline zone to zone travel times from the MSTM. In the second case, AVs use the road space more efficiently – I maintain 2015 travel times throughout the simulation even as the population grows.

Table 2.1: Uncertain Parameters

Uncertain Parameter	***Impact of AVs***	***Baseline value***	***Sample range***
Auto operating cost	Increase with new technology; decrease with increased sharing	8.4 cents/mile	2.1 – 12.3 cents per mile
Infill capacity	Allows for redevelopment of existing parking	Set at zone level	0-50% increase in capacity for new units
Relative value of access in location choice	Decreases value of access due to in vehicle comfort	Set by income group	0-25% decrease
Distance to work constraint	Willing to move further from work due to in vehicle comfort	Travel times = $\Gamma(k = 2, \theta = 17.2)$	θ in [17.2, 34.4]
Zonal access to jobs beta – Hansen accessibility	Decrease overall value of proximity	3	β in [1.5,3]
Zone to zone travel times	Decrease with AV efficient use of network	2030 baseline travel times from MSTM	Binary: {2030 baseline travel times; 2015 travel times[2]}

Policy interventions include common approaches for encouraging concentrated land uses. Increasing *transit-oriented development capacity* is modeled via a 25% increase in capacity, measured in allowable new dwelling units, in zones with transit stations. Without integration with a travel model, I assume that increasing the *fuel tax* 1 cent/mile decreases travel times over the network and household travel time to work by .5%. The 1 cent per mile increase is effectively a 1.2% increase on the baseline auto-operating costs in the SILO model, which includes fuel cost and other mileage dependent costs. A review of several of the literature found long-run VMT demand elasticities with respect to fuel cost as high as -.4, including in a recent (Litman, 2022). One of the recent studies that finds an elasticity of -.4 uses a microeconomic models to determine the fuel use impacts of AVs (Taiebat et al., 2019).The FHWA reports a one-to-one relationship between VMT change and travel time changes nationwide (Brand, 2009). This would translate to an effective .48% reduction in travel times.

I examine each policy two: first starting at simulation year 0 and delaying each policy to start in year 6. In 'delayed' policy runs, I run SILO with the baseline settings for year 0-5. This sets the groundwork for adaptive policy approaches (Walker et al., 2013). I run 100 scenarios from the LHS, which is comparable with other scenario discovery experiments in terms of the density of the sample in the multi-dimensional space (Swartz & Zegras, 2013).[3]

[2] Estimated in previous modeling work; approximate for the purposes of this research

[3] See methodological appendix for additional details on the selected number of scenarios

Table 2.2: Policies modeled through each scenario

Policy	***What is it?***	***When is it implemented?***	***How it is implemented in SILO?***
Baseline	No additional policy action	NA	NA
Transit oriented development	Expanded residential development capacity at heavy rail, light rail, and commuter rail	2015 simulation year	50% increase in residential unit capacity in zones with heavy rail, light rail, and commuter rail
Delayed transit-oriented development (year 6)	Expanded residential development capacity at heavy rail, light rail, and commuter rail	2021 simulation year	50% increase in residential unit capacity in zones with heavy rail, light rail, and commuter rail
Gas price increase	Increase gas price by 1 cent per mile	2015 simulation year	.5% decrease in zone to zone travel times .5% decrease in travel times to work preferences
Delayed gas price increase (year 6)	Increase gas price by 1 cent per mile	2021 simulation year	.5% decrease in zone to zone travel times .5% decrease in travel times to work preferences

Finally, I utilize seven indicators to capture additional points of comparison between the LHS sample to more limited scenario approaches. For instance, the results for a single indicator might indicate that the full LHS and the more limited sample produce a similar measure of policy robustness. However, comparing the robustness between LHS and a more limited sample across several indicators will help to determine whether the robustness measures are consistently similar or different.

In providing multiple indicators for comparison, I also wanted them to reflect different modules within the SILO model as well as different priorities for urban development. Core area households, inner suburban households, and high transit access households measure relative regional concentration of households. High transit accessible households are those in zones that are 75th percentile or higher in access to employment via transit. This includes some zones that are not on rail, such as zones near the core with high frequency bus service, and excludes some zones with rail, such as outer suburban zones with infrequent commuter rail. Outer suburban households and households beyond the metro areas measure dispersion. Cost burdened households pay more than 35%[4] of their income in housing expenses (U.S. HUD, 2021) and median housing cost track housing affordability. These indicators are also directly produced by the real estate development module rather than the household relocation module. Finally, households that locate in modeling zones that are higher than 75% targeted ecological area[5] are a proxy for environmental impacts.

[4] I use a higher figure than the US government because SILO bundles energy costs into the total price

[5] Targeted ecological areas are watersheds in the top decile for protection, as designated by the Maryland Department of the Environment.

Table 2.3: Indicators for comparing policy outcomes

Indicator	*Description*	*Purpose*	*Desired direction*
Core households	Number of households locating in Baltimore and Washington, DC	Measure relative regional concentration	Higher
Inner Suburban	Number of households locating in inner suburban jurisdiction	Measure relative regional concentration	Higher
Outer Suburban	Number of households locating in outer suburban jurisdiction	Measure relative regional dispersion	Lower
Beyond Region	Number of households locating in beyond the two regions as defined by MPO boundaries	Measure relative regional dispersion	Lower
High transit accessibility	Number of households located in zones that are 75th percental or higher in access to employment	Measure growth in areas with high regional access via transit	Higher
Households in > 75% tea	Number of households that are located in zones that > 75% targeted ecological areas by land area	Measure environmental impacts of development patterns	Lower
Median housing prices ($)	Median housing price within region	Measure regional housing cost impacts	Lower

In order to determine the information value of scenario discovery, I consider the sensitivity, the percentage of futures in the box which fail, and the precision, the percentage of all failing scenarios captured in the PRIM boxes. Additionally, I examine the results of the 100 futures against two scenario sets that approximate exploratory scenarios. The first case is the convex hull of the LHS sample (9 scenarios) and the second case selects the eight extreme points from three uncertainty dimensions (8 scenarios). To limit the dimensionality, I eliminated the per mile cost of auto mobility parameter and set the three accessibility parameters to vary together, i.e. they are together set to either their highest or lowest values. Both of these sampling techniques examine only futures on the outer edge of the sampling space, designed to resemble exploratory scenarios that focus on the edge of plausibility.

Results

Baseline Automated Vehicle Futures

I begin with an examination of the 100 baseline futures. For every indicator, AV scenarios scored both above and below the default, no-AV scenario (Table 2.2). On average, more households located in the core (+1.4%), more households could access transit (1.3%), and fewer households were cost burdened (-3.3%). More importantly, all the outputs differ considerably from scenario to scenario. They vary as much as 10.3% (outer suburban households) and as little as 5.7% (households in TEAs). This reiterates the importance of considering multiple scenarios. Though deep uncertainties cannot be validated against data, the range of simulations included growth outcomes similar to other modeling efforts (Soteropoulos et al., 2019). For instance, past modeling has found that core residential growth ranged from +.7% to -5.7% relative to the baseline. The same experiments found that residential growth outside the core increased between 1-5.7% (Gelauff et al., 2017; Thakur et al., 2016; Wellik & Kockelman, 2020). Our baseline futures also included outcomes beyond the previous finding, such as core household growth increasing by 6.1%. This is in part explained by the volume of futures examined in this experiment. Whereas the cited papers each examine less than ten scenarios each, this experiment includes 100 baseline scenarios. We should expect some results beyond the bounds of previous experiments. Additionally, the Baltimore-Washington application case is a different context from previous experiments.

Table 2.4: Baseline Automated Vehicles Futures

Indicator	***No AV***	***Scenario Range (Relative to No-AV)***	***Mean (Relative to No-AV)***	***Standard Deviation***
Core households (thousands)	833.09	(810.9 , 884.0) -2.7%, 6.1%	844.9 1.4%	20.0
Inner Suburban (thousands)	2,378.2	(2,324.9 , 2,440.0) -2.2%, 2.6%	2,387.2 0.1%	28.0
Outer Suburban (thousands)	603.8	(571.8 , 631.0) -5.3%, 4.5%	602.3 -0.2%	16.1
Beyond Region (thousands)	1,895.4	(1,828.0 , 1,928.6) -3.6%, 1.8%	1,878.4 -0.9%	29.1
High transit accessibility households (thousands)	294.7	(285.9 , 315.1) -3.0, 6.9%	298.6 1.3%	7.6
Households in > 75% tea (thousands)	358.1	(347.7 , 367.7) -.3%, 2.7%	357.9 -0.0%	4.7
Median housing prices ($)	709	(669 , 726) -5.7%, 2.4%	708.8 0.0%	11.8

Robustness of Policies in Automated Futures

From the policy perspective, transit-oriented development is highly robust across the majority of indicators, with robustness greater than .9 for five of the indicators. It is never the worst performing policy. Delaying transit-oriented development, however, increases regret on nearly all indicators. Though increasing the price of gasoline is the most robust with respect to core growth, it performs middling or poorly on all the other indicators. The low robustness with respect to inner household growth can partly be explained by the better performance within the core – the two regions often compete for residents. But, the lack of additional growth capacity also deflects a significant portion of growth to the outer suburban tier and beyond the region. Interestingly, the no-policy baseline often performed better than interventions for several of the indicators. Similarly, all policies that perform well on encouraging inner suburban growth perform poorly in encouraging core growth (Table 2.3).

Housing unit prices are the best measure of equity within this experiment. All else equal, lower housing prices throughout the region will reduce the relative cost of housing most substantially for lower income households. Transit oriented development performs particularly well in lowering housing costs. Many areas near transit are among the most well developed in the region and close to buildout capacity. They are also often in popular core and inner jurisdictions. Opening up capacity near these transit stations is valuable for creating more units and relieving prices where demand is high in almost all scenarios. This is further affirmed in the baseline runs – the infill capacity variable was by far the most important in lowering housing costs.

Table 2.5: Latin hyper-sample robustness scores

	Core Households	Inner households	Outer Households	Beyond Households	TEA Households	High Access Households	Median Unit Price
Base	.35	.24	.03	.11	.49	.81	.52
TOD	.50	.01	.03	.06	.56	.55	.06
Delay TOD	.63	.18	.31	.39	.15	.04	.32
Gas Price	.02	.95	.86	.71	.63	.58	.49
Delay Gas Price	.50	.62	.77	.73	.17	.02	.55

Table includes the robustness for each policy/indicator combination. Color coding is used to indicate policies that perform particularly well or poorly. Green: <.1; light green: <= .25, pink >= .75, orange > .9

Conditions for Policy Success

The conditions for policy success are determined by the PRIM algorithm, which generates multidimensional boxes designed to capture high concentrations of failed policy futures. Not all PRIM boxes performed equally well in identifying the conditions under which a policy performs well. Eight of the twenty-eight policy/indicator PRIM boxes met my criteria for performance: performed above the median for sensitivity (>.615) and precision (>.347), a robustness score between .05 and .95 (Figure 2.3). Table 2.4 below presents the limiting dimension for each of eight selected PRIM boxes[6] (red points in Figure 2.3). These are the dimensions that are relevant for determining when a policy succeeds or fails. For instance, the baseline policies perform worse in promoting core households when distances to work are shorter, value of access is higher, and travel times are briefer. Color highlights on the limiting dimensions indicate whether high regret areas resemble default value (green), more radical changes (red), or are ambiguously in between (yellow).

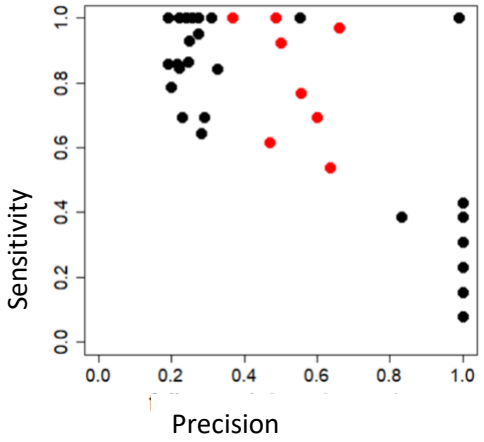

Figure 2.2: Sensitivity and precision of PRIM boxes. Red points selected for further analysis

Table 2.6: Latin hyper-sample robustness contingent policy dimensions. Color highlights on the limiting dimensions indicate whether high regret areas resemble default value (green), more radical changes (red), or are ambiguously in between (yellow).

Policy	Indicator	Limiting Dimension	Low limit	High Limit
Base	Core households	Distance to work	NA	.45
		Value of access	.28	NA
		Travel times	NA	.75
Base	Inner households	Infill capacity	.18	.71
		Distance to work	.08	.49
		Travel times	.24	NA
Base	Beyond households	Infill capacity	.35	.92
		Value of access	.21	.80
TOD	Core households	Distance to work	NA	.65
		Value of access	.26	NA
Delay TOD	Inner households	Infill capacity	.18	.78
		Distance to work	.07	.47
Delay TOD	TEA development	Infill capacity	.20	.90
		Zonal access to jobs beta	.44	.97
		Travel times	.06	.73
Gas Prices	Housing unit prices	Infill capacity	.21	.95
		Distance to work	NA	.75
		Value of access	.38	.94
		Travel times	.25	NA
Delay Gas Prices	TEA development	Infill capacity	.25	.77
		Value of access	.13	.74

The first thing that stands out is that there are often clear conditions under which the baseline policy is regretful. When distance to work preferences and value of access preference are similar to the default values, the baseline does poorly in promoting core households. In such circumstances, higher gas prices are better at

[6] The PRIM procedure sometimes determines boxes whose limits extend beyond allowable parameter values – less than zero or greater than one. For interpretation these values are no different from the true limit value.

promoting core growth. While higher gas prices still encourage core growth when people are willing to live further from work and other daily activities, they are less effective relative to the baseline. When households are willing to live further out because AVs have reduced the value of proximity, higher gas prices encourage households to locate in more central locations in the inner suburbs, rather than locating in the core.

Similarly, when infill capacity, distance to work, and travel times are close to the defaults, the baseline scenario often fails to promote inner suburban growth relative to TOD policies. Conversely, this means the no policy alternative is less regretful when AVs are most impactful: opening up parking lots to redevelopment, encouraging people to live further from work, and reducing travel times. In this case, the power of TOD to outperform the baseline is limited when AVs already open up significant capacity everywhere. However, this same infill capacity causes regret in baseline policies when attempting to discourage movement beyond the region. It seems that there is still some additional regional demand that TOD can soak up.

As seen in the previous table on robustness, TOD does not always perform well on encouraging core growth because it opens up so much capacity in attractive inner suburbs. This tends to happen with values closer to the baseline parameter values: stronger preferences for work proximity and general access. In such cases both the baseline and gas price scenario perform better. If AVs loosen these preferences, fewer households choose the core in the baseline and gas price policy scenarios, generally weakening the relative power of these policies encouraging core growth relative to TOD. A similar pattern is noted for delayed TOD failing to encourage inner suburban growth. When infill capacity is increased from AVs, the delay in implementing TOD is less costly because those communities can already absorb the increased demand.

Distance to work, the value of accessibility, and travel times determined regions of high regret in four or more of the selected policies. The results indicate that if AVs encourage longer commutes, our existing policies for encouraging core and inner suburban development are blunted. Across the indicators, AVs often reduce the difference between the best performing and the worst performing policies. An exception is the uncertainty regarding the infill capacity that AVs will open up. As central areas of the DC region are quite attractive, any additional capacity can aid in holding down housing prices.

In terms of housing prices, the chosen equity indicator, gas prices are identified as a contingent policy. In general gas prices are a regretful policy whenever the draw to live in the center is already strongest. As gas prices encourage core living, the increased demand for limited core housing units can exacerbate housing costs. This is true when AV impacts are closer to baseline: lower distance to work, higher value of access, and lower travel times. Additionally, when AVs open up significant development capacity, higher gas prices actually steer households away from the inner suburbs where much of that capacity is available.

Measuring the Relative Effectiveness of Scenario Discovery

Table 2.5 provides the failure rate for the full LHS sample, the convex hull, and the exploratory scenarios. This is the proportion of all scenarios in which the policy produced a failed outcome. Color coding is used to indicate policies that perform particularly well or poorly (Green: <.1; light green: <= .25, pink >= .75, orange > .9). For instance, increased gas prices are a robust policy in all samples for promoting core household growth, failing only 2% of the time in the LHS sample, 11% of the time in the convex hull sample, and 0% of the time in the extreme points sample. On the other hand, the failure rates for increasing gas prices with respect to median unit price differ substantially between the three sampling approaches. With the LHS sample, the gas price increase fails 49% of the time; with the convex hull sample, the gas price increase fails 22% of the time; and with the extreme points sample, the gas price policy fails 75% of the time. This suggests that the sample does matter for measuring robustness and that the LHS sample might be preferable in some circumstances.

Table 2.7: Failure rates for all scenarios

Latin hyper-sample	Core Households	Inner households	Outer Households	Beyond Households	TEA Households	High Access Households	Median Unit Price
Base	.35	.24	.03	.11	.49	.81	.52
TOD	.50	.01	.03	.06	.56	.55	.06
Delay TOD	.63	.18	.31	.39	.15	.04	.32
Gas Price	.02	.95	.86	.71	.63	.58	.49
Delay Gas Price	.50	.62	.77	.73	.17	.02	.55

Convex Hull	Core Households	Inner households	Outer Households	Beyond Households	TEA Households	High Access Households	Median Unit Price
Base	.22	.11	.00	.00	.56	.78	.56
TOD	.44	.00	.00	.00	.44	.56	.22
Delay TOD	.67	.22	.33	.44	.11	.00	.56
Gas Price	.11	1.00	1.00	.78	.89	.67	.22
Delay Gas Price	.56	.67	.67	.78	.00	.00	.44

Extreme Points	Core Households	Inner households	Outer Households	Beyond Households	TEA Households	High Access Households	Median Unit Price
Base	.50	.50	.25	.50	.625	.75	.375
TOD	.75	.25	.25	.375	.625	.75	.00
Delay TOD	.50	.00	.25	.375	.25	.375	.375
Gas Price	.00	.50	.50	.25	.375	.125	.75
Delay Gas Price	.25	.625	.75	.50	.125	.00	.50

Table includes the robustness for each policy/indicator combination. Color coding is used to indicate policies that perform particularly well or poorly. Green: <.1; light green: <= .25, pink >= .75, orange > .9

To understand how the alternative approaches compared to scenario discovery, I calculated the binomial p-value comparing the robustness scores for each scenario/policy pair. In this way, I sought to determine whether the robustness scores from the convex hull and the extreme points sample differed significantly from the robustness scores for the LHS sample. If the alternative samples produced similar results, on average, we should expect that the p-values should resemble those from 28 random subsamples – roughly evenly distributed between 0-1.

I present the CDF of the p-values for each in Figure 2.4 Assuming that the LHS sampled scenarios provide an accurate picture of the uncertainty space, these p-values indicated the probability with which the alternative samplings would provide inaccurate estimates of robustness. The convex hull sampling performed relatively well, with all p-values higher than .2 and more than half greater than .8. While it is not a surprise that a subsample should resemble the overall sample; the performance of the convex hull is generally better than we should expect from even a true random sample of the LHS scenarios – all the p-values are greater than .2, whereas with a random sample we would expect roughly 5 robustness scores less than .2. This might result from a sampling approach that will not incidentally overdraw from one region of the uncertainty space. We can then conclude that the convex hull provides a relatively accurate, albeit imprecise measure of robustness. Of course, all scenarios included were also in the LHS sample. Exploratory scenarios, however, can provide very misleading impressions of robustness. Several scenario/policy pairs have p-values less than .05.

Of course, scenario discovery methods are also used to clarify the conditions under which a policy is likely to succeed. Both the convex hull and the extreme values samplings clearly cannot do this because they do not provide enough information about the center of the distributional range. Of course, even with the 100 LHS scenarios, not all PRIM boxes generated clearly identified parameters influencing the success of a policy. More than half the PRIM boxes captured over 80% of the failure futures, but often at the expense of including many successful futures. The majority of boxes were more than half successes. In accordance with the criteria listed above, one quarter of the boxes produced clear policy suggestions. In practice, thresholds for precision and sensitivity should be determined by the risk tolerance of decision makers.

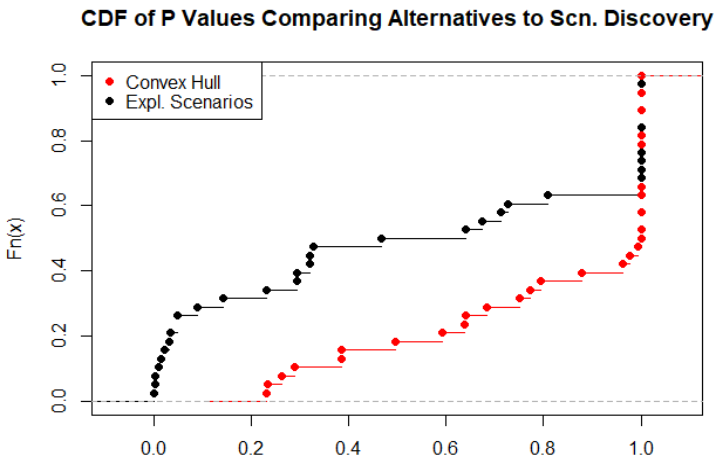

Figure 2.3: CDF of p values for sampling alternatives

Modeling Resources

On average, a single SILO run took 134 minutes to simulate fifteen years on a twenty core Windows server with dynamic memory up to 128G. Each processor was an Intel(R) Xeon(R) CPU E5-2667 v2 @ 3.30GHz. That means that the complete scenarios discovery run time was just over 1,133 hours of computer run time – more than 47 days. Any time stopping, starting, pre-processing, and post-processing was trivial compared to the total run time. The model area is large by North American standards. SILO micro-simulates over 8,000,000 people and 5,000,000 households. Nonetheless, such a similar experiment would still require days of runtime in a smaller region. The 500 runs require more than ten times the computer hours than the 45 convex hull runs or 40 extreme points runs. This will remain true, even if modelers can reduce run times.

Nonetheless, if run times are sufficiently reduced, the magnitude difference between the run time for scenario discovery run times and the run time for other approaches will no longer be an inhibiting factor. Several approaches could have sped the overall time used. First, I could have reduced the number of uncertain parameters and policies. The latter would have had more of an influence. In order to maintain the same density of scenarios in multidimensional space, the number of runs needs to increase exponentially with the number of uncertain parameters (see methodological appendix). With only three uncertain parameters, I would have explored the same density of the space with just 10 scenarios. Reducing the number of policies would also reduce the total run time, but only linearly.

The second approach would be to reduce the scope of the experiment temporally or geographically. If I ran SILO for fewer years, I might have been able to determine clear impacts with far less model time. Similarly, the SILO version for Baltimore-Washington contains significant population centers beyond the region, as explained in the methods. By cutting out areas east of the Chesapeake Bay and western areas of the model region, I could have reduced the micro-simulated population by over 1,000,000 people. Simulations in smaller regions would have significantly smaller run times.

The final approach to reducing the run time is to use faster servers. Of course, model complexity has tended to increase with computing power, so the modelers may want to maintain less complex models for exploratory approaches like this one. This is also in line with established practice in exploratory modeling – most authors recommend faster running, simpler models in order to increase exploration.

Conclusions

This research reinforces the need for urban modelers to increase the scenario count they use to explore the parameter space. The results of this analysis suggest that robust decision-making analysis using scenario discovery is a useful design for sorting through a high number of scenarios. My results indicate that full scenario discovery offers value over more limited explorations of uncertainty space in identifying contingent policies. Selecting limited scenarios at the edges of possibility can often overlook vast regions of robustness. Planners ought to be aware of extreme scenarios that break largely robust systems; however, they should also understand when the scenarios are rare outliers. Exploratory scenario exercises that incorporate modeling could easily give such false impressions. Additionally, utilizing large enough LHS samples also supports the deployment of PRIM to determine potential thresholds between policy options.

If the modelers cannot dedicate computational resources towards simulating an LHS sample, they should consider simulating the convex hull. In this experiment, the run time for the scenario discovery runs was greater than an order of magnitude longer than the convex hull. Nonetheless, the convex hull sample performed comparably in identifying the robustness of policies. Modelers may also wish to restrict the number of uncertain parameters, as they would be able to explore a similar density of scenarios in the multi-dimensional space with far fewer model runs. Exploratory scenarios may initially be easier to experiment with in smaller regions with fewer agents to micro-simulate. Those smaller regions can provide a testing ground while computational power increases sufficiently to run land use models like SILO in far less time.

Exploratory modelers might suggest a simpler modeling system in order to increase run times (Bankes, 1993). While there may be use cases for more aggregate modeling, the choice to use simpler models will depend on which indicators modelers choose to investigate. In particular, microsimulation models are better for estimating the distributional of outcomes between different populations, and thus more useful for studies of equity (Dawkins & Moeckel, 2016). Combining scenario discovery with microsimulation could provide a helpful tool in determining robust policies for regional equity.

The decision to use scenario discovery in urban planning depends on the goals of the planning process. If the primary goal of the planning is to inform key stakeholders about important uncertainties and consider how those uncertainties could play out, exploratory scenarios may still be the preferred approach. If the objective of planning is to determine robust and continent policies to include in long range planning, scenario discovery has already exceeded the performance of many exploratory scenario exercises. For agencies that have the resources to conduct a rich stakeholder driven process and execute several hundred simulations, there is great potential in combining the two approaches.

In considering the land use impacts of AVs, this experiment confirms some concerns regarding the influence of AVs on household location choices decisions. Should autonomous vehicles devalue accessible locations, households will move further out than they otherwise would. More surprisingly, however, if autonomous vehicles free up urban space dedicated to auxiliary vehicle uses, such as parking, it won't always counteract core household dispersion. Rather, inner suburban communities possess a far vaster supply of easily redeveloped land and, in the Baltimore-Washington Region, these communities are often among the most desirable places to live. On the other hand, when additional room is not provided in the inner suburbs, the core often benefits from households that prefer urban living with AV enhanced access the ring of suburban job centers.

In increasing the distance households are willing to locate from work, AVs may dull the effectiveness of smart growth policies. The highest regret scenarios, for both baseline and TOD, are associated with travel distances to work and accessibility preferences similar to current levels. The relative advantage of opening up

new room for development closer to the core is diminished by de facto opening of land on the fringe. On the other hand, if AVs do not allow for the redevelopment of parking, early TOD is essential in ensuring that land near transit stops is not underutilized.

This experiment also highlighted an understudied dimension of TOD policies that AVs are only bound to exacerbate. Not all TOD sites are created equally. Though TOD always performed well in preventing additional development on the margins of the study area, the development did not correspond to living in high accessibility areas. The Baltimore-Washington heavy rail and commuter rail network is suburban oriented relative to older North American systems and context-insensitive TOD will likely open up significant development in locations that, in spite of their train stop, are not provide high regional transit accessibility. A resident in the non-rail Brightwood Park neighborhood in Washington is much more likely to drive less and live in a less energy intensive home than a household living on the Reston Metro stop in suburban Virginia.

According to the modeling and analysis presented above, the potential for AVs to revolutionize where people are willing to live will not necessarily exacerbate sprawl and associated environmental impacts. Both increasing willingness to travel and redevelopment of parking areas will serve to decrease housing prices at a regional scale. Prices, however, may increase even more quickly in high amenity areas that are suddenly easily accessible to even more jobs than before. Quality of place will become even more critical than before as households are increasingly free to live wherever they choose. The most important amenities will be those that people cannot easily travel to access, such as school districts of community safety.

This has important implications for planning policy. Though efforts to guide development, such TOD, may be less effective overall, they will be all the more powerful in already desirable locations, such as the Baltimore-Washington inner suburbs. For some households, the most desirable place will be a house far away in the woods, but for many, the immediate appeals of specific neighborhoods, such as highly rated schools and low crime, will prevail if the prices are not too high. Though not included in this version of SILO, other quality of life factors may be crucial for location choice in some contexts. Though this experiment examined TOD policy specifically, AVs could provide the possibility for exciting, dense, walkable redevelopment anywhere with their ability to drop off passengers and depart to unseen locations.

This experiment also found that AVs could have potential equity implications with respect to the cost of housing. Most clear, anything that opens up new development capacity supports more generally affordable housing. This is true for both AVs allowing for the redevelopment of parking lots and conventional TOD policies. This research, however, also found that increasing gas prices could increase housing costs in an AV future. In encouraging core growth, they also encourage growth in the most capacity constrained areas on the region. Gas prices are not a regretful policy when AVs have decreased the value of proximity and shortened travel times. But this is only because the gas price policy is no longer successful in centralizing growth.

This experiment has several limitations that also open up pathways for future research. First, SILO only simulates residential location choices. Future employment is taken exogenously. While previous experiments with SILO in the Baltimore-Washington region have assumed different distributions (Knaap et al., 2020), I chose not to do that in this experiment. Directly simulating commercial and retail decisions would provide a much more complete sense of potential AV impacts. Historically, businesses responded to widespread car ownership by choosing more decentralized locations, which further encouraged the dispersion of households. The potential for such dynamics should be tested with a fully integrated LUTI model.

A second limitation is the lack of full integration with a transportation model. In this experiment, I took travel times as an uncertain parameter, rather than simulating them in response to land use changes. Though the overall pattern of households in the model was similar enough from run to run, it is unlikely to significantly change travel patterns, household agents were nonetheless unable to respond to travel time changes dynamically. Because I did not run a travel demand model, I was also unable to gauge the impact that

the full integration would have on run times, but prior experience indicates that it would have surely inflated the already long run times.

Finally, this experiment remains a largely technical exercise in scenario discovery. I compare the results of a scenario discovery experiment to more limited approaches, but this work has not yet been translated to decision makers such as MPO board members selecting from various investment profiles. While the language of robust and contingent policies has already entered the discourse via exploratory scenarios, I cannot conclude whether these model results can be usefully applied. There are two potential challenges in that regard. First, the results of scenario discovery might be too technical for translation. Second, regional decision makers might not possess the policy agility to apply adaptive policies, particularly when those policies, such as regional TOD, would require multi-party collaboration. Determining the value of exploratory scenarios to regional modeling and planning practice will thus require research that directly engages decision makers.

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Methodological Appendix

How PRIM Works and Interpreting PRIM Results

Each uncertainty parameterization is referred to as a *scenario* though they don't resemble the fully fleshed out stories of exploratory scenarios. Each scenario is run through the modeling suite without policy and with each policy intervention (Gross, 2018). For each completed run, or *future*, I will calculate four indicators: the median household zonal density, delta index of concentration, median housing prices, and median housing prices for the lower quartile. The indicators of each future are translated into *regret*, the difference between the highest performing future for each scenario and the performance of the selected future. Regret allows for comparison across futures in unlike scenarios.

With regret values calculated, scenario discovery utilizes data mining to explore the broader uncertainty space for regions in which a policy performs particularly well or poorly. I will employ patient rule induction method (PRIM), an algorithm that searches for lower dimensional boxes of concentration within higher dimensional space (Friedman & Fisher, 1998). Lempert et al promote this method for scenario discovery because it provides easier interpretations of results than comparable methodologies (R. J. Lempert & Groves, 2010). In order to operationalize PRIM, I convert regret into binary values of success and failure utilizing a semi-arbitrary threshold – such as all policy scenarios with regret above the median (Bryant & Lempert, 2010; Gross, 2018). Binary values allow for calculating the density of failure within a subspace. The PRIM algorithm sorts through each dimension of uncertainty, slicing it into two parts that exhibit the highest difference in failure densities. The lower density region is discarded and the algorithm moves onto the next dimension of uncertainty until all have been examined. The remaining subspace is declared a region of high regret and can be interpreted as futures that generally produce undesirable results. PRIM then iterates over the remaining space to determine secondary regions of concern. The process can similarly be used to determine regions of relative success. A key limitation of utilizing PRIM is that results are highly sensitive to the order in which the dimensions are analyzed. This research will then exercise the PRIM algorithm in all orderings to determine the consistency of results.

PRIM is designed such that whether a point is within or outside of the box in one dimension is independent of all other dimensions. Essentially this is a high dimensional rectangular box. The results for any dimension of the PRIM box can thus be interpreted directly in terms of which side of the threshold points fall on. For instance, when measuring the core households indicator in the baseline scenario, the PRIM box for distance to work is -.09 to .45. This indicates that failures are concentrated for distance to work LHS values below .45. While one could interpret this as a hard threshold, visual examination of the PRIM boxes in each dimension gives the indication that the boxes usually indicate tendencies. Thus, I prefer to interpret the PRIM box range as indicating that lower values of distance to work are associated with greater regret from choosing the baseline policy.

Density of Scenarios

Given this investigative framework, how many scenarios is sufficient? This is of particular concern given the runtime limitations of the SILO model and other models researchers and agencies would use for similar exercises. While there is no way to develop an absolute target, Swartz and Zegras (2013) developed a measure of the density of an LHS sample:

$$J = n_s^{1/k},$$

where n_s is the number of runs performed in any sample and k is the dimensions of uncertainty explored. Previous research has ranged in density from figures near 1.1 to 3.16. As such, I have selected to generate 100 scenarios, which corresponds with a density of 2.15, which compares favorably to the other experiments. For instance, Augusdinata and Dittmar (2009) generated 75,000 scenarios – however in 18 dimensions, their scenario density was 1.87 in spite of the far larger number of runs.

3. The Pernicious Effects of Uncertainty on Municipal Climate Action

Daniel L. Engelberg, Anne Hudson, Yonah Freemark, Joanna Moody, Jinhua Zhao

Abstract

Although there has been considerable research on how individuals make decisions under uncertainty, little of it has examined how elected officials, specifically, make policy. Seeking to fill that gap, this research investigates the extent to which uncertainty impacts climate action in large US cities. We set a survey to mayors and local legislators all US cities with populations greater than 100,000, querying their level of uncertainty related to the impacts of climate change and their support for a range of local climate policies. As part of the survey, we introduced a randomized loss/gain framing to investigate how uncertainty interacts with how climate change impacts are presented. To analyze the results, we use a structural equation model to develop a robust and novel measure of climate uncertainty and then examine the direct and indirect effects of climate uncertainty on a policymakers' propensity to support climate action. From 245 completed responses, we find that municipal elected officials are generally highly supportive of climate action. However, climate uncertainty has a significant effect in diminishing support for climate action among municipal officials. The findings indicate (1) that disinformation emphasizing 'skepticism' may directly affect local elected officials even when controlling for partisanship; (2) advocates and advisors should emphasize robust actions that support climate goals no matter the uncertainty; and (3) more research should be dedicated to understanding how uncertainty impacts a variety of policy arenas, from vehicle automation to global pandemics.

Introduction: Climate Change Uncertainty and Policy Action

Climate policy making at the municipal level is a balancing act between the powers granted to local governments and vast uncertainties associated with enacting policy. Local governments generally control land use, street space, city parks, and local building codes and may have limited taxation powers – though the specific powers vary. To *mitigate* greenhouse gas emissions, cities can encourage denser land uses, design more sustainable transportation systems, set greener standards for new construction, reduce the carbon footprint of city-controlled assets, and encourage more sustainable behavior, among other potential changes. Collectively, cities in the United States can take the lead in substantially reducing climate emissions even as governments at other scales drag their feet (Bulkeley & Castán Broto, 2013). Yet local governments cannot save themselves from an already rapidly warming world. From that perspective, urban *adaptation* measures – such as environmental restoration, floodplain management, and infrastructure designed and well maintained to resist natural disasters – might be even more important for many communities.

Though municipalities possess considerable powers both to mitigate and adapt in the context of climate change within their own boundaries, climate change is a global phenomenon whose impacts cannot be completely understood or managed by any single locality. Policies determining the scope of impacts will largely be set at the state, national, and international levels. Municipal officials must navigate the existing landscape of climate mitigation policies and adaptation resources available at different levels of government and recognize that the climate systems they seek to guide are neither static nor predictable. Municipal elected officials must make climate policy in an uncertain environment because of the nature of the global climate system, the limits of predictive science, and the jurisdictional limitations of local government. Understanding how this uncertainty impacts policy decisions is essential to understanding how to accelerate climate action.

Climate change provides one of many salient examples of uncertainty in municipal policy making: the contemporary city official encounters numerous arenas in which they lack knowledge that would be helpful in action. The events of the past fifteen years – including the financial system collapse, the Covid-19 pandemic, the advent of new transportation technologies, social uprising – have spotlighted the level of uncertainty that cities must prepare for, not only to prevent devastating outcomes but also to provide new opportunities for their residents. Yet, we know little about how uncertainty impacts local decision making. The following paper investigates the degree to which uncertainty about a policy issue impacts municipal elected officials' willingness to act. This paper demonstrates, in the context of climate change, that uncertainty is a relevant factor in the decision process of local elected officials, suggesting that it should be further studied and accounted for across a range of policy arenas and contexts.

Literature Review

Making Municipal Climate Policy under Uncertainty

While guides for city-level both climate change mitigation (Santamouris & Kolokotsa, 2016) and adaptation exist (Lenzholzer et al., 2020), there remains uncertainty around the precise impacts of many interventions in unprecedented climatic conditions. Climate change as a policy space is particularly challenging because it means planning for a future clearly outside of what current data can specify (Kandlikar et al., 2005). While science can offer valuable insights, projections about the future are necessarily imprecise. The science, as exemplified by the IPCC report (IPCC Working Group I, 2021), often provides multiple plausible scenarios, each with their own error bounds and a note on consistent uncertainty language (Mastrandrea et al., 2010). These uncertainties are exacerbated when forecasters attempt to downscale global climate forces to the sub-national or even city level (Chu & Schenk, 2017; Coonery, 2012).

In spite of the climate uncertainty, municipal climate action remains essential. Though the powers wielded by individual municipal bodies is a small part of the larger action needed to address the full extent of the problem, the collective action of municipalities can make a substantial impact and go a long way in catalyzing action on a broader scale. Municipalities are often motivated independently of higher levels of government and test new institutional structures for climate action (Anguelovski & Carmin, 2011). They possess the tools to act on climate change (Bulkeley & Kern, 2006) and networks of cities can multiply their effect (Betsill & Bulkeley, 2006).

Prior studies have shown that local climate decision depend on larger economic, social, and institutional contexts. National level priorities matter, for example (Emelianoff, 2014); nonetheless, many cities are out ahead of the federal government (Watts, 2017). Human and fiscal capacity issues, meanwhile, are identified as one of the primary constraints (Dierwechter & Wessells, 2013; Krause, 2011, 2012; Oulahen et al., 2018; Shi et al., 2015). Though structural factors matter, the proactiveness of political leadership (Oulahen et al., 2018; Shi et al., 2015) and the acknowledgement that the climate change is already impacting communities (Shi et al., 2015) are critical determinants of climate action - reinforcing the importance of understanding whether uncertainty is a barrier to political commitments. The literature of municipal climate action leaves a gap in terms of the thinking of individual elected officials. Though the broader structural forces are critical, the literature reinforces the potential of strong political leadership. But political leaders encounter the immense uncertainty of selecting actual policies to support. We argue that it is important to understand whether and how much uncertainty is delaying potential climate action and look to the climate communication literature for potential pathways forward.

The climate communications literature has tackled how uncertainty impacts decision making. In the communication of scientific uncertainty, the public often misinterprets error bound and those interpretations

are susceptible to narratives and framing (Shanahan, 2017). Additionally, local elected officials and the public they represent are often ill-informed regarding the current best practices in climate adaptation (Lenzholzer et al., 2020). Groups and individuals that oppose climate action in the English-speaking world, particularly in the United States, have been given a more consistent platform than in other nations in the global north (Grundmann & Scott, 2014). Organizations funded by fossil fuel companies and allied interests have supported research, communications, and lobbying that play up rare scientific dissenters. Much of the opposition is framed as doubt or uncertainty as opposed to outright denial – how can we be sure that climate change is real when scientists disagree? (Oreskes & Conway, 2011). When these parties concede the existence of climate change, they often argue that uncertainty should invoke caution lest we hurt the economy with unnecessary regulation (Carvalho, 2007).

The traditional US media's emphasis on balance and the controversy have tended to play up climate sceptics (Boykoff & Boykoff, 2007). Of course, the past decades have seen a decline in 'unbiased' journalism and an associated rise in both partisan media and social media. These outlets tend to reinforce the perspectives, providing additional skeptical voices to audiences already inclined to believe them (Painter, 2016). Conservative outlets tend to portray uncertainty as action paralytic. Progressive media often attach catastrophic messaging and the precautionary principle, arguing for action that accounts for worst case possibilities (Carvalho, 2007).

Media framing and discourse only matters so far as it is effective in changing the opinions and behavior of their audience. Additional context about climate change encourages certainty; controversy discourages certainty (Corbett & Durfee, 2004). Less sensationalist, "both sides of the story" reporting increases perceptions of uncertainty (Boykoff & Boykoff, 2007; Kohl et al., 2016). Attempts to mitigate these effects through "weight of the evidence" or discrediting language have proven effective in some studies (Clarke et al., 2015; Kohl et al., 2016) but not in others (Kortenkamp & Basten, 2015).

Research, mostly in the form of survey experiments, indicates that uncertainty can diminish the prospect of action. Prospect theory indicates that individuals assess uncertainty gambles relative to their current position - risk averse with gains and risk seeking with losses (Kahneman & Tversky, 1979). More recently, research has indicated that uncertainty combined with a gain framing can be more effective for climate action. Loss frames might cause despair and action paralysis (Lazarus, 1999). Losses can motivate urgency of action but can easily overwhelm one's sense of efficacy (Morton et al., 2011; Nerlich et al., 2010). On the other hand, Gustafson and Rice (2019) find that uncertainty framings are insignificant for belief, credibility, or behavioral intention, except for the small negative effect of "consensus uncertainty". In fact, reading fully bounded uncertainty estimates may increase trust in science. However, acknowledging unquantifiable uncertainty eliminates these effects (Howe et al., 2019).

From a policy perspective, there are three potential responses to uncertainty. The first is reversion to a reference narrative (Marris, 2003). In such a case, uncertainty should have no effect and policy makers adopt policies in line with their worldview and constituent preferences. The second possibility is the employment of the precautionary principle (Carvalho, 2007). In the context of climate change, the precautionary principal is often deployed to support immediate and drastic climate action, less the cost of inaction is the worst-case scenario. Finally, uncertainty can be paralytic (Carvalho, 2007). Policy makers may continually delay policy action until they are fully confident in its existence, impacts, and policy solutions. Such a case might be justified by reversing the precautionary principle - that climate action should not be pursued until we are sure it will not heedlessly destroy the economy.

An important gap is understanding how elected officials respond to climate uncertainty. At a base level, our elected officials possess the same human tendencies, predilection, and biases as the rest of us. However, our reactions to uncertainty are deeply context specific, including our personal dispositions and social positions

(van der Linden et al., 2016). There are several good reasons to believe that policy makers could respond to uncertainty framing differently from the general population. Most elected officials in large cities are higher information actors with government staff supporting their decision needs. While this only changes the authors of the communication, it could make the official less susceptible to the marginal addition of information from the media. Second, elected officials might be less concerned with scientific uncertainty and more concerned with ambiguity among their constituents and their fellow elected officials. An otherwise supportive official might oppose policy action if they are unsure where their supporters stand on the issue. Third, elected officials are self-selected based on the personality required to run for office and attract votes. Our research seeks to fill this gap in the communications and climate action literature by examining specifically how climate uncertainty is directly impacting the decisions of municipal elected officials.

Measuring Uncertainty

Much of the literature on climate communication is based on randomized, limited context, framing experiments with members of the general public. Uncertainty is introduced via the study design – such as presenting alternatively framed articles – rather than measured in the world (Clarke et al., 2015; Kahneman & Tversky, 1979; Kohl et al., 2016; Kortenkamp & Basten, 2015). This research design provides a clean, controlled signal but doesn't hint at how to measure uncertainty in non-laboratory settings.

Several studies have made efforts to measure uncertainty within the context of decisions. In political science polling, attitudinal questions may be followed by asking how certain the respondent is (Alvarez & Franklin, 1994). Alternatively, business surveys often request that respondents present a range of expected values. For instance they may be asked to give lower bound, most likely, and higher bound GDP growth estimates (Bachmann et al., 2018). Both of these approaches are helpful within their context but neither seeks to develop a measure of general uncertainty.

We take a different approach suited to measuring individual uncertainty regarding climate change policy. We define uncertainty as the perceived gap between the knowledge that we have and the knowledge we would prefer to have in making a decision (Dewey, 1929). We take this to refer to the intellectual state of an individual (Marris, 2003) – this contrasts with what we describe as the 'indeterminacy' of some social and natural processes. The two interact insofar as an individual cannot be fully certain about the outcome of an indeterminate process without holding a false belief.

One's sense of uncertainty is not unidimensional and any general measure should account for all its dimensions. In order to measure general climate action uncertainty, it is then necessary to capture all pertinent directions. We work from Kwakkel et al. (2010), which introduces three dimensions of uncertainty: location, level, and nature.

The location refers to where uncertainty enters our model of the system we would like to act within. Though this classification tends to emphasize location within a computation model (inputs, relationships, etc.), this concept can be easily transferred to the mental models of decision makers (Kwakkel et al., 2010). With respect to climate change, we choose to distinguish between uncertainty of climate change impacts and uncertainty of climate policy. The former includes both uncertainty with regard to the existence of climate change as well as the specific impacts that climate change will have on our communities. The latter refers to uncertainty regarding the efficacy or desirability of potential interventions.

The level of uncertainty refers to the scales used to describe the uncertainty. Level 1 (shallow) uncertainties are probabilistic. Level 2 (medium) uncertainties can be ordered in likelihood. Level 3 (deep) uncertainties can have their possibilities enumerated but relative likelihood cannot be judged. Finally, level 4 (recognized ignorance) uncertainty acknowledges that surprises happen.

The three natures are epistemic, ontic/variability, and ambiguity. Epistemic uncertainties can be known but are not yet available. This does not mean that decision makers will always attempt to know all that is knowable. They must decide how many resources to dedicate to resolving epistemic uncertainty. Ontic uncertainties are inherently probabilistic or deeply uncertain – relative probabilities cannot be assigned. This is the uncertainty that corresponds to indeterminate features of the natural and social world. Ambiguity refers to differences in frame and values. Frames are different ways in which participants understand and make meaning of the same phenomena (Kwakkel et al., 2010).

Breaking down uncertainty into its constituent elements is central to our measurement of uncertainty. Any robust measure of climate action uncertainty must look across all locations and natures. Otherwise, the measure might be missing key barriers to action. Querying the level is important for classifying specific uncertainties but it is less important for measuring the existence of uncertainty. A latent measurement of general climate action uncertainty can then take an individual's underlying level of uncertainty as a given.

As a latent variable, uncertainty cannot be measured directly. We thus utilize factor analysis and structural equation modeling, an approach that is able to shed light on unobservable variables via multiple observable indicators – the answers to survey questions in our case. In order to capture an individual's sense of uncertainty – nature and location – it's essential to include indicators that capture the unobserved in all its richness. This ensures that the measure is robust because the measure is less likely to be distorted by any particular dimension of uncertainty.

Research Questions

We seek to answer two research questions:

- Q1: How does uncertainty impact the likelihood of municipal elected officials to support policies for climate change mitigation or adaptation?

- Q2: How does uncertainty interact with gain or loss framing to impact the likelihood of municipal elected officials to support policies for climate change mitigation or adaptation?

We develop the following hypotheses:

- H1: General climate action uncertainty will diminish the likelihood that an elected official supports strong climate action.

- H2: General climate action uncertainty combined with loss framing will diminish the likelihood that an elected official supports strong climate action.

This study seeks to contribute to policy and planning literature in three ways. First, we look to understand how uncertainty impacts the likelihood of policy action. Our results indicate that uncertainty diminishes the likelihood that policy makers support climate action. We take climate change as a valuable first case, but further research should determine whether our results can be generalized to other areas of uncertainty. In the process we develop a robust measure of uncertainty that accounts for its multidimensionality. Second, we examine how uncertainty interacts with framing in the case of deeply uncertain, wicked problems. We find no evidence of framing effect. This may be the result of either firmly held positions or the very cursory framings we presented. Finally, to our knowledge, this is the first survey of municipal elected officials asking for their views on climate change, providing a valuable tool for better understanding policymakers' opinions on climate change policy.

Methods

Survey Methods

We investigate these research questions using a survey-based approach. This allows us to reach out to a large group of municipal officials and provides a consistent template for measuring uncertainty, modeling its impacts, and testing the framing of climate change policy.

First, we compiled an email list of elected mayors and local legislators (such as councilors, supervisors and alderpeople) for all non-county municipalities of 100,000 or more people in the United States, based on 2019 US Census data. Through interpolations for unavailable emails and calls to local legislative offices, our emails were successfully transmitted to all but 8 of the 2,754 elected officials in our population.

We collected data in three stages. First, we contacted 100 random officials in a "pilot" launch on Feb. 4th, 2021 to get an estimate of response rate and to test the survey. We followed up with non-respondents via phone. Next, we contacted the remaining 2,654 officials in two randomly assigned groups within the period Feb 22nd to April 22nd to account for any fluctuations related to global events. For each of the groups we sent three follow-up emails over the course of two weeks. We also randomly selected 100 non-respondents- from each of the two groups to call in order to boost the sample size. Our response rate was 8.9% across all three data collection stages (245 completed responses).

Non-response may have biased our sample in terms of the characteristics of communities represented. Our outreach email specifically mentioned climate policy. If one is suspicious of climate change and academic institutions, it is unlikely that they will choose to complete the survey. Those that are more enthusiastic about climate policy might believe that it's their civic duty to contribute to such research.

We validated individual elected official characteristics of our sample against those of mayors and local legislators more broadly in order to account for response bias. To do this we compare our respondents' race, gender and party membership against Einstein, Palmer, and Ornstein (2019) (Table 3.1), who sought to establish these characteristics from publicly available data.

One area of concern is under sampling of Black elected officials and oversampling of Hispanic/Latino/Latinx officials. As EPS-2019 used visual identification to select the race of individuals they may have classified some individuals as Black that would have chosen 'other' or 'Hispanic / Latino / Latinx' because of mixed race heritage. Still this probably does not explain the entire discrepancy. We similarly under sampled male respondents and oversampled Democrats. The latter is particularly important because Republicans are likely to be more skeptical of climate change and less likely to support climate action. Notably, this potentially means that we may have underestimated the effects that we are measuring as the Republican officials may be more susceptible to the uncertainty messaging frequently transmitted by conservative media.

Table 3.1: Elected Official

	EOP 2019	Our Sample	p-value
Gender			

Male	65.20%	56.54%	.008
Female	34.36%	43.04%	.007
Unknown/other	0.45%	0.42%	.947
Race			
Asian	3.02%	4.41%	.269
Black	21.93%	9.63%	.000
Indian	0.05%	0.80%	.185
Hispanic / Latino / Lantinx	11.34%	16.86%	.017
Middle Eastern	0.20%	0.82%	.286
White	62.77%	62.60%	.726
Unknown/other	0.69%	4.90%	.003
Hawaiian or Pacific Islander	N/A	0.40%	
Partisanship			
Democrat or Likely Democrat	53.17	65.40%	.000
Democrat	51.24%	65.40%	
Likely Democrat	1.93%		
Republican or Likely Republican	17.08%	11.39%	.006
Republican	16.39%	11.39%	

Likely Republican	0.69%		
Other	19.16%	5.06%	.000
Unknown/other	18.96%	5.06%	
Dem Socialist/Socialist	0.10%		
Green	0.05%		
Libertarian	0.05%		
Independent/unaffiliated	10.59%	18.14%	.000

We additionally validated by comparing the characteristics of the cities that they represent to the characteristics of all cities with greater than 100,000 people (Table 3.2). Most of the city level characteristics align well with the general population of cities. Several of the variables are statistically significant, yet the substantive differences are often small. Our sample was notably biased towards cities with larger populations.

Table 3.2: City Characteristics

	All qualifying places	In Sample	p-value
Population	296,487	431,240	.007
Population Density (per sq. mile)	4,275	4,268	.976
Car Commute Alone Share	0.76	0.73	.001
Single Family Housing Share	0.62	0.60	.017
Home Owner Share	0.54	0.52	.022
Median Home Value	301,491	306,834	.699
Democratic Share 2016	0.54	0.56	.067
County Water Stress Risk	3.97	4.01	.589
County Sea Level Rise Risk	1.89	1.84	.530
County Hurricane Risk	2.16	2.02	.131

Survey Design

The survey consisted of three distinct blocks. The first block collected policymakers' sense of urgency and uncertainty in addressing climate change as well as their estimates of its impacts on their communities. The second block included a randomized framing and then asked respondents for their likelihood to implement different climate-related policies. The order of the first two blocks of the survey was randomized to control for any potential ordering effects. The final block requested socio-demographic information and political dispositions. Finally, we asked the respondents if they were made aware of the survey before filling it out to account for any potential exposure bias.

Block 1: Uncertainty

The first block collected respondents' general perspective regarding the impacts of climate change on their communities, their feelings of urgency, the level of certainty associated with their answers to the

aforementioned questions, and their 'confidence' in other climate change-related knowledge. The uncertainty data was collected in two manners. The first approach was to request their level of confidence in prior responses about the impacts of climate change using a three-point Likert scale from 1 = "not confident" to 3 = "very confident".

The second approach was to ask them directly using a five-point Likert scale from 1 = "strongly disagree" to 5 = "strongly agree". These included questions related to the sufficiency of information for decision making and their confidence in their knowledge of the perspectives of other elected officials and constituents. Individual questions addressed epistemic, ontic, and epistemic uncertainty. Similarly, questions addressed both uncertainty regarding impacts and policies (Table 3.3). Responses to these statements were used to estimate a latent measure of ***climate action uncertainty*** (see Appendix).

Table 3.3: Survey Questions

Question Name	**Statement**	**Nature**	**Location**
Impacts uncertainty	You noted that you think climate change will have *[_from previous_]* impact on your city. How confident are you about your belief?	General	Impacts
Decision Uncertainty	I feel that I have enough information about the impacts of climate change to make a decision on local ordinances that would increase climate resilience in my city.	Epistemic	Impacts, policies
Information uncertainty	Our city needs more information about the impacts of climate change on our community before implementing new local ordinances that would increase climate resilience in my city.	Epistemic	Impacts, policies
Ontic Uncertainty	We should wait and see what the impacts of climate change are before implementing new ordinances for increasing climate resilience in my city.	Epistemic, Ontic	Impacts, policies
Ontic Uncertainty 2	We can never know the full impacts climate change will have on our city in advance.	Ontic	Impacts
Council Ambiguity	I am confident that I know which climate change policies other elected officials in my city support.	Ambiguity	Policies
Constituent Ambiguity	I am confident that I know which climate change policies my constituents support.	Ambiguity	Policies
Means Uncertainty	I am unsure of the best policies for adapting my city to climate change.	General	Policies
Urgency Uncertainty	You indicated that you believe that developing local ordinances for climate change is *[_from previous_]* urgent. Please indicate your level of confidence in this belief.	General	Policies

We also asked a series of questions regarding the elected official's perception of current and future impacts. The first question asked the official what impact climate change **has already had** in their community from 1 = "no impact" to 4 = "a devastating negative impact". The second question asked them what impact they expect climate change to have in the future with the same scale. Finally, we asked what they expect the impact

to be in their city relative to other cities in the United States from 1 = "much more mild" to 5 = "much worse".

Block 2: Framing and Policy Actions

The second block of the survey was designed to determine how a loss or gain framing may influence propensity for climate action. Respondents were randomly assigned either a neutral prompt, a loss framing focusing on the impacts of climate change, or a gain framing focusing on the positive impacts of early climate action. All the prompts began with, "We are seeking to understand the policies that you may be considering to increase climate resilience in your city." The gain and loss framing followed with alternate versions of the same sentence:

> Recent studies have demonstrated that ***[early action/waiting too long to take action]*** to prepare cities for climate change will have long-term ***[positive/negative]*** impacts on urban communities. ***[Acting now/Failing to act immediately]*** could ***[provide a substantial windfall/result in substantial losses]*** in terms of health, economy, environment, and quality of life.

Though the brevity may have reduced the effectiveness relative to longer narrative framing, even brief and fleeting frames can have behaviorally significant effects in everyday decision making (Kahneman, 2003).

The officials were then asked to indicate how likely they would be to support eight different climate mitigation and adaptation policy proposals:

1. "Fund street trees for all eligible city streets within 10 years" [adaptation 1 - street trees]
2. "Require critical systems (like air conditioners) in private development to be above flood levels" [adaptation 2 - critical systems]
3. "Charge land owners with impervious surfaces a fee and dedicate funds to environmental restoration" [adaptation 3 - impervious fee]
4. "Require climate impact assessment for all government supported infrastructure" [adaptation 4 - impact assessment]
5. "Commit to reducing citywide greenhouse gas emissions from private and public sources 90% by 2050" [mitigation 1 - ghg goals]
6. "Require all new public facilities to be carbon neutral" [mitigation 2 - public facilities]
7. "Reallocate at least 10% of city-owned street space to buses, bicycle, and pedestrian use" [mitigation 3 - non-auto space]
8. "Reduce city employee air travel by at least 50% from 2019 levels" [mitigation 4 - air travel]

We selected specific proposals for which there is a precedent yet workshopped the survey with experts in the field to ensure that they were ambitious enough to increase the variance in answers between respondents. We also selected policies that municipalities are likely to possess jurisdiction over, providing a disclaimer asking them to assume such. Finally, we selected policies that should be applicable in all cities, which meant excluding some significant policies such as measures to mitigate coastal flooding (which are not applicable for inland cities). It is important to note that we did not seek to provide a comprehensive list of climate policies since the primary purpose of this survey was not to understand the specific policy predilections of municipal officials. Rather, we presented ambitious policies from across a variety of policy domains (building codes, transportation, public facilities, etc.) in order to get a general sense of propensity to enact climate policy.

Modeling Approach

Structural equation modeling (SEM) possesses two key strengths relative to regression methods. First, SEM allows for the estimation of latent variables that cannot be directly observed in the data. Though regression models utilize implicitly latent variables in many cases, they often are included as simple averages of observable variables. In SEM the latent variables are instead estimated via the correlation structure of responses which inherently accounts for measurement error in the latent variable construct - something regressions do not do when they treat latent variables as observed. Additionally, SEM modeling allows for the estimation of causal pathways – instead of solely estimating a set of relationships between the independent variables and a single dependent variable. This allows the modeler to drop the assumption of independence and additionally provides estimates of both direct and indirect effects.

Latent Variables

We estimate three latent variables to include in our model. The latent variable for ***uncertainty*** is estimated using nine of the questions from the first block of the survey. We ensured that the full spectrum of uncertainty was covered. Using exploratory factors analysis, determined that uncertainty could not be broken up into multiple latent variables based on different dimensions of uncertainty. Rather, we found that a unidimensional measure of uncertainty that included correlated error terms for statements measuring the same nature of uncertainty best fit the observed data. In particular, error terms for the two statements measuring ambiguity were correlated (Figure 01).

The second latent variable that we estimated was ***perceived impacts***. This variable was measured using three questions addressing perception of existing impacts, expectation of future impacts, and expectation for impacts relative to other cities.

Finally, we estimated a latent variable measurement model for the ***propensity to pass climate policy***. This was derived from the eight policy propensity questions. Exploratory and confirmatory factor analysis indicated that we should not divide the variable into separate factors for adaptation and mitigation. Responses to the policy questions were provided a five-point Likert scale from 1 = "Very Unlikely" to 5 = "Very Likely" as well as the option to indicate if their city had already passed such a policy. We coded responses that the city had already passed such a policy as a 5. Though it is possible that some respondents may have diverged from the established policy of their city, it is likely that those that selected the 'already passed' option are strong supporters of the policies indicated. From responses across the eight policies, we estimated a latent variable for the ***propensity to pass climate policy***. Though some of the policies may be favored for reasons outside of climate action, together they are able to estimate an elected official's propensity to act on climate change.

All CFA models were estimated using the lavaan package in R (Rosseel, 2021) using the default maximum likelihood estimation. We treat the 5-point Likert-scale values as continuous rather than ordinal as a simplifying assumption shown to be valid for scales with more than 4 points.

The SEM

Our full SEM (Figure 1) provides two pathways for climate uncertainty to influence intention to pass climate policy. First, uncertainty can directly impact climate policy propensity **(A)** - as the framing literature has established the link between uncertainty in decision intentions (Morton et al., 2011). Second, uncertainty can act via a sense of urgency regarding climate action **(B → C)**. This is the pathway pushed by conservative commentators - they argue that uncertainty regarding climate change ought to temper our rush to action (Carvalho, 2007). Those that are more uncertain about the impacts of climate change should feel less urgency

to implement mitigation or adaptation. Feeling less urgency, they would be less likely to support action. Our model also includes a pathway for the perception of impacts to influence urgency as officials that perceive greater impacts would likely feel more urgency to act.

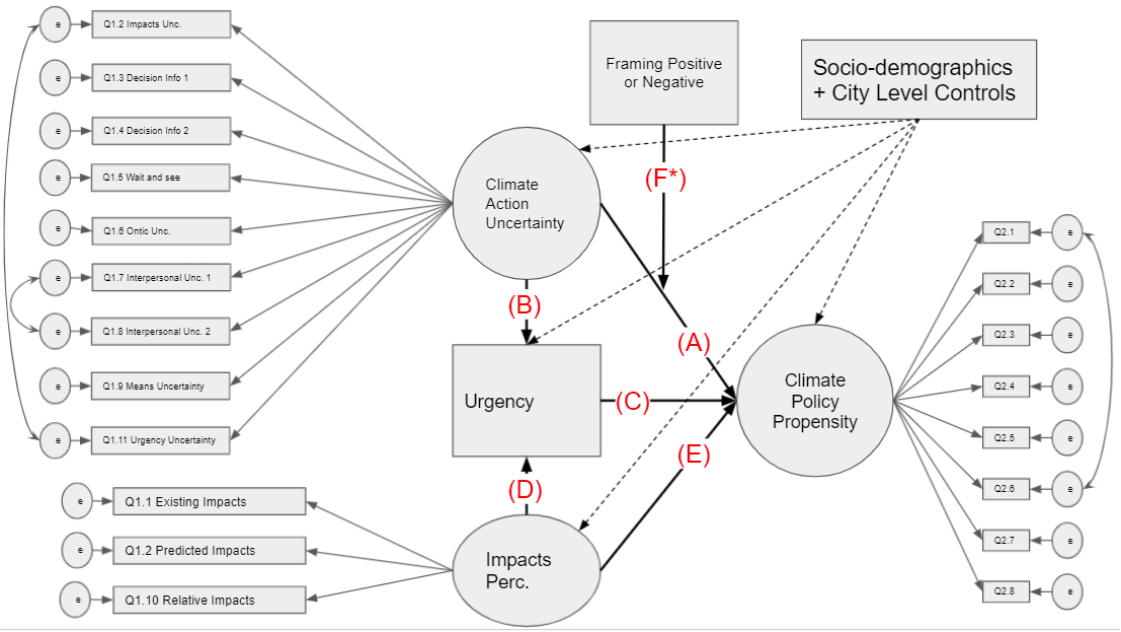

Figure 3.1: Structural equation model for impacts of uncertainty of climate policy propensity

In our model uncertainty **(A)**, perception of impacts **(E)**, and urgency **(C)** all directly affect the elected official's climate policy propensity. Additionally, we have included relevant individual level and municipal level covariates for all regressions. Individual variables measured directly through the survey include race, political party, political leanings, age, gender and education. Municipal level covariates include estimates of the log of population, log of population density, percent that commute by car alone, and home ownership share from the American Communities Survey 2015-19 five-year sample. We also include county level measures of water stress, sea level rise, and hurricane risk from the American Communities Project.

Finally, we attempted to investigate the influence of the neutral/loss/gain framing via two approaches **(F*)**. First, we introduced the framing as mediators. This is similar to an interaction term in simple linear regression. In SEM, this requires estimating two additional latent variables from the interaction of the uncertainty questions with the binary variables indicating the framing (Little et al., 2006). These framing/uncertainty latent variables are then included in the policy variable regression but not the urgency regression. Second, we attempted a multi-group analysis. This approach estimates separate models for each framing group, holding everything constant across groups except for the effect of uncertainty on the policy latent variable.

One key mediator that we did not include was a sense of efficacy - which is often indicated as a key factor influencing the intention of individuals to act on climate change (Nerlich et al., 2010). This was not included for two reasons. First, we wanted to keep the length of the survey down in order to maximize the response rate from already busy city councilors. Second, we selected policies that should be within the legislative possibility of all respondents – though there may be some exceptions depending on the enabling legislation provided by the state. Additionally, the feeling of efficacy may differ depending on the seniority or power

structures within individual municipalities. While we do not investigate this mediator in our own research, we encourage further research in this direction.

Results

Descriptive Results

What Policies Do Municipal Officials Support?

For almost every adaptation and mitigation policy, the majority of municipal officials indicated that they were likely or very likely to support that policy (Figure 3.2). For all but one of the policies, the plurality indicated that they had already passed or were very likely to support such a policy. This is an important finding on its own, showing that the appetite for climate action – and its co-benefits – is strong.

Though our policy list was not exhaustive, they included a range of program areas some of them represented considerable departures from the status quo. Among the adaptation policies, officials indicated that they were most likely to support funding street trees and require climate impact assessments. The former has many positive impacts beyond climate adaptation – such as reducing heat island effects and increasing resident wellbeing. The availability of co-benefits short circuits the longer feedback cycle of climate action (Bain et al., 2016). The least supported policy was charging land owners impervious surface fees. Elected officials might prefer approaches that are less directly costly to the broad middle-class homeowner community.

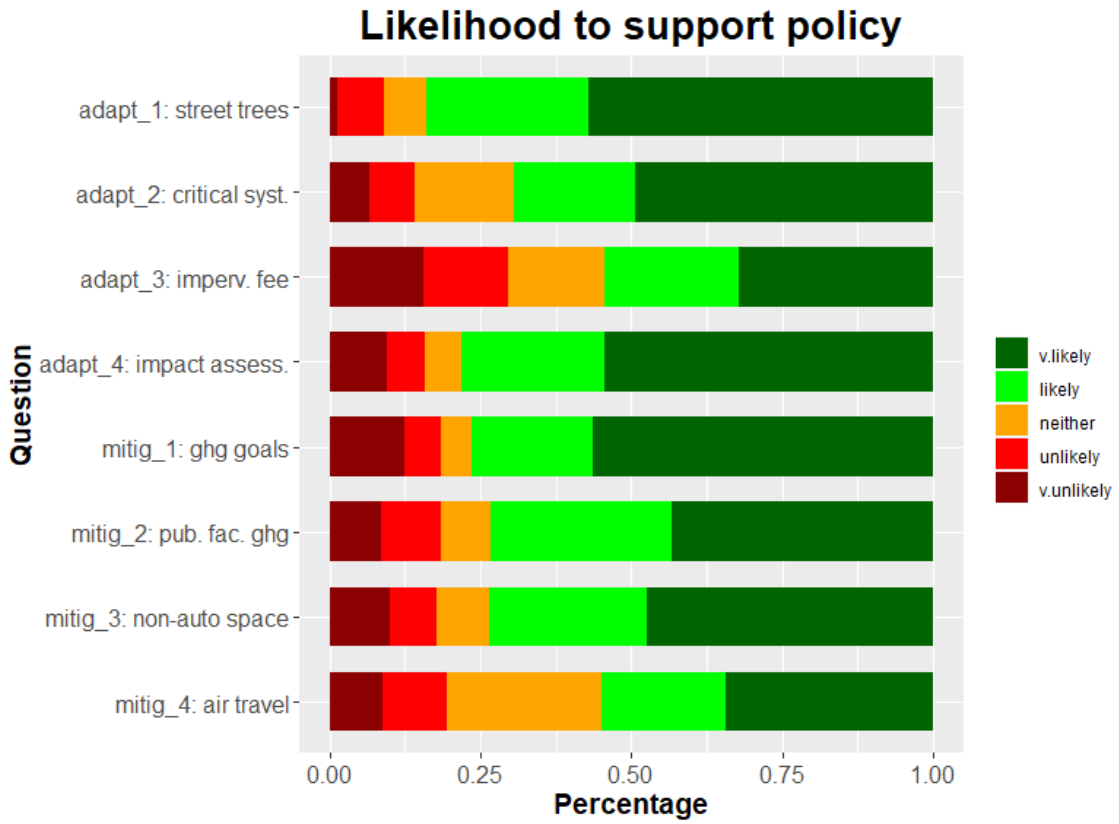

Figure 3.2: Likelihood to support climate policies

Among mitigation policies, committing to ambitious greenhouse gas reduction goals was the most well-supported policy. Similar to climate impact assessments, this policy might be palatable because it doesn't commit to the allocation of resources. Elected officials can advertise support for ambitious goals without

garnering the opposition when substantial policies antagonize particular interest groups. Interestingly, setting climate goals also had relatively strong opposition. As the policy is climate-specific – without intimation of co-benefits – it most clearly polarized respondents into their climate position. A similar polarization is noted from climate impact statements. This opposition is small enough that it should not be a concern in most large municipalities.

The policy on reducing air travel 50% from 2019 levels had the lowest level of support of mitigation policies with a large portion of respondents indicating that they would be "neither likely nor unlikely" to support such a policy. This may have to do with the uncertainty associated with business travel roughly one year into the Covid-19 pandemic.

Who Supports Climate Policy?

Before developing our latent variable of propensity to support climate policy, we examine who among our sample supports the policies we presented. It is clear that self-identified Republicans and conservative individuals were more reluctant to support any of the policies that we presented. This affirms the evidence that climate action has become a partisan issue (Dunlap & McCright, 2008).

Interestingly, the proposition of planting street trees and requiring critical systems to be elevated saw a higher degree of cross-party support. Both of these policies with higher support among Republicans do not explicitly mention greenhouse gasses or climate. Their co-benefits are clear and serve the population broadly. Further, they may be seen as within the status quo of local government action. Planting street trees, in most cases, improves neighborhood well-being without substantial reallocation of the uses of public space. Similarly, all US cities already possess building codes to ensure the safety of residents – the critical systems policy might be seen as a natural extension.

Partisanship and ideology best explained the gap in support when the policy explicitly targeted climate action, such as climate impact assessments, greenhouse gas goals, and carbon neutral public facilities (Figure 3.3, 3.4). These policies appear to trigger national political identities more substantially than policies that do not mention greenhouse gasses or climate – such as street trees. The explicit climate policies would provide numerous co-benefits but those co-benefits are less salient.

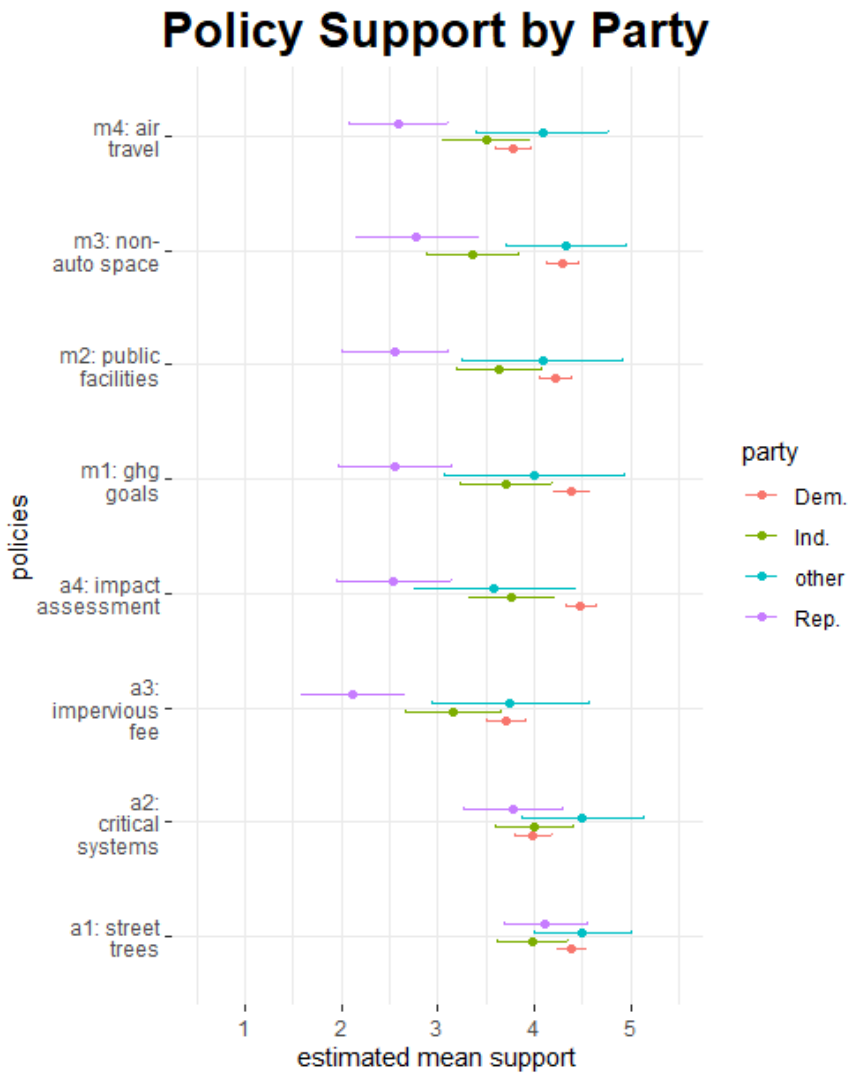

Figure 3.3: Estimated mean support for climate policies by party

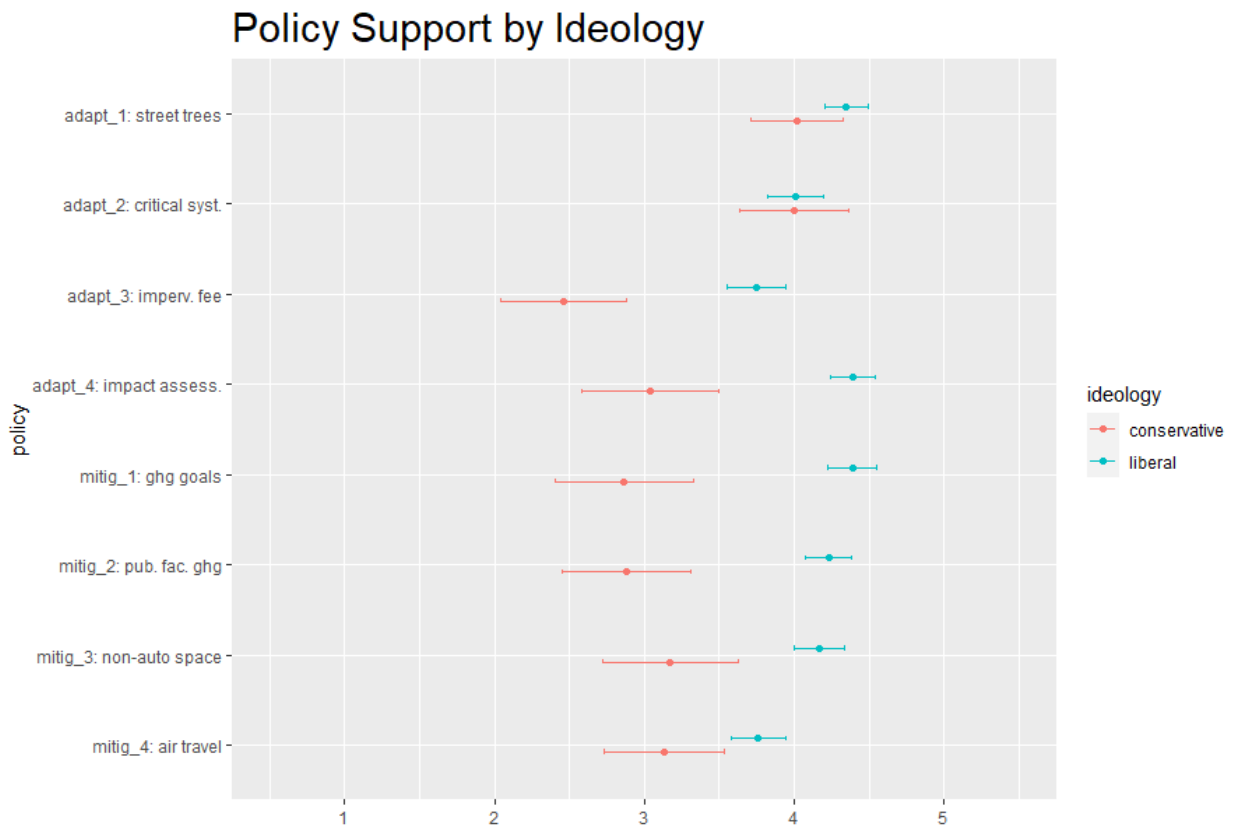

Figure 3.4: Estimated mean support for climate policies by ideology

Another key factor in determining elected officials' support of climate policies is their perspective on the role of municipal government in making climate policy (Figure 3.5). Of our sample, 66% agreed that cities should play a leading role in climate change adaptation and mitigation. Taken alone, this perspective was associated with higher mean levels of support for climate policies than being a Democrats or ideologically liberal. Those that agreed that cities play a subordinate role were less likely to support all policies with the exception of critical systems requirements. Those that saw no role for city government in combating climate change expressed outright opposition or neutrality towards all policies. with the exception of street trees.

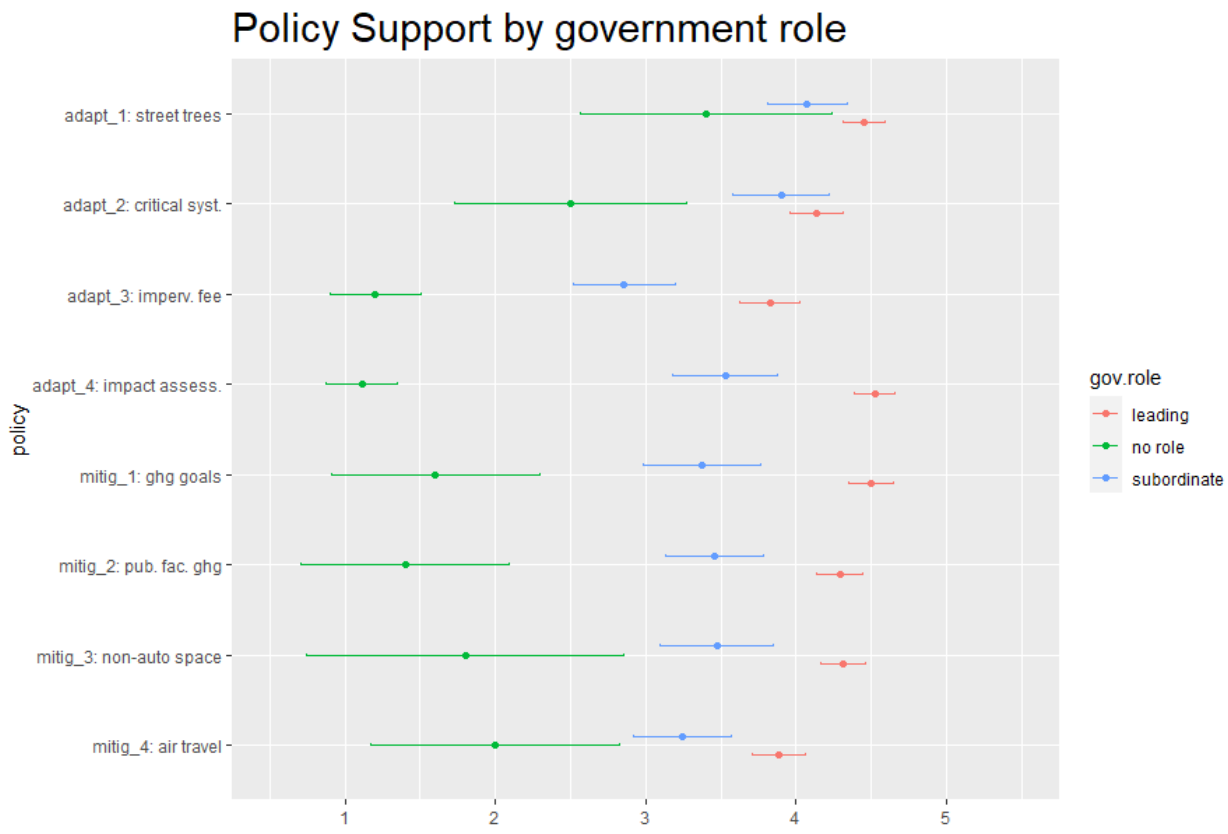

Figure 3.5: Estimated mean support for climate policies by government role

We additionally examined the socio-demographic variables that we collected. We found that demographic factors rarely explain policy positions across the board though they are statistically significant in explaining some individual policies. For instance, younger elected officials (<44 years) were more likely to support carbon neutral public facilities (mu = 4.17, P = .03) and air travel restrictions (mu = 3.86, P = .03). Older elected officials (>65 years) were less likely to support critical systems regulations (mu = 3.63, P = .02), carbon neutral public facilities (mu = 3.52, P = .02), and air travel restrictions (mu = 3.30, P = .03). Black officials were more likely to support impact assessments (mu = 4.5, P = .03) and setting greenhouse gas goals (mu = 4.46, P = .02). Impact assessments have been one approach for mainlining justice concerns into investment decisions (Walker, 2010).

The sole socio-demographic variable that was consistently significant was gender (Figure 3.6). Women were more likely to support impact assessments (mu = 4.36, P = .01), greenhouse gas goals (mu = 4.32, P = .01), carbon neutral public facilities (mu = 4.23, P = .00), and more non-auto space (mu = 4.17, P = .04). This may reflect the growing political gender divide. The women in our sample, paralleling US women more generally, are more likely to be liberal and Democrats. These results also reflect the growing "eco gender gap" (Brough et al., 2016).

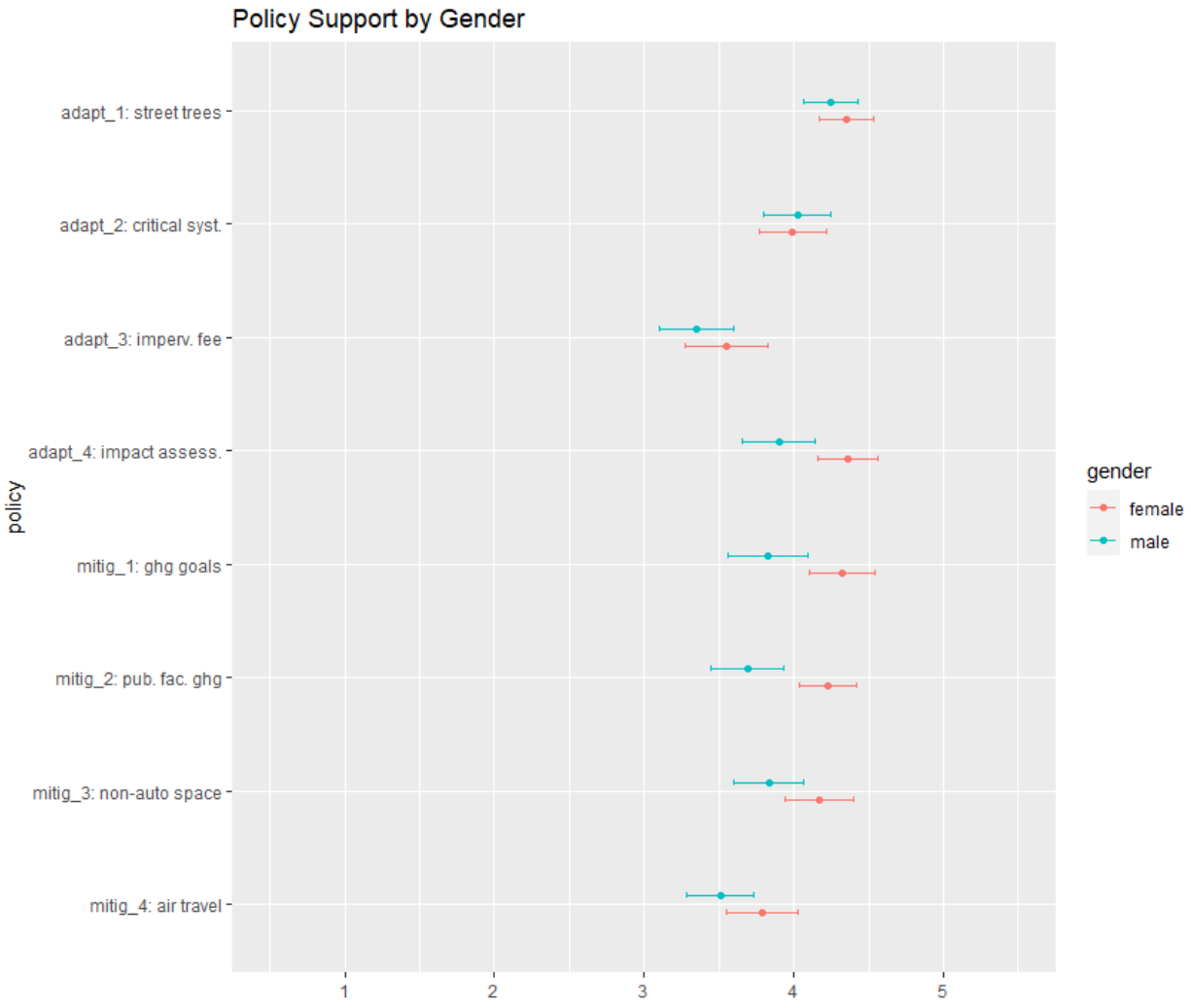

Figure 3.6: Estimated mean support for climate policies by gender

Uncertainty

Respondents, overall, expressed confidence in their answers. For all the questions that we asked, the majority either somewhat or strongly agreed that they were certain in their answers (Figure 3.7). In particular, respondents felt that they possessed sufficient information to decide on local ordinances (78%), perhaps reflecting climate urgency overcoming climate uncertainty. Similarly, though many agreed that we cannot assess the full impacts of climate change in advance (42%), the vast majority still disagreed that we should "wait and see" what those impacts are (86%).

Together, the responses related to uncertainty indicate a tension between the urgency of combating climate change and the desire to better understand how to combat it. A full 37% (relatively high) feel that they need more information about local impacts before implementing new local ordinances. Similarly, 33% are unsure of the best policies for adapting their city to climate change. Respondents seemed to distinguish between sufficient information to act – which they believe they already possess – and desiring additional information for improving climate policy.

The ambiguity questions elicited a different line of response as they rely on the elected officials' ability to reliably infer the positions of others. Elected officials feel confident about the policies that their fellow councilors (54%) or constituents would support (68%). But, these two questions also elicited the lowest rate of 'strong agreement'. Additionally, these two indicators each scored the highest on "not sure" - 25% and 16% respectively. This pattern differed from the other responses that tended to be bimodal with respondents either agreeing or disagreeing. This might reflect the greater difficulties in knowing where others stand as opposed to taking a personal position on an issue. This result is particularly interesting since these questions get to the core political concerns of being an elected official. If they can't be sure of political support, they won't be able to move policies forward.

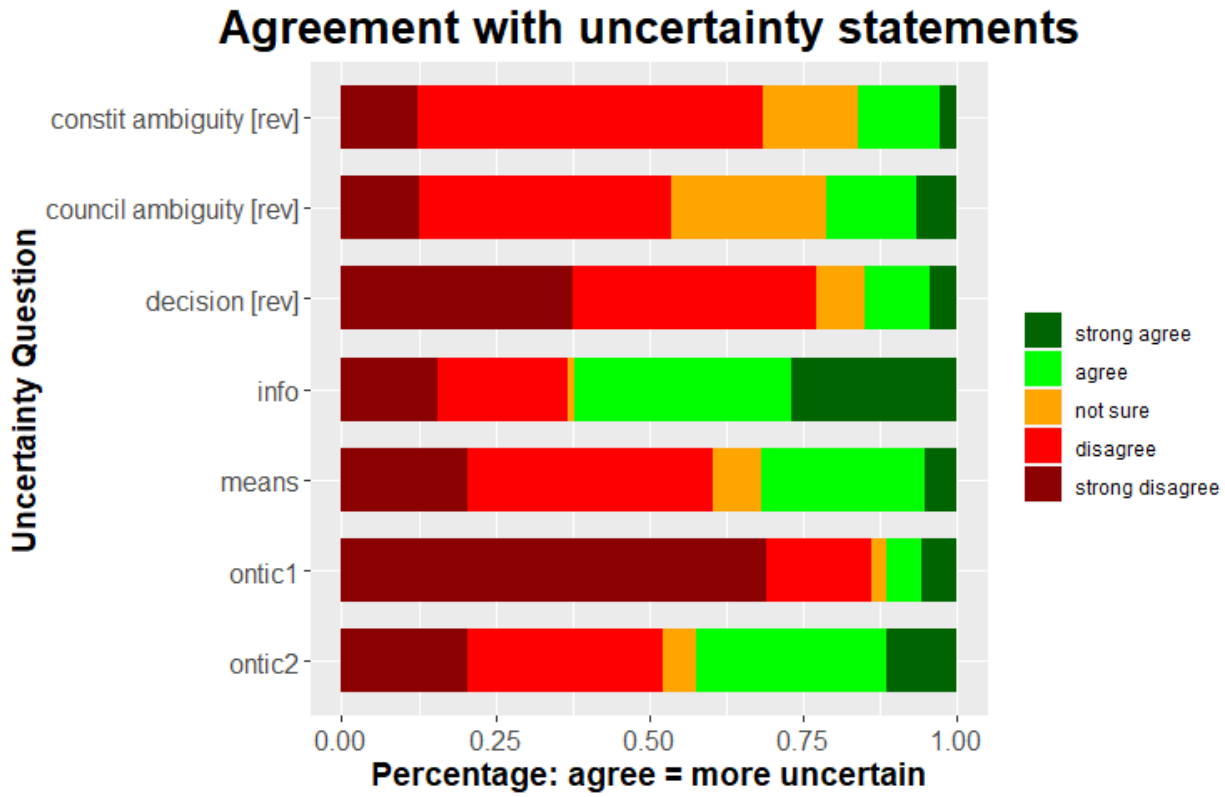

Figure 3.7: Agreement with five-point uncertainty statements

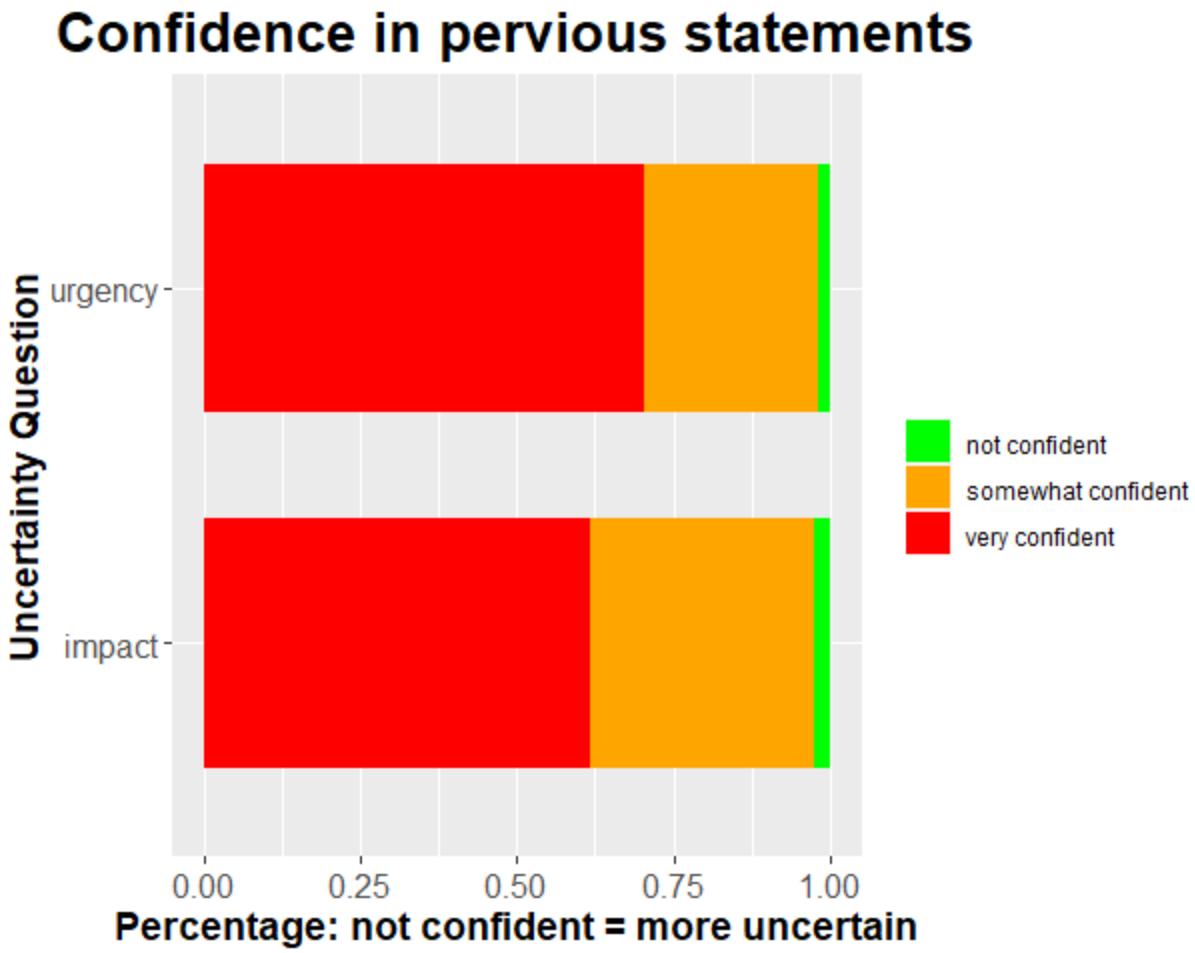

Figure 3.8: Confidence in climate urgency and impact responses

When asked to indicate their own confidence in assessing impacts or urgency, 62% and 70% respectively indicated that they are very confident (Figure 3.8). The high level of confidence regards question that asks the officials to reflect on a previously stated position. It's unsurprising that many should express confidence. Yet, this confidence is not distributed equally among the respondents. Those that expressed extreme assessments of impacts/urgency tended to possess greater confidence in their view (Figure 3.9, 3.10). This may simply reflect the inherent uncertainty of choosing a central score on a Likert scale as opposed to taking an endpoint position. Or it might indicate a genuine difficulty that some officials have in establishing their position.

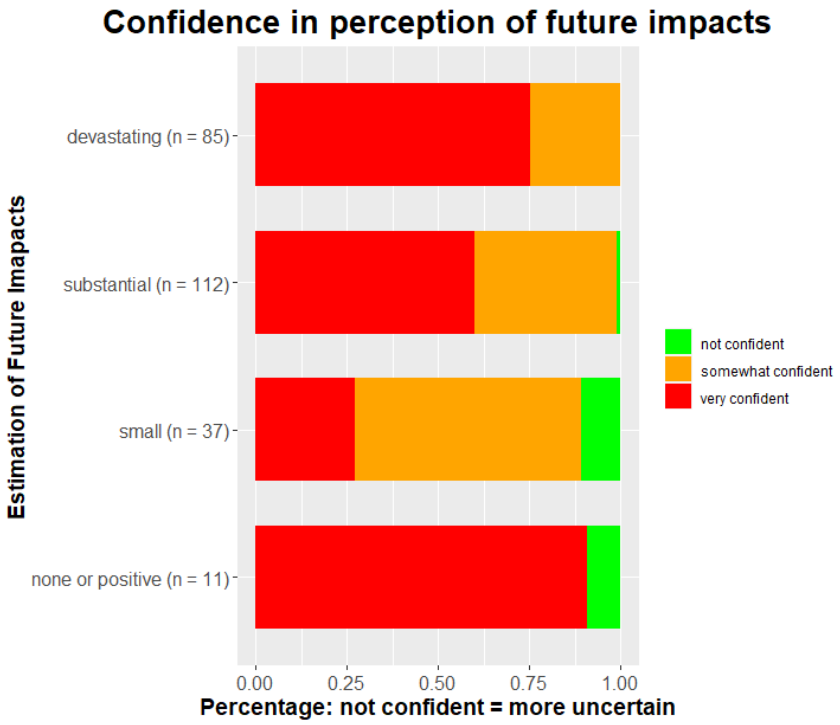

Figure 3.9: Confidence in perception of future impacts based on estimation of impact

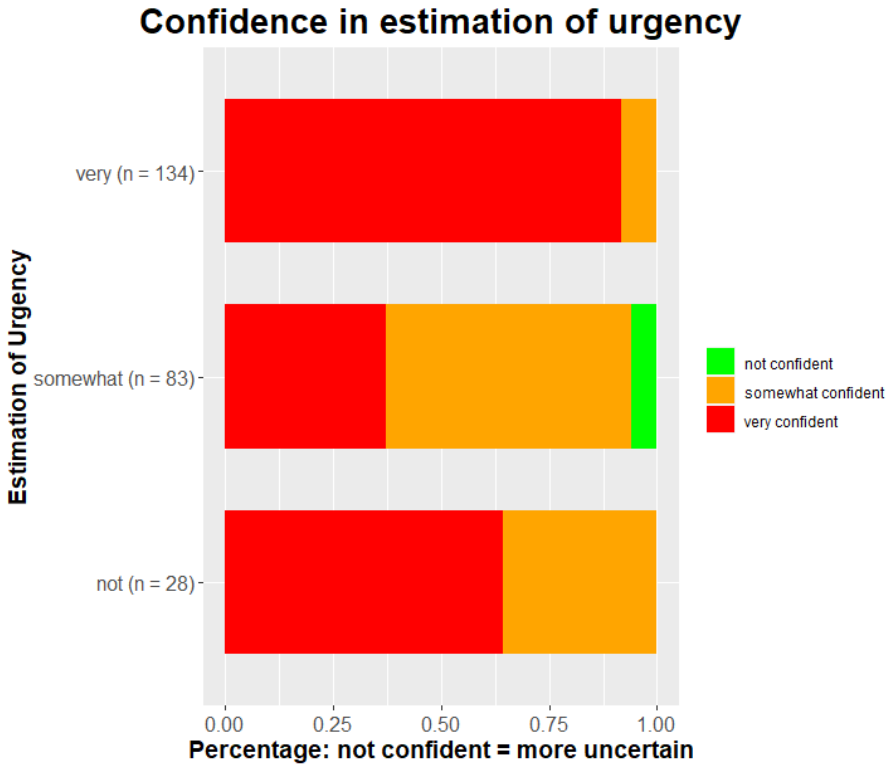

Figure 3.10: Confidence in estimation of urgency based on estimation of urgency

Impacts and Urgency

Almost all officials (91%) indicated that climate change has already impacted their communities and a majority (58%) believe that it has already had a substantial or devastating negative impact. When asked about their future impacts, those indicating a substantial or devastating negative impact increases to 81%. Assessments of the impact of climate change in their cities relative to other US cities are relatively balanced. Though a plurality believe that climate change will be worse in their city (42%), a substantial portion believe that the impacts will be about the same (26%), or more mild (32%) (Figure 09).

Finally, the majority of officials believe that climate change is very urgent (55%). Only 11% assess climate change as not at all urgent. This appears to align with the sentiment that we should act now even as many respondents agreed that we need more information about policy or impacts (Figure 3.10, Table 3.4). This also aligns with the 77% of officials that expressed a liberal ideology and 64% of officials that indicated that they were members of the democratic party.

Table 3.4: Estimation of present and future impacts of climate change; relative impacts; and urgency

Table 04: Impacts	No impact or a positive impact	A small negative impact	A substantial negative impact	A devastating negative impact	
Past Impacts	9%	33%	48%	10%	
Future Impacts	4%	15%	46%	35%	
Impacts	Much more mild	Somewhat more mild	About the same	Somewhat worse	Much worse
Relative Impacts	7%	25%	26%	33%	9%
Urgency	Not at all urgent	Somewhat urgent	Very urgent		
Urgency	11%	34%	55%		

CFA Results

Confirmatory factor analysis is utilized to determine the extent to which our latent variables - uncertainty, climate policy propensity, and perceived impacts - capture consistent constructs. Several measures of fit are examined - the comparative fit index (CFI), the Tucker-Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR). Generally, CFI and TLI should be above .9 (moderate fit) or above .95 (good fit). The RMSEA and SRMR should be below .08 (moderate fit) or .06 (good fit) (Klein, 2016).

Table 3.5: CFA Results

	Uncertainty	***Climate Policy Propensity***	***Perceived Impacts***
CFI	0.895	0.978	1.000
TLI	0.849	0.968	1.000
RMSEA	0.081	0.068	0.000
SRMR	0.064	0.032	0.000
Model Test User Model	40.263 (P = .003)	65.672 (P = 0.000)	-
Model Test Baseline Model	999.461 (P = .000)	422.934 (P = 0.000)	256.854 (P = 0.000)

The ***climate action uncertainty*** latent variable has a moderate fit (Table 3.5). The RMSEA and SRMR fit within or are just outside the accepted bounds. The CFI and TLI, however, are lower than what are generally considered a moderate fit. We determined that we could improve the fit if we excluded the two ontic uncertainty questions. The CFI increases to .954 and the TLI increases to .919 while the RMSEA and SRMR decrease. We chose, nonetheless, to keep these two questions within the construct because we believe that it would be theoretically unsound to measure uncertainty while excluding ontic uncertainty. Appendix XX presents the two constructs in greater detail.

We used the structure of the latent variable to estimate the uncertainty for each individual in the sample. The latent variable has a standard deviation of .14 and a median of -.01. The distribution is not quite normal but generally skewed to the right (Figure 3.11).

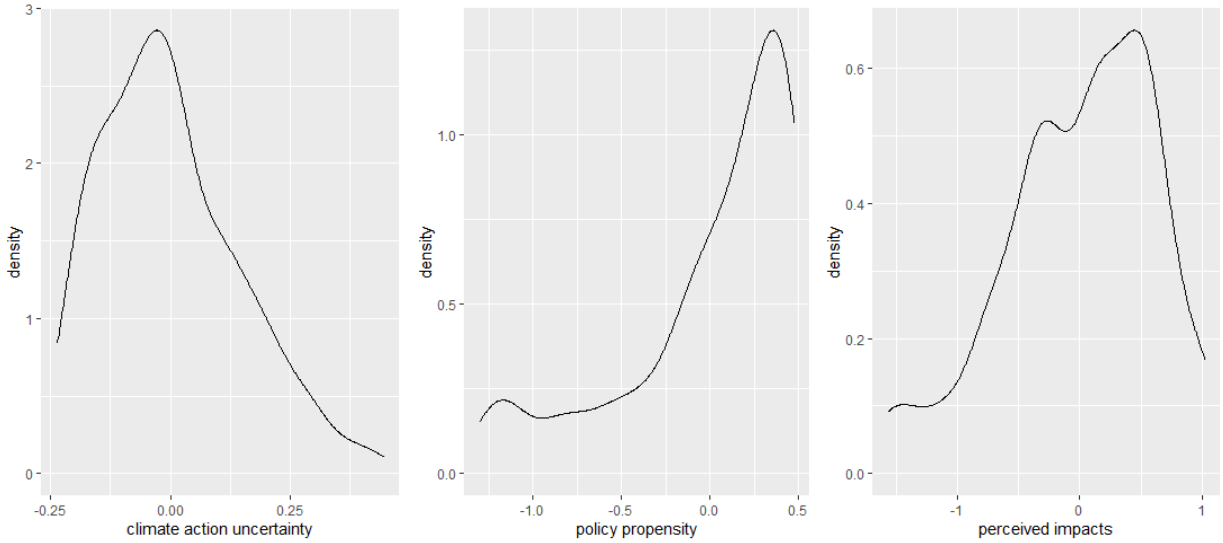

Figure 3.11: Estimated distribution of climate action uncertainty, policy propensity, and perceived impacts latent variables

The ***climate policy propensity*** and ***perceived impacts*** both have strong fits. Climate policy propensity is well within the bounds of a good or moderate fit for all measures. Perceived impacts would appear to have a perfect fit - but this is an artifact of the modeling process. Latent variables built from just three observed variables will always have a perfect fit.

Unsurprisingly, the policy propensity latent variable has a distribution similar to the many of the responses to the adaptation and mitigation policies. Policy propensity estimates have a standard deviation of .49 are concentrated at the high end, indicating that respondents generally possess high intention to pass local climate action - though there is a cluster that have extremely low intention to take climate action. The perceived impacts have a standard deviation of .61, indicating the widest spread of any of the latent variables. The variable is also skewed to the left. The similar skews of climate policy propensity and perceived impacts both likely reflect the small portion of officials in our sample that hold deeply conservative views on climate action (Figure 11).

SEM Results without Framing

The model presented above is complicated, with several latent variables and multiple pathways that influence. Instead of introducing the full model all at once, we chose to slowly increase the complexity of the model in order to ensure that the additional complexity improved the fit and in order to ensure that the model estimates were robust to changing specifications.

Model **(1)** only includes the direct paths from uncertainty, urgency, and impacts to policy propensity. Model **(2)** adds individual socio-demographic controls additionally predicting the policy propensity. Model **(3)** includes paths from uncertainty and impacts to urgency, introducing indirect pathways from uncertainty and impacts to policy propensity through urgency. Model **(4)** adds individual socio-demographic controls to the explanatory variables uncertainty, urgency, and impacts. Finally, model **(5)** adds the municipality specific controls (Table 3.6). All models are estimate with Robust Heber-White standard errors to account for potential heteroskedasticity.

Table 3.6: SEM Results

	(1) Direct - no control	**(2)** Control on policy propensity	**(3)** Indirect channel via urgency	**(4)** Controls on uncertainty, urgency, impacts	**(5)** Municipality specific controls
Model fit indices					
CFI	0.746	.701	.742	.819	0.805
TLI	0.709	.670	.715	.784	0.767
RMSEA	0.113	.092	.087	0.076	0.073
SRMR	0.166	.154	.151	0.109	0.099
Standardized Regression Coefficients Predicting Policy Propensity (unless otherwise noted) All regression coefficients are the standardized estimates are based on the variances of both (continuous) observed and latent variables					
Urgency (C)	.317	.141	.016	.018	-0.034
Impacts (E)	.450	.311	.405	.399	0.358
Uncertainty (A)	**-.124 (P = .186)**	**-.172 (P = .068)**	**-.200 (P = .048)**	**-0.197 (P = .047)**	**-0.168 (P = .083)**
urgency ~ impacts (D)			.757	0.657	0.614
urgency ~ uncertainty (B)			-.174	-0.168	-0.152
Ind. Effects (B → C)			-.003	-.003	0.005
Total Effects (A + B*C)			**-.203 (P = .033)**	**-.200 (P = .033)**	**-0.163 (P = .072)**

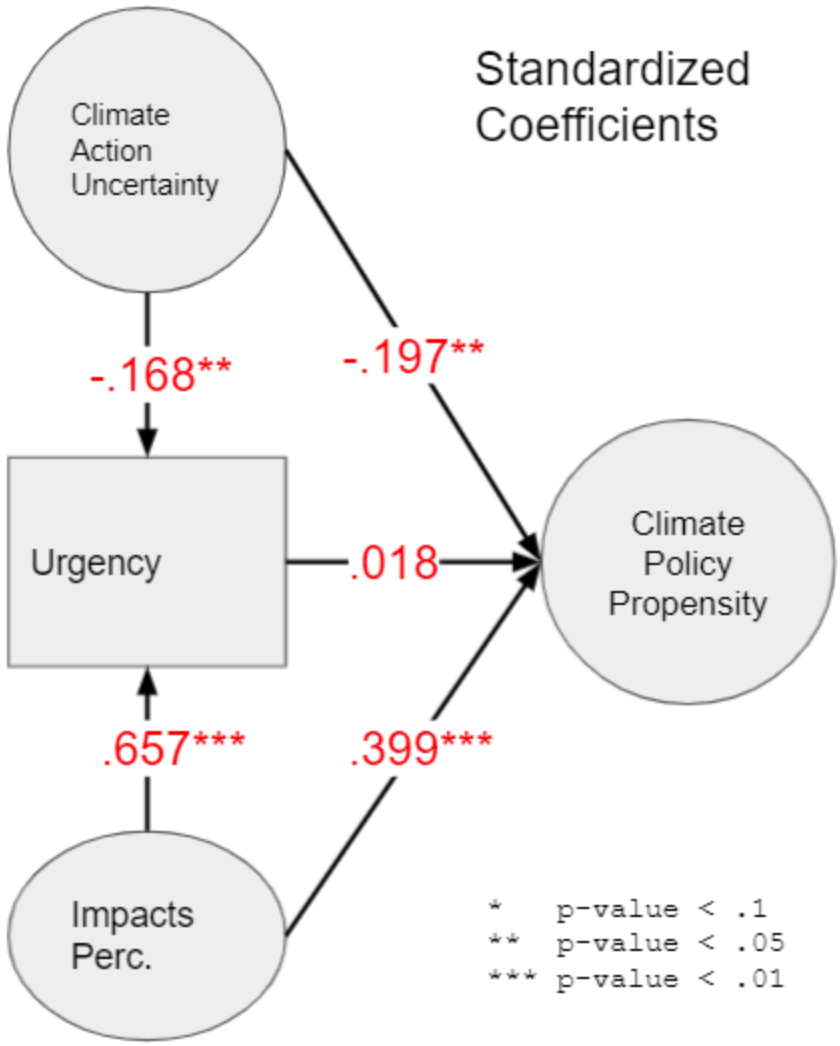

Figure 3.12: SEM standardized coefficients

The stepwise addition of complexity to the model generally increased the model fit until we attempted to add geography specific controls. In this case the CFI and the TLI both substantially decreased indicating that the variables associated with the city as a whole do not improve the explanatory power of the model. Municipal elected officials generally represent subareas of their cities and the citywide statistics might not be appropriate in modeling their thinking. An official from a denser city might be representing a sparsely populated district for instance.

The final measures of fit are within the bounds typically considered reasonable for an SEM model. Where this model may have fallen short of ideal standards, it is likely due to our modest sample size. As can be observed in table 06, the direct relationship between uncertainty and policy propensity is relatively consistent and statistically significant at a P = .05 level once indirect channels are added **(2)**. Including the indirect effects in the model does not significantly change the total effect of uncertainty on policy propensity. While uncertainty did correlate with a decreased sense of urgency, the measure of urgency itself was generally uncorrelated with policy propensity when controlling for other variables. According to these results, policymakers' sense of impacts and uncertainty are direct drivers of propensity to support policies (Figure 3.12).

As latent variables have no observable meaning, it is important to illustrate the meaning of the relationships via examples in the data. To do this, we used the R function *lavPredict* to determine the predicted uncertainty and policy propensity score for each individual in the sample. From this we know that the difference between the 25th and 75th percentile uncertainty score is .206. Using the unstandardized total effect of uncertainty on policy propensity (-.568), we determine that moving between these two percentiles would decrease policy points by -.12 points or .24 standard deviations. This is equivalent to 9.4% of the distribution. The effects of uncertainty are real, but only represent a fraction of important variables influencing policy support.

Table 3.7: Covariates

	Estimate	Robust Standard error	p-value	Standardized Coefficient
Urgency	.013	.074	.860	.018
Perc. of Impacts	.312	.111	.005	.399
Uncertainty	-.559	.282	.047	-.197
Black	.025	.087	.777	.015
Hisp.	-.104	.073	.155	-.081
Other non-white	-.047	.072	.517	-.029
Male	-.104	.057	.071	-.105
Liberal	.064	.076	.401	.059
Leading role of cities	.466	.145	.001	.455
Subordinate role of cites	.338	.136	.013	.312
Dem	.009	.064	.885	.009
Rep	-.152	.096	.113	-.097

Not all of the socio-demographic and political identity covariates that we included were significant in determining policy propensity, nonetheless, we kept several of them in the model because of their general significance in guiding climate policy (Iyengar & Krupenkin, 2018) (Table 07). The perception of impacts is strongly correlated with policy propensity, with a standardized coefficient greater than of uncertainty. This is a strong indication that any attempt to convince elected officials to act on climate change should begin by articulating the impacts. The role of cities in climate change adaptation is also important for policy propensity. Those that saw cities as playing a leading role (n = 157) had a policy propensity .466 points higher than those that saw no role for cities in adapting to climate change. Those that saw a subordinate role fell between. A similar pattern emerged for perception of impacts and climate uncertainty.

Male officials were less likely to support climate policy and less likely to be uncertain. Race was not significant in determining policy propensity - the lone exception being Hispanic individuals had higher perception of impact. Interestingly, none of the political identity variables are significant in determining policy propensity when controlling for other variables. Liberals were more likely while Republicans were less likely to perceive strong climate impact (relative to individuals not affiliated with the two major parties). The signs on the

political variables generally pointed the correct direction - Republican are less urgent, less policy supportive, perceive lower impacts, and are more certain of themselves - but significance may have been limited by sample size.

SEM Results with Framing

The above results were estimated for the entire sample of respondents, regardless of the framing they were presented. We also attempted to consider the interaction of uncertainty and loss/gain framing in two manners. First, we utilized a mediator approach, introducing latent variables that interacted the framing with each of the uncertainty measures. This approach slightly increased the SRMR and significantly diminished CFI and TLI (indicating worse fit). The results indicated that the framings as well as the mediator latent variables all had statistically insignificant effects on policy propensity.

The second experiment with the framing was a multi-group analysis that fixed all regression coefficients across groups except for the effects of the uncertainty variable. This regression significantly diminished the fit along all measures - which is unsurprising when dividing our sample into three groups. Though each of the uncertainty terms were statistically different from zero, we believe that this approach sliced the sample too thin for substantive analysis.

The results indicate that the framing had no effect within our sample. This does not align with the bulk of the research on framing. However, Gustafson and Rice (2019) found uncertainty framing effects may not be significant in impacting climate change behavioral intentions. Framing effects may diminish with strongly held beliefs and previous contemplation – such as may be the case fore elected officials. Additional research may be able to determine an effect with stronger framing language and a larger sample size.

Conclusions

Climate policy represents a classic case of policy making under uncertainty. The scientific evidence will never provide precise estimates of its impacts nor the effectiveness of possible policies or solutions. In addition, local municipal officials lack the scientific and policy support infrastructure available at the national and global scale. Additionally, many political, media, and business leaders have played up uncertainties in an effort to paralyze policy making. Council members will necessarily need to make policy choices in a fog of uncertainty. And yet municipal climate policy is not just possible but necessary for reducing our greenhouse gas emissions and adapting to climate impacts. Elected officials should be empowered to act confidently in spite of the inherent uncertainty.

In such circumstances policy makers can either revert to reference narratives, enhance actions out of precaution, or cautiously slow the pace of action. In order to determine which effect was most plausible, this study employed an SEM model to a survey of 245 municipal elected officials from cities with more than 100,000 people. Our findings indicate that the primary effect of uncertainty on climate action is paralytic – policy makers that are more uncertain regarding climate impacts and policy are less inclined to take climate action, even when controlling for their sense of urgency, perception of impacts, socio-economic characteristics, and municipal characteristics. Though we believe that this is likely causal, our research design prevents us from making strong conclusions. Policy makers that are disinclined to support climate action might be 'backfilling' uncertainty as a rhetorical excuse fed to them by conservative media sources.

While uncertainty was clearly associated with decreased propensity to take climate action, our results did not establish loss or gain framing as significant in determining policy support. There are several potential reasons for this that deserve further investigation. The first possibility is that the framing we provided was too cursory

to influence the propensities of our respondents. While this is possible, there is a long record of trivial framing and anchors having significant effects in the right circumstance. We hypothesize that the elected officials, dealing with the complex, embedded problems are likely to have more stable policy perspectives than psychology experiment subjects presented with novel, context-less puzzles. It is reasonable to assume that most of these policy makers - surveyed towards the end of their term – have established positions on similar policies.

This is not to say that elected are not influenced by what they see in the media, but rather that those influences have probably worked towards a more stable perspective that changes slowly. Municipal policy makers must be treated as a unique community in the study of climate policy. They are not representative of the general population in that they self-selected to run for office and possessed attributes appealing to their constituents. They also differ from policy makers at higher levels because they are not afforded the same research and policy resources to guide the decision making under uncertainty.

The public may imagine our elected officials as inherently empowered. They are endowed with legislative or executive policy roles that allow them to collectively make decisions on our behalf. And yet, our elective officials are still human. Just like the rest of us, their propensity to act will depend on the sense of agency that they feel. Whether they believe that the urban policy arena is inherently constrained or they think that congress should lead in climate action, their belief in a limited role is associated with more tepid attitudes towards policy making. While the remainder of this paper emphasizes the importance of uncertainty on the decisions of policy makers, agency and jurisdiction may be even more important factors.

Finally, this assessment of elected official uncertainty was performed in the context of climate policy. However, this is the first study we are aware of that demonstrates that uncertainty can impact the level of policy support. In that sense, it's an existence proof, establishing policy uncertainty as a relevant variable for policy advocates and future research. We argue that there is good reason to believe that similar uncertainty halts action in a variety of municipal policy spheres. Future research should seek to replicate our results and determine its validity across policy spheres.

Policy Relevance

As municipal policy makers confront changing technology, volatile economies, unprecedented pandemics, and turbulent national politics, understanding how local elected officials incorporate uncertainty into their thinking will be more important than ever. On top of the natural uncertainty inherent in these local policy endeavors, we should also expect vested economic interests to continue to play up the uncertainty in their sectors to avoid regulation. As we are writing this, crypto currency traders are making the case to congress that regulation of their industry is premature for just those reasons.

This research supports two clear policy implications for advocates and advisors. The first, obvious, implication is the importance of continuing to assuage policy maker uncertainties. This includes additional research into those impacts and policies which are seen as the most uncertain. Such a research agenda would bridge additional social science research towards understanding how elected officials approach climate policy with scientific research aimed at more precision in their areas of concern.

A second approach is that advocates and policy advisors should focus on selecting robust policies - those policies that will promote climate goals no matter the circumstances. Communicators should emphasize the robustness of the approaches they promote. It is impossible to fully remove uncertainty surrounding climate change but we can be assured that we do have good options for all possible cases. Emphasizing the co-benefits of policies is another manner of promoting robustness. A policy that makes a city healthier, more just, and ecologically sustainable is worthy of enactment even if it has limited climate impacts.

Limitations and Additional Research

In its design and execution this study has several limitations that provide opportunities for future research. Our sample was sufficient for fitting the SEM model but a larger sample size would have helped to draw stronger conclusions, especially with respect to the effects of framing. In order to collect the limited sample, we kept the survey as brief as possible. This included a very limited framing. Additional research should examine the impacts of more immersive framing on elected officials' propensity to take climate action.

The brief survey also prevented us from including several questions that could have built better measures of uncertainty, perceived impacts, urgency, and policy action. With regard to uncertainty, additional questions could have aided us in distinguishing different natures or locations of uncertainty. With such distinctions in place, we may have been able to determine which kinds of uncertainty are the most pernicious in slowing policy action. Another key shortcoming was our measurement of urgency with a single question. While confident in our wording, fitting an additional latent variable would have allowed us to measure urgency with less error.

We additionally wish to emphasize the non-stationarity of our results should they be used to guide future action. All quantitative social science findings are always specific to the place and time they are collected - our concepts are socially constructed and embedded in ever changing relationships. This may be particularly true of the manner in which municipal elected officials make decisions. The population that we sampled from no longer exists. Cities can change rapidly in terms of demographics and local business composition. The perspectives of their elected officials are likely to change as well.

A final essential piece of future policy research is in determining the relationship between the propensity to support policies and the actual passage of climate action. Our survey respondents generally expressed high support for all the policies but few of these policies – selected as stretch goals – have actually been broadly implemented. Clearly the machinations of urban politics are complex and involve influences beyond the baseline level of councilor support for policies. Political scientists, sociologists, planners, and other disciplines have long argued whether such individual level factors are key variables relative to larger structural forces at play.

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Appendix

A Note of the Sample Size

There are many good reasons for this low response rate - some of which are admitted limitations of our study. First, elected officials are quite busy. They might decide that they do not have the time to complete the survey or staff may not pass it on for similar reasons. Second, an email linking to an external survey might be regarded with suspicion. City governments have been prime targets for ransomware. Some email systems may have sorted it into spam. Others may have chosen not to click on the link out of their own judgement. In fact, in one of our calls the respondent requested that we send the url instead of a link because they felt more comfortable copying and pasting it into their browser.

Socio-Demographics and Policy Support

The main text of this document included a graph on policy support by gender because that variable is significant for explaining the variation in support for several policies. In this appendix section below, I include graphs for socio-demographic the other socio-economic variables.

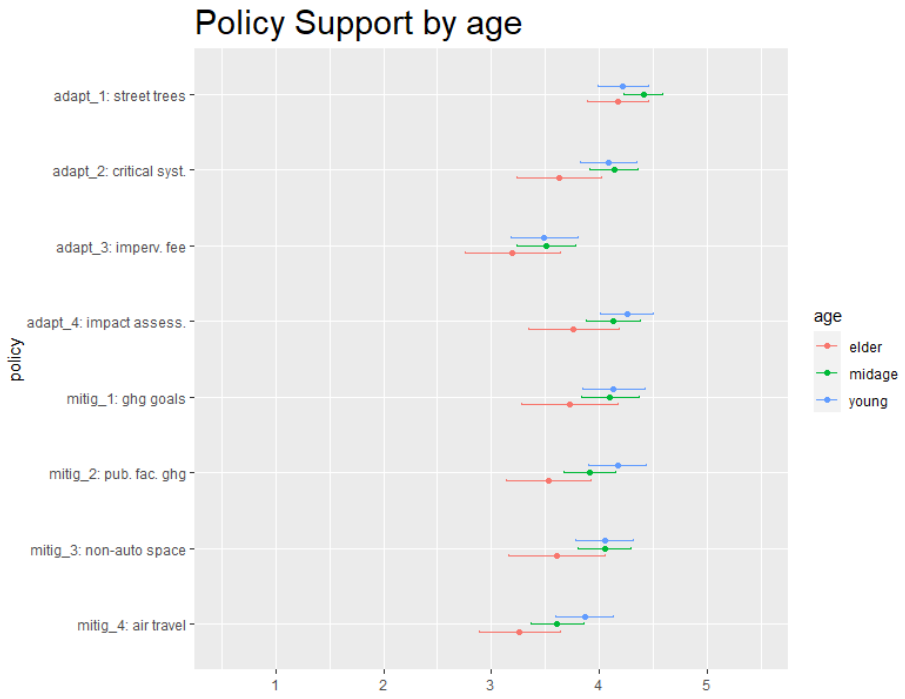

Figure 3.13: Estimated mean support for climate policies by age

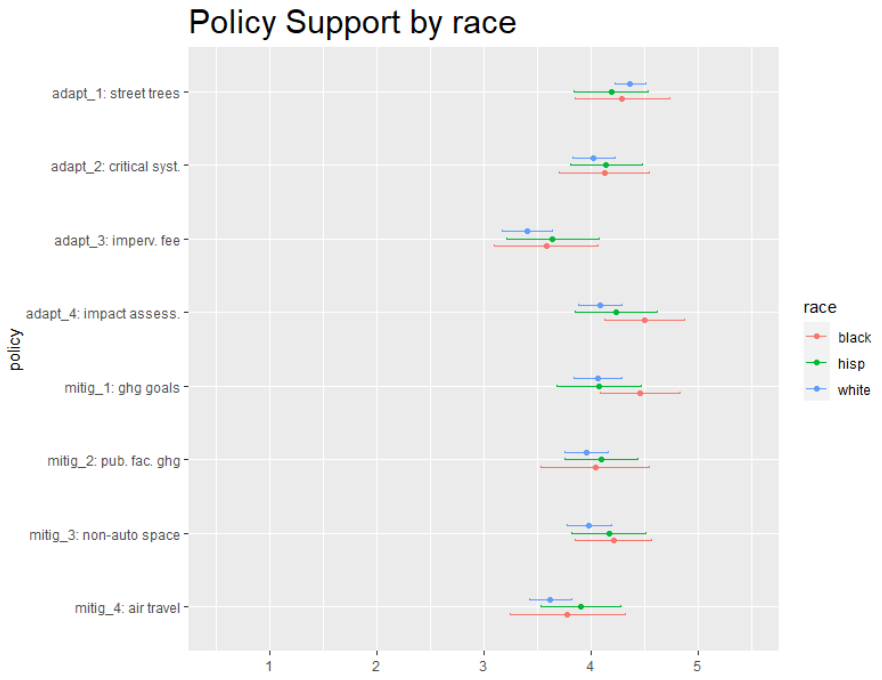

Figure 3.14: Estimated mean support for climate policies by race

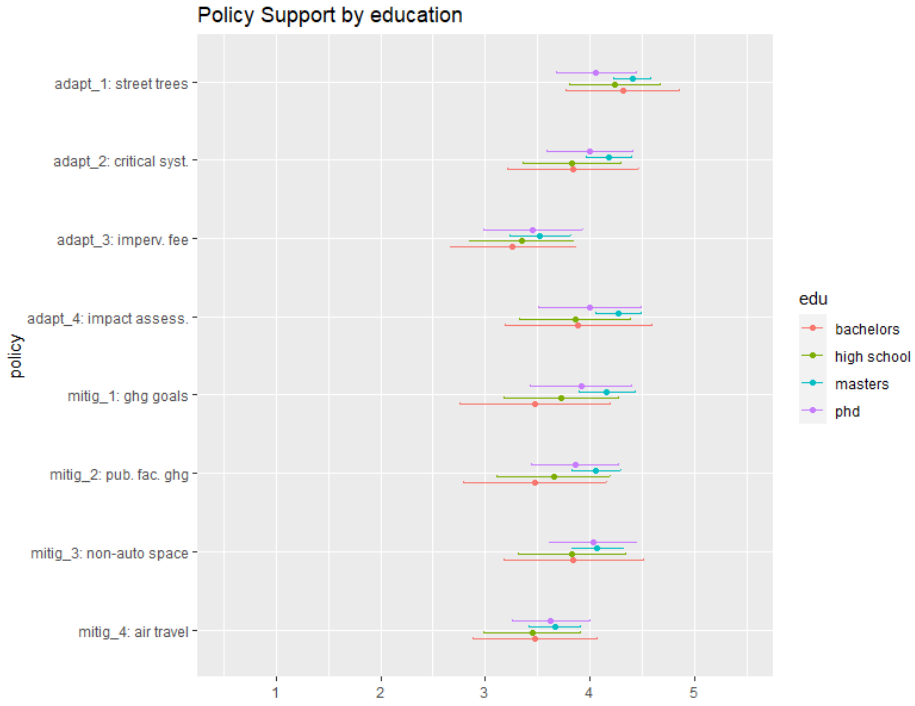

Figure 3.15: Estimated mean support for climate policies by education

Confirmatory Factor Analyses

Details of Confirmatory Factor Analysis

Table 3.8: CFA Estimation for Uncertainty

Item Code	Statement	Unstandardized Factor Loading	S.E.	Two-tailed p-value	Standardized Factor Loading	R^2
Impacts uncertainty	You noted that you think climate change will have *[_from previous_]* impact on your city. How confident are you about your belief?	1.000			0.309	0.095
Decision Uncertainty	I feel that I have enough information about the impacts of climate change to make a decision on local ordinances that would increase climate resilience in my city.	4.984	1.260	0.000	0.733	0.538
Information uncertainty	Our city needs more information about the impacts of climate change on our community before implementing new local ordinances that would increase climate resilience in my city.	3.725	1.236	0.000	0.425	0.181
Ontic Uncertainty	We should wait and see what the impacts of climate change are before implementing new ordinances for increasing climate resilience in my city.	0.822	0.623	0.187	0.119	0.014
Ontic Uncertainty 2	We can never know the full impacts climate change will have on our city in advance.	1.528	0.644	0.018	0.186	0.035
Council Ambiguity	I am confident that I know which climate change policies other elected officials in my city support.	3.285	1.023	0.001	0.504	0.254
Constituent Ambiguity	I am confident that I know which climate change policies my constituents support.	3.150	0.945	0.001	0.549	0.301
Means Uncertainty	I am unsure of the best policies for adapting my city to climate change.	4.755	1.383	0.001	0.645	0.417
Urgency Uncertainty	You indicated that you believe that developing local ordinances for climate change is *[_from previous_]* urgent. Please indicate your level of confidence in this belief.	1.362	0.344	0.000	0.446	0.199

Table 3.9: CFA Estimation for Policy Propensity

Item Code	Statement	Unstandardized Factor Loading	Robust S.E.	Two-tailed p-value	Standardized Factor Loading	R^2
adapt_1	Fund street trees for all eligible city streets within 10 years	1.000			0.515	0.265
adapt_2	Require critical systems (like air conditioners) in private development to be above flood levels	1.207	0.217	0.000	0.492	0.242
adapt_3	Charge land owners with impervious surfaces a fee and dedicate funds to environmental restoration	1.909	0.305	0.000	0.668	0.447
adapt_4	Require climate impact assessment for all government supported infrastructure	2.229	0.334	0.000	0.867	0.752
mitig_1	Commit to reducing citywide greenhouse gas emissions from private and public sources 90% by 2050	2.366	0.360	0.000	0.859	0.738
mitig_2	Require all new public facilities to be carbon neutral	2.209	0.322	0.000	0.877	0.770
mitig_3	Reallocate at least 10% of city-owned street space to buses, bicycle, and pedestrian use	1.769	0.230	0.000	0.686	0.470
mitig_4	Reduce city employee air travel by at least 50% from 2019 levels	1.449	0.249	0.000	0.571	0.326

Table 3.10: CFA Estimation for Perceived Impacts

Item Code	Statement	Unstandardized Factor Loading	S.E.	Two-tailed p-value	Standardized Factor Loading	R^2
Existing Impacts	Please select the statement below that most closely matches your beliefs about the impacts that climate change has already had on your community:	1.000			0.851	0.723
Future Impacts	Please select the statement below that most closely matches your beliefs about the impacts climate change will have on your community over the next 20 years:	1.045	0.105	0.000	0.849	0.721
Relative Impacts	Relative to other cities in the United States, I expect the impacts of climate change in my city to be:	0.949	0.115	0.000	0.568	0.323

Divergent Validity

We finally tested the divergent validity of our three constructs. This is a test that our three latent variables are distinct. We run a CFA model of climate action uncertainty, climate policy propensity, and perceived impacts, simultaneously estimating the three latent constructs and allowing them to correlate.

The model fit is somewhat poor (chi squared (164, 239) = 465.628, $p < .01$, CFI = 0.844, TFI = 0.820, RMSEA = 0.088 with 90% CI [0.078. 0.097], SRMR = 0.127]. As with our uncertainty measure, the fit along all measures is acceptable if we remove the ontic uncertainty questions. Factor loading for each of the latent variables is consistent with the individual measurement of each variable. The uncertainty measure and the impacts measure are uncorrelated. The uncertainty and policy indicator are lightly correlated but their correlated is in the expected negative direction and slight (b=-0.023, S.E.=0.009, $p = .01$, β=-0.272). Similarly, perception of impacts and policy propensity are positively correlated. This correlation is also small (b=0.206, S.E.=0.037, $p = 0.000$, β=0.655).

4. A Framework for Implementing Racial Equity in Scenario Planning in Regional Scenario Planning

Abstract

Planning under uncertainty and planning for racial equity both require an expansive imagination. In confronting the uncertain future, regional planners often opt for exploratory scenario planning – the practice of telling multiple unlike stories about the future in order to prepare for whatever might come. For equity planning, imagination supports vision beyond the oppressive and deeply unequal conditions of the present – a necessity when policy tinkering and muddling are insufficient for creating a more equitable future. And yet, scenario planning and equity planning are oddly estranged. Though regional planners increasingly desire to incorporate equity into their practice, they lack guidance on how to use scenarios to advance equity planning. Likewise, equity planning may benefit from scenario planning's deep analysis of driving forces and creative opening up of multiple futures. This paper seeks to close this gap in providing a framework for the incorporation of racial equity into scenario planning and demonstrating its applicability. This framework builds on the five types of racial equity, a six-stage hybrid scenario process, and the three outcomes of public sector scenario planning: organizational learning, organizational strategy, and community learning. Using this framework, I assess the inclusion of equity in the Delaware Valley Regional Planning Commissions *Dispatches from Alternative Futures* scenarios plan. This plan successfully raises racial equity as a concern for the future of the Philadelphia region. However, the stakeholder group was not sufficiently diverse for full deliberative justice and the scenario planners do not utilize tools that can assess the distributional outcomes of scenarios and policies. Neither epistemic nor restorative justice were a significant part of the scenario plan, leaving open the possibility for more radically co-designed scenarios for racial equity in the future.

Introduction

Regional planning under uncertainty and planning for racial equity both require an expansive imagination. In confronting the uncertain futures, regional planners often opt for exploratory scenario planning – the practice of telling multiple unlike stories about the future in order to prepare for whatever might come (Avin, 2007). For equity planning, imagination can support vision beyond the oppressive and deeply unequal conditions of the present – a necessity when policy tinkering and muddling are insufficient for the necessary change. And yet, scenario planning and equity planning are oddly estranged. Though practitioners should wish to engage with both, they lack guidance on how to go about it. This paper seeks to close this gap in providing a framework for the use of scenarios to support racial equity planning and demonstrates the use of the framework by applying it to the Delaware Valley Regional Planning Commission's *Dispatches from Alternative Futures* (*Dispatches*) scenario planning effort.

Racial equity planning is a planning approach that is defined by government institutions explicitly prioritizing racial equity, setting clear equity goals, and pursuing policies and programs to achieve more equitable outcomes. I specifically look to metropolitan planning organizations (MPO), federally mandated regional transportation planning bodies, which have come a long way on equity planning since their inception. As recently as 2002, scholars observed that equity concerns, while increasingly entering MPO plans via federal mandates, were not explicitly a part of the agenda (Bollens, 2002). And while many MPOs still struggle with the capacity and competencies for equity planning (Zapata & Bates, 2017), they are increasingly setting ambitious equity goals (Martens & Golub, 2021). Much remaining hesitancy was resolved when the 2020 uprisings for racial justice demanded that planning organizations examine their past culpabilities and present

complacency in systems of racial discrimination and dispossession. In order for scenario planning to remain a relevant practice for MPOs, it must inform this ever more central part of their mission.

I also seek to provide racial equity planners with an additional tool to develop robust strategies for advancing racial equity. Many of the systems driving continued racial inequity are regional in scale, such as transportation networks and housing markets. Among other objectives, regional scenario planning is often oriented towards understanding key trends and driving forces at the regional level. Such a focus on the deeper causes of regional dynamics could be well directed towards collective understanding of the root causes of segregation, displacement, unequal access, and other manifestations of continuing structural racism. Having these conversations within the structure of the MPO could bring in regional decision makers who may not yet fully grasp how the inequitable forces impact everyone's lives historically, presently, and into the future. At a more tangible level, scenarios can inform robust and adaptive strategies for racial equity.

This paper primarily addresses the use of *exploratory* scenarios (Schwartz, 1991; Wack, 1985; Zegras et al., 2004) for equity planning. This approach examines outside driving forces, and sometimes key local factors, in order to tell several unlike stories about the future. Through these stories, decision makers can explore future possibilities and be better prepared for whatever future comes, whether it resembles a single scenario, a combination, or none of those presented. The approach is 'exploratory' in that it is oriented towards exploring driving forces, uncertainties, and plausibilities rather than designing or directing a desired future (Avin, 2007). However, in this paper, I argue that regional exploratory scenarios need to adopt a more "hybrid" approach which accounts for community goals and desires in the development of scenarios (Bezold, 2009). For readability, I use the term 'scenarios' except when more precision is needed to distinguish between approaches.

The intention of this article is not to empirically determine whether deploying this framework in fact produces more equitable regional decisions and investments. Such a laudable objective is difficult to measure given the distant and sometimes indirect ways in which scenarios influence actual policy decisions. Rather this study sits well with those examining equity in elements of MPO long-range planning. These studies measure regional actions and ambition with respect to equity relative to established standards (Martens & Golub, 2021; Zapata & Bates, 2017). As scenarios become ever more central elements of regional long-range planning, we need tools to similarly assess them. My own research is informed by the often-repeated observation that if planning processes do not actively acknowledge and seek to address racial inequities, then those processes are likely to exacerbate those inequities (Goetz et al., 2020).

This paper seeks to contribute a theoretically and experientially grounded framework for practitioners seeking to center racial equity in scenario planning, and for scenario scholars seeking to understand and improve scenario planning. I demonstrate the applicability of this framework utilizing the DVRPC case. This paper then also provides an analysis of how a leading state-of-the-practice scenario planning practice is used to promote racial equity, and how it falls short. Though planners should fine tune their scenario planning approach to the context in which they operate, MPO planners beyond DVRPC will likely find lessons due to the common constraints and aims of these organizations. In the following two sections, I introduce the literature and my research question. The subsequent two sections develop the framework and apply it to the use of *Dispatches*. The methodology for answering each of the two primary research questions is split between these sections, a format that I found to be easier to follow. Finally, I summarize what the case illustrates regarding the framework and draw conclusions.

Literature Review

In the following section, I seek to establish the importance of using scenarios to support racial equity planning. Though I find the importance of racial equity in all planning self-evident, scenario planning can be a complicated process and planners need to believe that integrating racial equity will provide valuable insights. To start, I will introduce both scenario planning and equity planning. Subsequently, I reinforce why we should use scenarios in equity planning. Finally, I briefly examine the limited current literature addressing the topic of how we use scenarios to promote equity.

Scenario Planning and Its Purpose

Scenario planning is defined as "long-term strategic planning that creates representations of multiple, plausible futures of a system of interest" (Goodspeed, 2020). In practice, there are three broad types of scenario planning. Predictive scenarios are used to ask, "what will happen?" through forecasts, predictive modeling, and what-if stories. Normative scenarios ask "how can we reach a specific target?". This is achieved either by setting a target and backcasting or by telling multiple stories so that stakeholders might select the preferred futures. Finally, exploratory scenarios tell multiple stories about the future as driven by uncertain, external forces, so that stakeholders can think more strategically about the unfolding present. Exploratory scenarios require narratively rich storytelling to ensure that they are plausible, coherent, and compelling (Goodspeed, 2020). Beyond the three pure types, a "hybrid" approach to scenarios combines the normative, value-driven ambition with exploration of uncertain driving forces (Avin, 2007; Bezold, 2009).

The core exploratory scenario planning process consists of three steps. First is the identification of important trends, constraints and issues that are impacting the future of the region. Second, major external trends are classified according to their potential to impact regional priorities and uncertainty regarding their future direction. The trends that are most impactful and uncertain are designated structuring driving forces for the scenarios. Finally, planners and stakeholders build scenario stories from the artful combination of those driving forces. The narrative scenarios may be accompanied with quantitative modeling to better grasp their implications (Avin, 2007).

Scenario planning is often accompanied by several additional activities, either as a part of a broader process, or in related scenario analyses. In this paper, I highlight these phases because they are essential in the use of scenarios and because several actual scenario planning processes include these activities (Avin & Goodspeed, 2020). Planners and stakeholders will often develop criteria for evaluating scenarios, or they may use criteria already established from previous planning. The stakeholder group may also suggest strategies and evaluate them through the scenarios. Additionally, hybrid processes will involve some sort of stakeholder value identification, and even the creation of desired futures to accompany possible futures (Avin, 2007). Throughout this paper, I argue in this paper that such a hybrid approach is necessary for using scenario planning to promote racial equity.

Public sector scenario planning aims to produce three outcomes: stakeholder learning, strategic guidance, and community learning. Stakeholder learning is a significant holdover from the primary purpose of private sector scenario planning (Schwartz, 1991). Through the collective deliberation over driving forces and development of scenarios, critical stakeholders learn about underlying regional dynamics and potential pathways for regional change. Having gained these insights the stakeholders are more open to the changes that do occur and more prepared to adapt as circumstances change (Zegras & Rayle, 2012). Strategic guidance refers to the development of specific strategic recommendations. Planners and stakeholders test potential policy options through the scenarios to determine robust strategies – those that work in all circumstances – and contingent strategies – those that are appropriate in limited conditions(Zegras et al., 2004). Both qualitative and quantitative approaches may be utilized in determining these policies.

Community learning, the third potential outcome, is particularly well suited to the public sector (Goodspeed, 2020). Well-designed and well-told scenarios should be interesting to a public beyond the stakeholders that developed them. Public reports, videos, websites, and any variety of other media may be used to inform the broader public. Participatory processes can even bring the public into scenario development. The goal is to help the broader community better understand dynamics at the regional level that are impacting their daily lives. An example of particularly successful public scenarios is the Club of Rome's *The Limits to Growth* report, which renewed global concern for resource-intensive growth economies with predictive scenarios (Meadows et al., 1972).

Scenario planning has been particularly prominent at the regional scale, including public, private, and academic sector planning efforts (Chakraborty, 2010; Knaap et al., 2020; Sherman & Chakraborty, 2022). In spite of their broad geographic scale, regional planning organizations often possess few direct powers to guide regional priorities, and thus are particularly aware of the importance of uncertain, external driving forces. This includes both macro scale forces, such as the national economy, as well as micro scale forces, such as land use decisions controlled by local governments. The US Department of Transportation has also encouraged the use of scenarios for regional planning. In fact, the legislation mandating that MPOs develop long-range plans includes a clause encouraging optional scenario development (Moving Ahead for Progress in the 21st Century Act, 2012), and the Federal Highway Administration has produced multiple guidebooks (Bauer et al., 2015; Twaddell et al., 2016).

Defining equity, equity planning, and justice

Within this paper racial equity refers to accounting for racial difference and working to remove barriers to a more equal distribution of goods and opportunities (Karner et al., 2020). Equity planning is a planning approach that is defined by government institutions explicitly prioritizing equity, setting clear equity goals, and pursuing policies and programs to achieve more equitable outcomes (Krumholz, 1982; Zapata & Bates, 2017). While racial equity has been central to equity planning from the start, this paper's emphasis on *racial* equity planning is meant to focus attention on this specific long-standing planning inequity.

I want to contextualize my definition of racial equity planning relative to justice-oriented movements in planning. Racial equity planning refers to agency driven practices of analysis, planning, and public engagement that nonetheless maintain power positions, while justice-oriented movements seek to transform social and political systems so that the distributions of goods and opportunities is inherently more equal, and power is shared more broadly (Karner et al., 2020; Sanchez & Wolf, 2005). MPOs remain central organizations in the distribution of federal transportation funds and are unlikely to embrace the radical redistributions of their power. While outside, justice-centered movements should challenge established structures, regional planners are interested in what they can do now to ensure that transportation investments are distributed more equitably, as demonstrated by often strong normative commitments (Martens & Golub, 2021). This paper is directed towards aiding those planners.

The unrealized values in using scenarios for racial equity planning

The racial equity planning perspective is crucial if scenario planning is to remain relevant to the next generation of planners. Nearly a decade of Black Lives Matters protests, and other associated movements for racial justice, have reawakened the profession to the ongoing legacies of racialization and oppression. An increasing commitment is also evident with metropolitan planning organizations that often set normative standards for benefits and burdens that go beyond federal Title IX and Environmental Justice requirements (explained at greater length in DVRPC case) (Martens & Golub, 2021). Metropolitan regions possess a unique

opportunity in the equity landscape because they are properly scaled to address equity problems that transcend municipal borders such as affordable housing and access to opportunity (Pastor et al., 2011).

Racial equity planning can strengthen the value of scenario planning by bolstering lagging approaches to community engagement and broadening the insights captured in scenarios. Though some authors have emphasized the importance of stakeholder-driven values and goals informing scenario planning processes (Avin, 2007), many actual scenario plans remain technocratic exercises driven by expert perspectives (Zapata & Kaza, 2015). Rather than being value neutral, we can expect that such plans will reflect the perspectives of the technocratic class that produces them (Goetz et al., 2020). Incorporating a broader range of stakeholders, particularly those from marginalized communities will likely also help to expand the range of driving forces and scenarios considered. BIPOC communities will help to highlight those forces specifically implicated in the perpetuation of structural racism. Scenario stories can then aid in understanding the consequences of perpetuating inequities – for those directly affected as well as the larger community.

Using scenarios for equity planning will only be meaningful, if the scenarios can be additive to equity planning goals. One of the intended outcomes for scenario planning is organizational learning and an expanded imagination for the future (Schwartz, 1991; Zegras & Rayle, 2012), suggesting that meaningful scenarios development with BIPOC communities could produce meaningful lessons for organizational leaders and community members alike. If scenario planning is oriented towards equity it could broaden our imagination for equitable futures. Planning for equity and justice requires a more expansive imagination than is currently present in equity planning efforts (Inch, 2021; Zapata, 2021) and scenario planning could help to unearth possibilities. In focusing on driving forces, scenario plans have the potential to bring regional partners together to discuss ongoing processes that enforce racial inequities and structural approaches to diminishing them. In examining multiple futures, scenarios can offer a reminder that the future is not a simple trend line doomed to reproduce the inequitable present. Through subsequent strategy identification, scenarios can provide plausible pathways for moving the region towards a more equitable future no matter the external forces.

The Current State of Equity in Scenario Planning

The inclusion of community values is among the factors that differentiate public sector scenario planning from its predecessors in business and military strategy. Avin (2007) argues that scenario planning requires parallel trend-analytic and goals-oriented processes – in essence suggesting a hybrid approach to scenario planning (Bezold, 2009). In the trends analysis process, technical experts identify trends and driving forces in order to develop possible futures. This process mostly closely resembles the ideal scenario process as practiced in the business sector (Swart et al., 2004; Zegras et al., 2004). In the values identification process, public stakeholders identify their values and goals in order to craft preferred futures. Planners, stakeholders, and the public then craft draft scenarios from the artful combination of possible and preferred futures. Later papers have affirmed the importance of values identification in order to ensure that the final set of scenarios is grounded in community concerns, relevant to policy makers, and compelling for the general public (Avin & Goodspeed, 2020). Practically, running parallel processes is difficult and expensive. The same stakeholder group may serve in both capacities or the guiding values are established in separate, asynchronous visioning exercises.

Including values generally in the scenario planning process is necessary but not sufficient to explain how to use scenarios in racial equity planning. Prioritizing equity makes its own specific demands of both the planning process and outcomes. First, planning for equity means determining target populations, setting normative principles, and determining specific actions (Zapata & Bates, 2017). Second, equity is cross-cutting and requires distributional goal setting across other value fields (Bills & Walker, 2017). Finally, equitable

planning must include broad public participation in both the generation of use of scenarios from those traditionally left out of planning processes (Zapata & Kaza, 2015). This can include deliberative approaches to bring members of those communities in as stakeholders, procedural approaches to elevate their voices, and epistemic approaches to transform scenarios according to BIPOC community knowledge processes.

The literature directly addressing equity in scenario planning is exceedingly sparse. Avin et al (2014) argues that the analytics techniques used in scenario plans do not produce useful equity measures. The authors note technical, knowledge, conceptual, resource, and political limitations, and proceed to suggest several largely technical recommendations. They are particularly boosterish on equity indicators and opportunity mapping. Bauer et al (2015) is a highly technical manual on scenario planning for transportation systems that has a surprisingly rich treatment of equity. The document suggests developing specific goals, objectives, and performance measures in widely representative stakeholder processes.

In *Scenario Planning for Cities and Regions*, Goodspeed (2020) dedicates the final chapter to the potential for transformative practices. The author argues that, while scenarios have the potential to lead to more progressive results due to the opening up of multiple futures, this potential is not always realized. In order to achieve more equitable outcomes, scenario planning needs to take on the task of imagining more emancipatory futures. That will require genuinely empowering people of color and other marginalized communities in developing scenarios relevant to their concerns. Goodspeed (2020) also highlights a case of an insurgent alternative scenario developed by Equity, Environment, and Jobs in response to Bay Area Metropolitan Planning Commission scenarios as an example of how justice-centered communities can expand our plausible scenarios.

Finally, Ayambire et al (2022) is a systematic review of social equity in the scenario planning literature. The authors echo my own disappointment in the current state of equity in scenario planning but largely refrain from additional suggestions. The depth of their study into scenario planning influences this work, but leaves open a gap in terms of synthesis. Aside from the above studies, most of the suggestions for using scenarios to promote racial equity are scattered in bits and pieces of publications focused on other scenario planning concerns. In the present article, I seek to weave those pieces together into a coherent framework that professionals and academics can deploy towards a more equitable scenario planning.

Research Questions

From the above literature, I focus on two research questions:

> *How can regional planning organizations use scenarios to inform racial equity planning?*

Answering this question requires a synthesis of the existing literature, which is currently too scattered on the use of scenarios for racial equity planning. In order to provide an answer, I develop a framework for incorporating equity into scenario planning pulling from the scenario planning literature, the broader regional equity planning literature, and my own experience.

> *How does the DVRPC use* Dispatches from Alternative Futures *to inform racial equity planning?*

Answering this question allows me to demonstrate the viability of the framework developed in answering the first question. The use of *Dispatches* by DVRPC is a paradigmatic case of the current equity planning practices in regional scenario planning. I performed in-depth qualitative analysis to understand how DVRPC conducted the scenario planning process and how equity was incorporated. I then map these findings to the framework and assess the strengths and weaknesses of *Dispatches* with respect to informing racial equity planning.

A Framework for the Use of Scenarios in Racial Equity Planning

Methods for Developing the Framework

To build a framework for the use of regional scenarios in racial equity planning, I first looked to the public sector scenario planning literature as a guide. I deliberately combed through all articles in *the Journal of the American Planning Association*, *the Journal of Planning Education and Research*, *Planning Theory and Practice, Planning Theory*, the *Environment and Planning* journals, *Transport Reviews,* and the *Transportation Research* journals. From those articles, and through Google Scholar search for additional articles, I compiled articles that discussed scenario planning methods. I also spoke to practitioners and scholars in order to ensure that I incorporated books, articles, and gray literature that the initial search overlooked. In addition to an initial reading, I searched each article for equity words and topics. I looked for equity topics broadly instead of just racial equity because some of the suggested more general approaches may also be applicable for the use of scenarios in racial equity planning.

As the literature on equity in scenario planning is incomplete relative to the theorizing of the scenario planning process, I also considered papers on the inclusion of values generally in scenario planning. While the crosscutting nature of racial equity requires some different approaches, many of the suggestions for incorporating values remain applicable. I secondarily sought out the much broader literature on regional equity planning to fill in gaps in the framework.

The framework is also informed by my own experience with regional scenario planning (Knaap et al., 2020) and through conversations with scenario planners and scholars. While it is more difficult to pinpoint their contributions to an exact point in the framework, many of their conversations generally highlighted the challenge of scenario planning with multiple stakeholders holding competing values.

Three Primary Dimensions for the Use of Regional Scenarios in Racial Equity Planning

The framework this section introduces is for the use of scenarios in racial equity planning. The framework is designed for both assessing existing scenario plans as well as guiding new planning efforts. I ask three central questions in developing the framework. 1) What can planners do to promote the "five types of justice" (Sheller, 2018) throughout creating and using the scenarios? This question ensures that users of the framework are thinking broadly about the promotion of equity rather than narrowly focusing on distributive end results. 2) What can planners do in each stage of the process to ensure that they are using scenarios to promote racial equity? This will provide a practical check for planners as they design scenario processes. 3) How can scenario planning outcomes support racial equity outcomes? This looks to the three intended outcomes of scenario planning, which I previously introduced, in order to ensure that those outcomes are serving racial equity.

My intent in developing this framework is not to require planners to dedicate the entire regional scenario plan to advancing equity alone. MPOs will always have a variety of important priorities they seek to advance. It is my intention that this framework can be applied to scenario plans that address a variety of regional priorities, such as the *Dispatches* plan, in order to focus attention toward the racial equity components of the plan. In the process, I argue that regional scenario planners must embrace some hybridity in their scenario planning: working with BOPIC communities to explicitly forward racial equity values in the scenario generation process.

The five types justice/equity

I look to Sheller (2018) who argues that focusing solely on the more equitable distribution of goods and opportunities is insufficient for promoting mobility justice. Rather, those pushing for a more just society, should look to promote five different types of justice: equitable distribution of goods and opportunities, fair inclusion in the deliberation, an inclusive decision-making process, the restoration of previous harms, and equality among different epistemic perspectives. Though Sheller uses the term "justice" and is arguing for the kind of social transformations that align with my definition of the term, I find that the five types of justice can be easily translated into types of equity. The key difference, according to the definition that I presented, is who advances these priorities and how they are advanced. If advanced through agency driven initiatives, then they are a part of equity planning. Some of these types will necessarily be more difficult to advance in such a manner. For instance, it will be more challenging for government agencies to value different epistemic perspectives without radically rethinking how they operate.

Distributive equity refers to promoting a fairer distribution of goods and opportunities, with a particular focus on ensuring greater opportunity for those who have the least. Within scenario planning, promoting distributive equity begins with ensuring that the trends and driving forces include social and political structures that shape current unequal distributions. This would in turn inform scenarios that demonstrate how current forces can shape future distributive outcomes. The stakeholders should select and evaluate policies to address the distribution of goods in each scenario. The regional planning organization should develop and deploy tools that can assess the distribution of key measures across different racial identities and other key equity groups (Avin et al., 2014).

Deliberative equity is the fair inclusion of racialized or other marginalized communities in planning processes. BIPOC populations should be included proportionately to their share in the regional population or greater. Planners can also look for the inclusion of equity-focused community leaders, identified for their visible role as leadership in social justice non-profits and movements (Twaddell et al., 2016). To ensure deliberative equity the scenario planning group should also ensure that equity is a focused topic of conversation within each stage of the planning process.

Procedural equity is crafting the planning process such that impacted communities can participate as equals. This includes access to information, informed consent, and local understanding, as well was specific procedures to guide deliberations towards racial equity. Within the scenario planning process, planners could employ an equity-focused working group within the larger stakeholder body. Their job would be to ensure that equity is considered in each phase of the process. To achieve procedural equity, the planners should also seek to engage BIPOC communities outside of the stakeholder room in scenario development and utilization.

Restorative equity requires admission of responsibility for harms, truth and reconciliation, and finding ways to make reparations. As scenario planning focuses on external trends and forces in the early stages, they should be clear about actions taken at the local and regional level that reinforced these systems of structural oppression. The scenarios narratives should not be 'blameless'. Rather the scenarios can be an opportunity to name forces of racism, capitalism, and colonialism, and those who tacitly support those systems, as drivers of inequality and worse outcomes for everyone. In the final stages, the stakeholders can suggest and test reparational policies for their region.

Epistemic equity is the recognition of BIPOC ways of knowing and looking to BIPOC communities for the generation of appropriate knowledge and facts to reconcile past injustices and present inequities. For scenario planning, seeking epistemic equity would entail genuine co-creation of not just the scenarios but of an entirely novel scenario generating process that centers the BIPOC knowledge. Such reimaging of scenarios might be too much for agency-driven equity planning.

The stages of the scenario planning process

I ground the stages of my framework in the scenario building process presented first in Avin and Dembner (2000) and later refined in Avin (2007). This framework clearly sets out stages in a hybrid scenario planning process and explicitly incorporates values into the selection of scenarios. The mapped-out process (Figure 1) consists of four distinct phases. Prior to planning, the scoping phase determines whether scenarios are appropriate for problems at hand and the political environment. If the scenario process proceeds, two parallel processes identify possible futures according to trend analysis and desirable futures that align with community values. Finally, possible and desirable futures inform indicators, interventions, scenarios, and plans. Testing and evaluation should provide feedback for additional trend and values analyses.

I colored red the stages that I include in my framework for the use of scenario planning to promote racial equity. As many regional scenario planning efforts follow a process that more closely aligns with exploratory scenarios, they rarely employ a parallel values identification process. Without the parallel development of desired futures, the possible futures stage is also not relevant. Nonetheless, the selection of stakeholders and the establishment of goals for the process remains essential for guiding the orientation of public sector scenarios because which stakeholders to include are rarely obvious and their goals are never unified (Avin & Goodspeed, 2020).

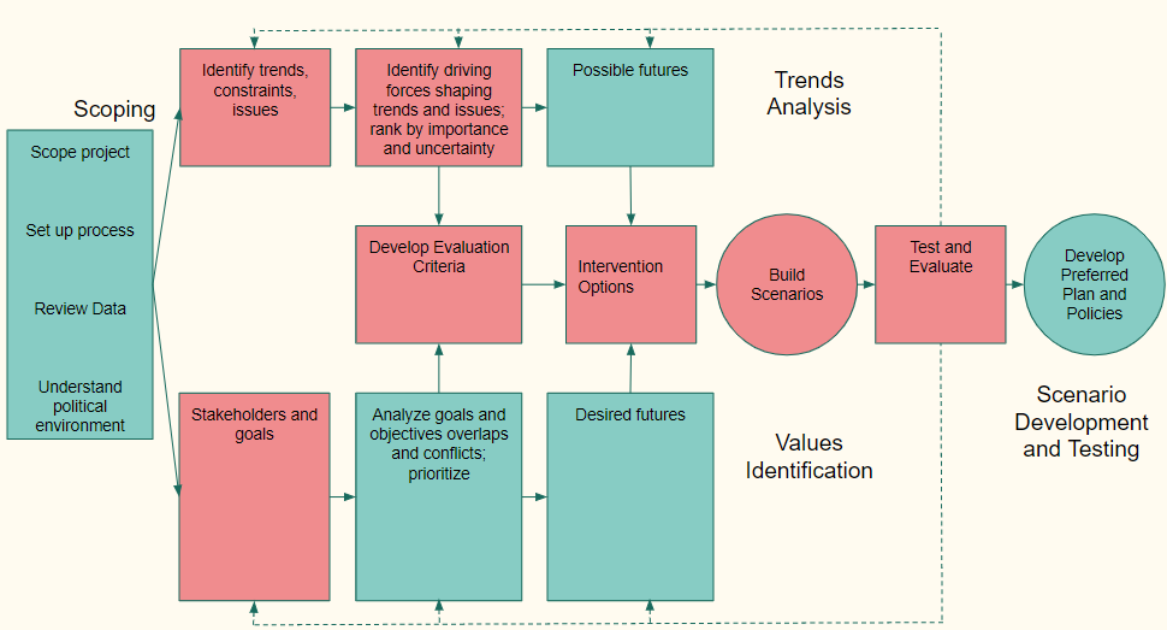

Figure 4.1: The Scenario Planning Process – Steps included in my framework in red

I have also chosen to exclude both the scoping and preferred plan stages of the Avin process. This framework assumes that the scoping has already been completed, and planners have identified scenario planning as a preferred approach and racial equity as an organizational priority. The preferred plans, while influenced by the scenarios, are often distant from many of the immediate scenario planning outcomes. Finally, I do include several stages that are not strictly scenario development: the development of evaluation criteria, the selection of intervention options, and the testing and evaluation of both scenarios and interventions. These activities sometimes take place alongside scenario development, and sometimes after the scenarios are complete. But they are directly related to the use of scenarios to advance organizational goals and thus this framework. Within the framework I also combine the development and deployment of evaluation criteria for simplicity and legibility.

In setting the scope as I have, I am establishing wide boundaries for the development and use of scenarios. I am examining stages, such as intervention evaluation and testing, that are often beyond the immediate scenario development process. However, it is often the case, though not always, that the assembled stakeholders are engaged in these activities. For instance, four of the five scenario planning processes examined by Avin and Goodspeed (2020) directly involved their scenario stakeholders in some form of insight, planning, and strategy development once the scenario stories were completed. Further, in examining the *use* of scenario planning in regional equity planning, I wish to capture the broader ways in which scenarios are used, not simply their development.

Scenario planners agree that ***stakeholder*** groups should be large and diverse across a number of dimensions (Chakraborty, 2010; Swart et al., 2004), but more limited, technocratic stakeholder groups have usually been selected to support actual scenario planning (Bartholomew, 2007; Zapata & Kaza, 2015). In equity planning, stakeholders should disproportionately represent marginalized populations (Xiang & Clarke, 2003), include human service experts to assess how the scenarios impact human service issues (Bartholomew et al., 2010), and include equity leaders (Twaddell et al., 2016), as identified by their leadership role in social justice organizations and movements. The planners should be trained to pay attention to the actual influence in the room – not just the overall representation – or they should bring an appropriate external expert in managing power dynamics (Twaddell et al., 2016). And though a limited stakeholder group is often required, scenario development should be participatory and engaging of the broader public (Avin & Goodspeed, 2020; Bartholomew et al., 2010; Chakraborty, 2010).

In the trend analysis, planners need to drop the myth of rationality. What are considered ***trends, constraints, and issues*** are dependent on what communities' value and prioritize. Though the same trends might exist more broadly, those trends that stakeholders prioritize are dependent on which ones are impactful in their lives. For instance, suburban commuters might emphasize vehicle automation as an important trend, while a resident of a dense inner core neighborhood might not. What uncertainties matter, and what issues those uncertainties threaten to upset, is highly dependent on one's socio-economic position (Marris, 2003). Racial equity planning also encourages a deeper examination of the causes and constraints of poverty (Zapata & Bates, 2017), housing insecurity (Berbés-Blázquez et al., 2021), transportation accessibility inequalities (Martens, 2017), and unfair labor markets (Clark & Christopherson, 2009) among other issues.

The causes and consequences of poverty should be central among the ***driving forces*** (Twaddell et al., 2016; Xiang & Clarke, 2003). Equity planning should address the root causes of inequity (Krumholz, 1982), and scenario planning can alert stakeholders to these forces (Schulz, 2015). To be clear, the scenario should still prioritize external driving forces, but there are many external forces of inequality that regional planning can consider. This includes structural racism, colonialism, and federal government policy. In looking forward to more equitable futures, planners should revisit the historical institutional structures that caused and continue to reproduce racial inequity (Frick et al., 2015). Racial inequity should also be emphasized as a cause of larger democratic dysfunctions (McGee, 2021).

Intervention options should be specific and designed to address equity. They should include actionable policy, not just further studies (Zapata & Bates, 2017). The scenarios can help to highlight and test equity-oriented policies (Goodspeed, 2020). Policies can be later examined qualitatively and quantitatively by considering how they play out within each scenario (Avin, 2007).

The ***scenario narratives*** themselves are an opportunity to richly illustrate plausible futures for the region. The best scenarios are emotionally interesting and connect with issues that are important to communities (Xiang & Clarke, 2003). Richly imaginative stories (Sandercock, 2004) could aid the broader community in better understanding the underlying forces causing racial inequities. They can also generate hope for solutions (Zapata, 2021). Equity concerns should be woven throughout all scenarios to illustrate the equity

consequences of all driving forces, but single scenarios could capture pathways and outcomes of more and less equitable future (Trombulak & Byrne, 2022). The intention is not to slip into a more normative approach to scenarios, in which stakeholders select a preferred outcome among the scenarios because that scenario is more equitable. Rather, the intention is to illustrate how the driving forces have real racial equity consequences and may necessitate different local responses. Person-oriented narratives can increase the relatability and emotional resonance of scenarios (Zapata, 2007).

Racial **equity *evaluation criteria*** with specific outcomes and metrics (Zapata & Bates, 2017) should be included in all regional equity planning. Some indicators, such as the percentage of families that are housing/transportation cost burdened, can serve as direct measures of equity (Avin et al., 2014; Knaap et al., 2020). Others might prefer weighted composite factors (Holway, 2012). Opportunity mapping and social vulnerability mapping tools are a spatially meaningful, and theoretically grounded, way to understand the equity implications of scenarios (Avin et al., 2014; Goodspeed, 2017, 2020; Knaap et al., 2020). The analysis should also be able to measure the distributional impacts across different populations (Bills & Walker, 2017; Jones & Lucas, 2012; Karner et al., 2018). Clear and ambitious targets should be established: to minimize disparities (Martens, 2017), to ensure everyone meets minimum capabilities (Pereira et al., 2017), or address historic disparities (Frick et al., 2015). ***Scenario testing and evaluation*** examines the impacts of scenarios by themselves as well as the impacts of policies through the lens of the scenarios. This applies the previously developed indicators and normative standards. The technical tools need to be able to produce equity outcomes (Zapata & Bates, 2017). Data and analysis should provide a starting point, but qualitative assessment will always be central in understanding how such disparate futures play out (Avin et al., 2022). Scenarios could prove as a critical check on equity policies – determining which ones are robust to changing circumstances, and which ones make advance equity in only limited conditions (Avin, 2007).

The three outcomes of using scenarios is racial equity planning

The three outcomes of using scenarios, as introduced above, are organizational learning, organizational strategy, and community learning. As different scenario planners intend to utilize their planning efforts to different ends, I wanted to ensure that the framework can be used to promote equity in any preferred outcomes. Because there is little evidence of creating and using scenarios with intention towards promoting racial equity, this section extends some of the ideas in the two previous subsections a little bit further.

If organizational learning is the intended outcome, then scenario planning can be used to inform the board and planning staff regarding the underlying causes and deep consequences of systemic racial inequity. Planners can cultivate a process that brings together in the room BIPOC community members and equity leaders alongside the board and other key organizational decision makers. Procedurally, the planners guide discussions towards those trends and uncertain driving forces that are causing present inequities and will determine whether the region moves into a more equal direction in the future. In preparing creative but coherent stories around these themes, organizational decision makers are asked to consider how structural forces operate to reinforce racial inequities. The focus on organizational learning naturally manifests in a process more focused on the stakeholder selection through scenario development, with less emphasis on interventions and evaluation.

If organizational strategy is the intended outcome, then the emphasis of the scenario planning should be on identifying robust and contingent strategies to promote racial equity. Planners would want to focus the planning process on distributive and restorative equity in the selection, testing, and evaluation of interventions. They should also examine equity impacts of policies that are nominally racially agnostic. In order to perform these tasks well, the planning staff also needs tools that can assess the distributional impacts of policies. If the staff is unable to produce distributive measures of scenario and intervention outcomes, then

they could consider drawing on the lived expertise of BIPOC people and advocates to understand which policies will advance equity for their community within each scenario.

If organizational community learning is the intended outcome, planners can utilize the scenarios to engage community members regarding equitable futures. Planning organizations interested in supporting community learning should be particularly focused on deliberative and procedural justice early on in the process. In particular, scenario planners should develop approaches for bringing communities into the scenario planning process from the very early stages. This would include sourcing trends, issues, and driving forces in and with communities of color, then recruiting them to aid in the storytelling process. Naturally, only a small subset of any regional population can ever participate in any public process, but robust engagement with a few communities in the development of scenarios could deliver a final product that is more compelling to BIPOC communities.

The Complete Framework

I bring the framework together in figure 2. The stages of the scenario planning process are laid out across the top. Arrows run across each of the stages representing the five types of equity that the planners are seeking to promote through the scenario planning. The reader can also imagine this portion of the framework as a 5x6 matrix as presented in Appendix A. In each cell, I locate a specific recommendation for the use of scenarios for equity planning. For instance, in order to promote distributive equity in the driving forces stage, scenario planners should instruct stakeholders to identify driving forces impacting the distribution of goods and opportunities between different racialized populations. In order to promote procedural equity in the scenarios, they should be written with community members in language that is meaningful to them. See the appendix for the full table.

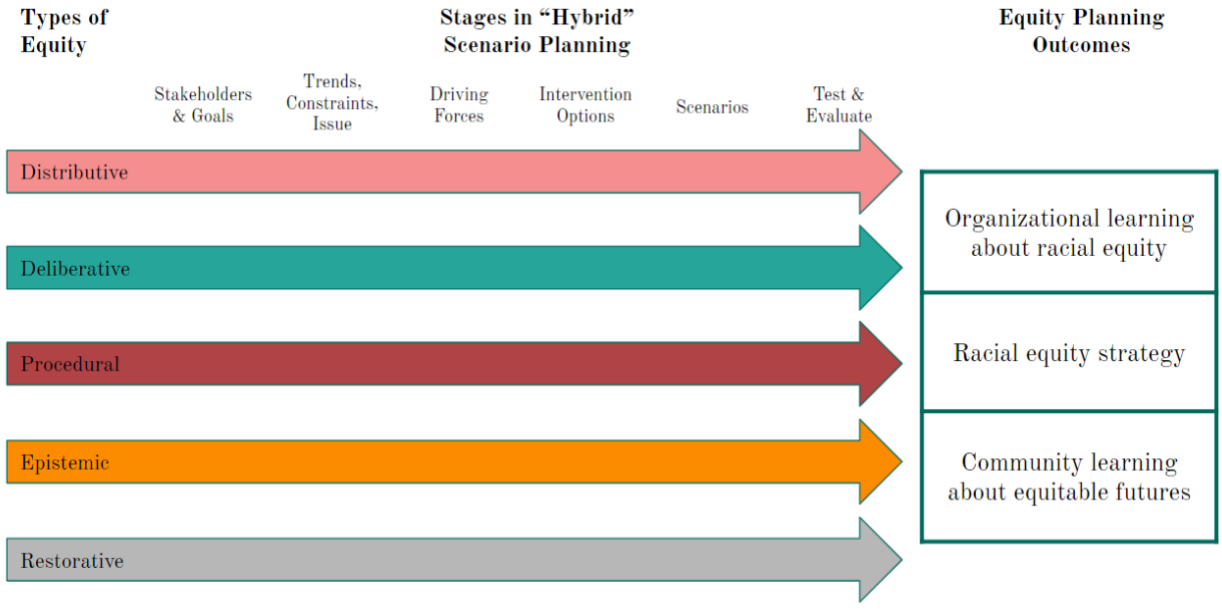

Figure 4.2: A framework of the use of scenarios in equity planning

The Context for the Case

The following section introduces the context for the case to which I apply the framework. As DVRPC is MPO for greater Philadelphia, I first review the history of racial inequity in the region as well as some of the present conditions. I then introduce DVRPC more thoroughly, with a particular focus on their scenario planning and equity planning activities. Finally, I introduce *Dispatches*. In later sections, I will explain why the use of *Dispatches* by DVRPC is a paradigmatic case for my research question, introduce my methods of analysis, and apply the framework.

Racial Inequity in the Philadelphia Region

Contemporary racial inequities in Greater Philadelphia have roots in settler colonialism. Thomas Penn, son of William Penn, reneged on his father's agreements with Indigenous peoples and commenced centuries of dispossession. The modern metropolitan area is now home to 13,000 Indigenous residents. The Lenape and Nantego, on whose unceded lands Philadelphia lies, are recognized tribes in New Jersey and Delaware but many members are displaced to Oklahoma (Nanticoke and Lenape Confederation, 2021).

Swedish colonizers brought the first African enslaved people to Philadelphia in the mid-17th century. Though many Quaker founders of the city opposed slavery, the institution was integral to developing the region. By 1710, enslaved people constituted nearly twenty percent of the city's population. With a strong abolitionist movement, slavery was largely phased out prior to the civil war but both escaped enslaved people and free Black people were in danger of kidnapping due to the fugitive slave act and proximity to the southern states. Philadelphia's industrial base also relied on raw goods extracted from slave economies (Gigantino, 2021).

Abolitionist support and the civil war only brought forth new forms of racial inequity in Philadelphia. Planning played a central role in enforcing this inequity. With industrialization and southern terror, Philadelphia became a major destination for families in the great migration. They arrived in a city that enforced residential segregation in squalid and unsanitary conditions (Du Bois, 2010). Restrictive covenants, redlining, exclusionary zoning, and outright acts of terror maintained the status quo (Hillier, 2003; Rhynhart, 2020). Jurisdictional fragmentation allowed whiter, wealthier communities to draw employers and tax dollars (Rothstein, 2018). Highways displaced Black communities and the transit network never kept up with job dispersal (Zuk et al., 2015). These inequities and injustices remain inscribed in communities to this day, impacting Black people as well as more recent Latinx, Asian, and other racial populations (Potter, 2022; Shukla & Bond, 2021).

Table 4.1: Racial and poverty Demographics in DVRPC counties (U.S. Census Bureau, 2022)

	POPULATION	ASIAN ALONE	BLACK ALONE	WHITE ALONE	HISPANIC	% OF REGIONS NON-WHITE POP.	% IN POVERTY
PENNSYLVANIA							
BUCKS	646,538	5.4%	3.9%	80.7%	6.2%	5.1%	6.5%
CHESTER	534,413	6.6%	5.3%	75.9%	8.1%	5.2%	6.6%
DELAWARE CO	576,830	6.3%	22.0%	63.0%	4.6%	8.7%	10.1%
MONTGOMERY	856,553	7.9%	9.3%	72.2%	6.4%	9.7%	7.0%
PHILADELPHIA	1,603,797	8.3%	38.3%	34.3%	14.9%	42.8%	22.3%
NEW JERSEY							

BURLINGTON	461,860	5.6%	16.2%	63.8%	8.7%	6.8%	7.6%
CAMDEN	523,485	6.2%	18.2%	53.3%	18.2%	9.9%	12.0%
GLOUCESTER	302,294	3.1%	10.4%	74.5%	7.3%	3.1%	7.7%
MERCER	387,340	12.5%	19.5%	43.5%	21.7%	8.9%	10.4%
TOTAL	5,893,110	7.2%	19.5%	58.2%	10.9%	N/A	12.3%

The Philadelphia region remains segregated, with BIPOC households experiencing worse quality of life across a variety of indicators. Over 42% of the region's non-white population lives in Philadelphia (Table 1). Outside the city, the non-white population remains highly clustered, particularly in Trenton (49.1% Black, 36.7% Hispanic), Chester (71.9% Black, 9.0% Hispanic), and Camden City (42.9% Black, 52.8% Hispanic) (Figure 3). While it is difficult to locate inequality data at the regional scale, data at local levels is informative as those four jurisdictions house the majority (50.2%) of the region's non-white residents. Census data established that households in each of these jurisdictions have lower incomes, higher poverty rates, lower home values when they own, and lower educational attainment (Table 2). In terms of transportation – DVRPCs central mandate – 14% of Black workers and 6% of Hispanic workers took transit to work as opposed to 2% of white workers, a significant inequity in a region where the average travel times to important destinations are often 2-3 times longer by transit for people in poverty (TransitCenter, 2021; U.S. Census Bureau, 2022)

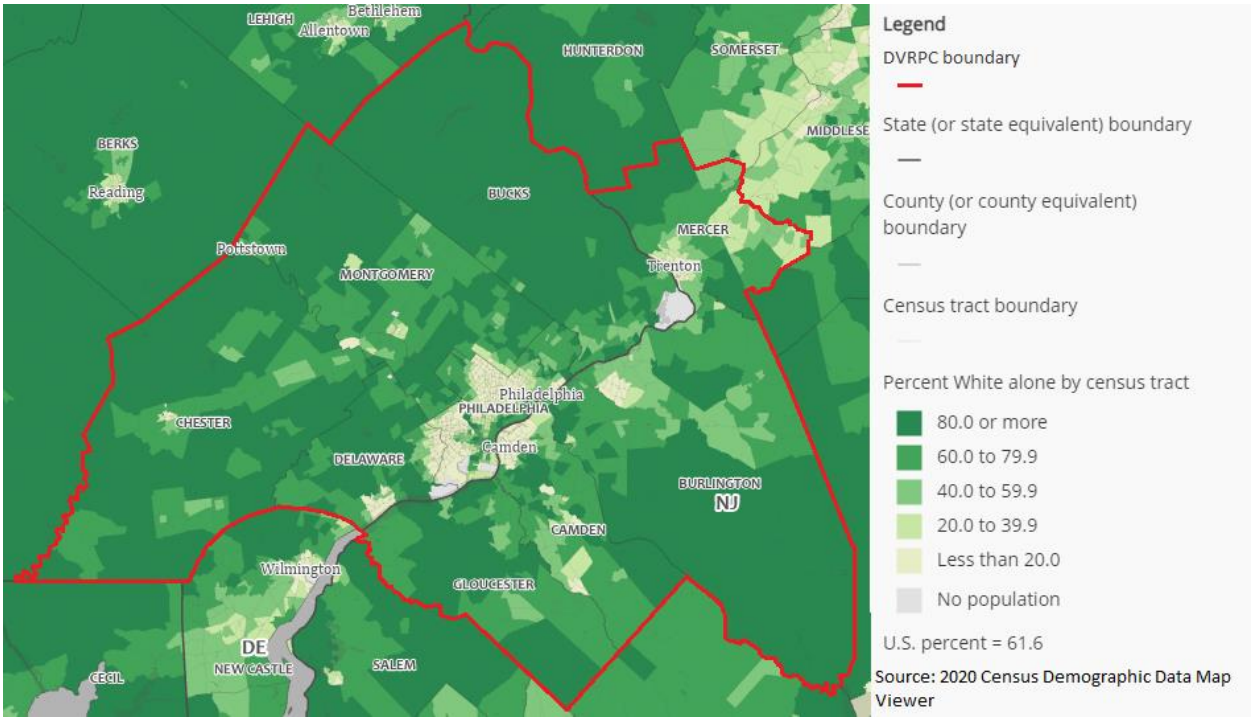

Figure 4.3: Map of percent white alone by census tract in DVRPC

Table 4.2: Census indicators for four DVRPC jurisdictions with majority of regions non-white population (U.S. Census Bureau, 2022)

INDICATOR	PHILADELPHIA	CHESTER	CAMDEN	TRENTON	STATISTICAL AREA
MEDIAN HOUSEHOLD INCOME	$52,649	$35,751	$30,247	$39,718	$80,007
PERSONS BELOW POVERTY LINE	22.80%	28.50%	33.60%	27.70%	12.30%
MEDIAN VALUE OF OWNER-OCCUPIED HOME	$184,100	$71,300	$85,800	$96,700	$300,000
HIGH SCHOOL GRAD OR HIGHER	86.60%	85.00%	68.40%	75.50%	91.90%

The Delaware Valley Regional Planning Commission

DVRPC is the MPO for the greater Philadelphia region covering the City of Philadelphia and four counties each in Pennsylvania and New Jersey (Figure 4). Federal legislation requires that every United States region possess an MPO to aid in planning for and dispersing federal transportation funding. MPOs are required to produce continuing, cooperative, and comprehensive long-range (15-30 year) every three to four years. These board-approved plans set the regional vision as well as establish a list of priority projects of regional importance as constrained by fiscal projections for state, local, and federal funding. It's within the context of long-range planning activities that federal legislation encourages scenario planning. DVRPC considers scenario planning to be an essential step in their long-range planning process, as detailed in the following section. MPOs also produce the 5-year transportation improvement program, which is a list of projects that the MPO intends to fund in the next five years.

In addition to transportation planning, DVRPC is empowered by the two state governments to plan for related regional priorities. The organization's vision, "for the Greater Philadelphia Region is a prosperous, innovative, equitable, resilient, and sustainable region that increases mobility choices by investing in a safe and modern transportation system; that protects and preserves our natural resources while creating healthy communities; and that fosters greater opportunities for all" (DVRPC, 2021a). This mission is advanced under the guidance of the board consisting of one representative from each county, one each from Philadelphia, Camden City, Chester City, and Trenton, and three from each state government. Supporting the board is a staff of over 100 transportation planners, community planners, analysts and other staff.

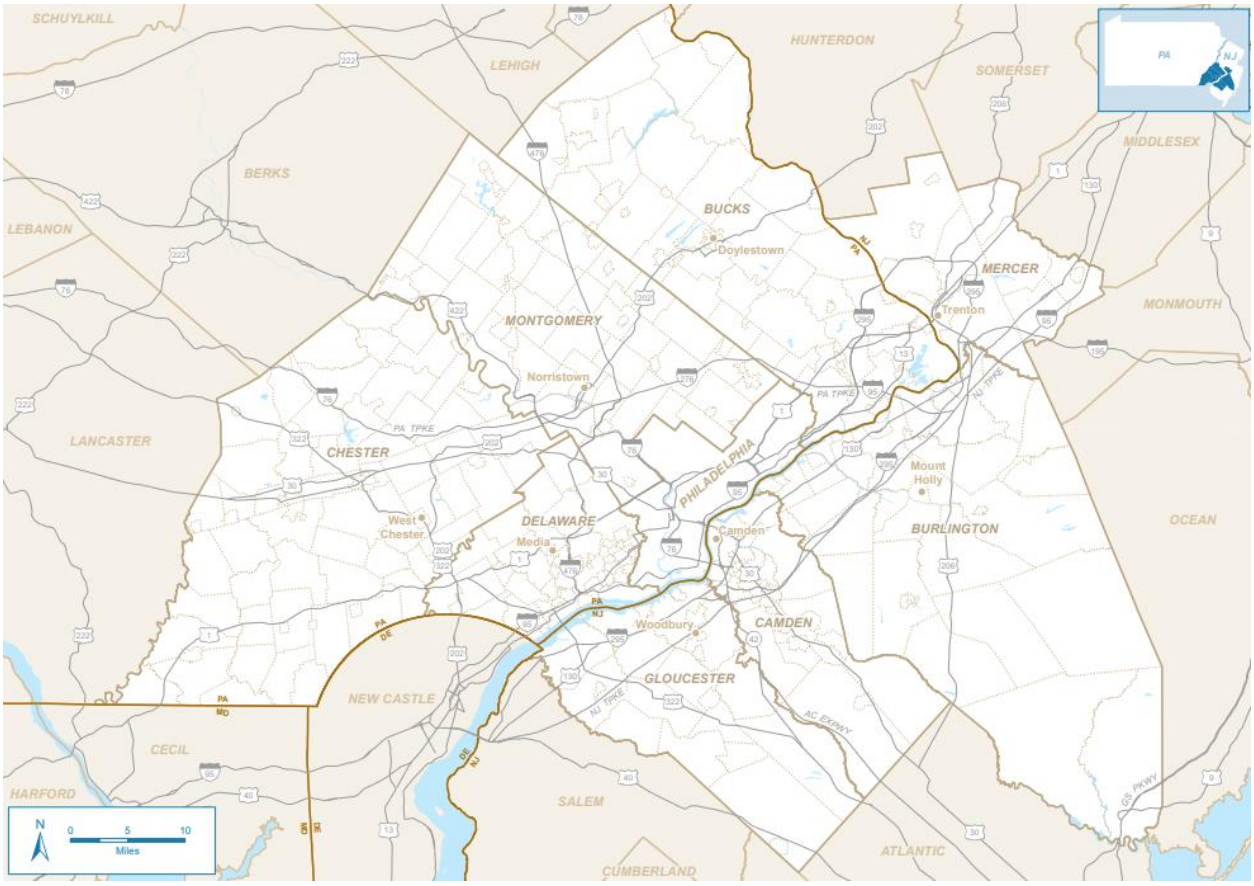

Figure 4.4: Map of DVRPC region

The actions of any MPO with respect to equity always take place within the context of federal requirements. Regulations require analysis for equity impacts of planned transportation investments as guided by Title VI of the Civil Rights Act of 1964, which ensures the fair distribution of benefits to marginalized populations, and environmental justice guidelines stemming from Executive order 12898, which protects against disproportionate harms. According to the Federal Department of Transportation, these regulations are to apply to both the processes and products of planning (Martens & Golub, 2021). MPOs must meet these minimum requirements but are also welcome to exceed them. While the guidelines leave much to interpretation, MPO documentation of equity action has generally focused on the process of developing the long-range plan and the impacts of projects within the plan. Scenario planning has not been incorporated in any MPO equity analysis to my knowledge, including at DVRPC.

A History of Scenario Planning at DVRPC

Long-range planning at DVRPC adheres to a four-year planning cycle that culminates in the production of the federally mandated 20-year plan. The most recent long-range plan, *Connections 2050*, presented the process as a four-stage cycle: evaluation, vision, strategies, and decision making (Figure 5). Trends and forces are represented as feeding the visioning stage alongside the evaluation of the previous long-range plan. Scenario planning is officially represented as a component within the trends and forces analysis. Scenarios aid DVRPC in grappling with future uncertainty in conjunction with the projection of more predictable drivers of change (e.g. aging population) (DVRPC, 2021a).

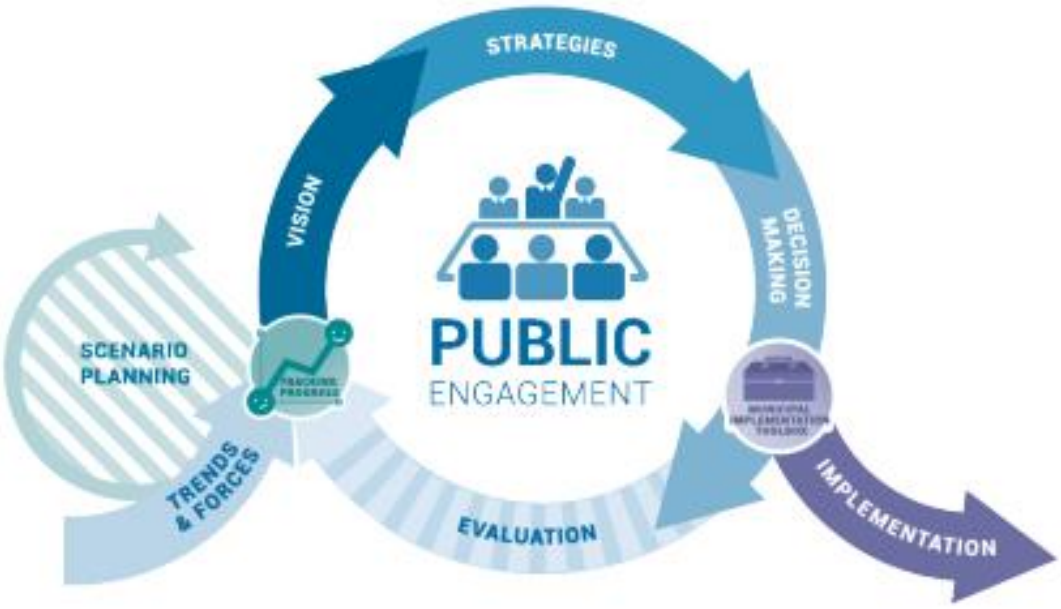

Figure 4.5: DVRPC long-range planning cycle from Connections 2050

Whenever DVRPC returns to the scenario stage in the planning process, they either develop new or deepen existing scenarios. This began in 2003 with the *Regional Analysis of What-If Transportation Scenarios* (DVRPC, 2003). The creation of the "Futures Group" in 2014 – a quarterly stakeholder group that supports ongoing examination of long-range trends shaping the region – launched a new era of more sustained and focused scenario planning at DVRPC. Their first scenarios, *Greater Philadelphia Future Forces* informed the *Connections 2045* long-range plan, completed in 2017. This planning effort didn't result in full narrative scenarios – rather it pointed to some outside driving forces of high uncertainty and concern (DVRPC, 2016).

Connections 2045 set forth the prevailing planning vision for DVRPC when they were preparing *Dispatches*. The vision consisted of five principles: sustain the environment, develop livable communities, expand the economy, advance equity and foster diversity, and create an integrated multimodal transportation network. *Dispatches*, a set of explicitly exploratory scenarios which presents four scenarios emphasizing the influence of technology, climate, and equity, initiated the planning process for *Connections 2050,* which was approved by the board in 2021 (DVRPC, 2021a). In 2022-2023, DVRPC decided to continue with *Dispatches* scenarios for the next round of scenario analysis because, as planners indicated in interviews, they believed that the themes were still relevant (Figure 6).

Figure 4.6: Timeline of DVRPC scenario and long-range planning activities

With respect to formal MPO requirements, the primary purpose of DVRPC scenarios is to inform strategic suggestions in the long-range plan. Both the *Connections 2045* and *Connections 2050* include sections on the previous round of scenarios. The sections briefly cover the findings of the scenarios, universal strategies applying to all scenarios, and "scenario-specific" or "adaptive" strategies informed by each scenario. These strategy suggestions were directly informed by input from the futures group as part of the scenario planning phase of the DVRPC long-range planning cycle. In the case of *Dispatches*, I look primarily to Futures Group meeting minutes as activities taking place within the scenario planning process. The strategic recommendations within the long-range plans have processed the Futures Group input through layers of staff and board judgment.

DVRPC does not use scenarios in modeling, project selection, or any other formal requirements analysis. The quantitative measures in *Dispatches* are provided by the Impacts 2050 systems dynamics model. While this tool is useful in illustrating the scenario impacts it is not a part of the formal modeling toolset used to meet federal requirements for long-range plan analysis. That toolset includes a 4-step transportation model for estimating travel demand and network utilization, and the UrbanSim land use model for projecting land use change, and the Motor Vehicle Emission Simulator for modeling air quality. Similarly, the specific projects in the long-range plan are not assessed through the lens of each scenario in order to understand whether the projects are robust or contingent to outside driving forces. Finally, the scenarios play no role in any other formal requirements, such as Title VI, environmental justice, or air quality conformity determinations.

The Futures Group includes representatives of DVRPC, local/county government, state agencies, developers, businesses, advocates, higher education, and grass-tops nonprofits. In addition to their role in scenario development, the Futures Group hosts speakers, panels, and workshops designed to highlight emerging forces or stimulate thinking about the future. These events provide attendees intelligence to bring back to their own organizations and provide DVRPC staff with deeper perspectives on elements of the long-range plan. One example is the recent report: *Preparing Philadelphia for Highly Automated Vehicle Deployment* (DVRPC, 2020b).

A Commitment to Equity in Planning

To understand the equity planning context of *Dispatches*, I look to the two most recent long-range plans. As previously indicated *Connections 2045* – the plan in place when Dispatches was authored – included advancing equity and diversity as one of the planning principles in the vision. The four goals under this principle address equitable access for vulnerable populations, age-friendly communities, childhood access to good schools, and a commitment to development without displacement. *Connections 2050,* elevated equity to one of three cross-cutting principles, alongside sustainability and resiliency, to be applied to the four focus areas: the environment, communities, multimodal transportation, and the economy. In addition to the federally required equity and EJ analyses, equity is mentioned throughout the plan including sections on education, housing, and transportation. In the long-range plan and the transportation improvement program, equity constitutes 12% of project benefits evaluation criteria. This is scored based on whether projects serve census tracts with a high "Indicator of Potential Disadvantage communities" score (DVRPC, 2021b).

Consistent with the new cross cutting approach, equity is apparent in several MPO activities. The Indicators of Potential Disadvantage tool utilizes age, gender, race, language, disability, and income to spatially identify communities that meet the federal definition of target populations. The tool is publicly available and they utilize it in a variety of additional analyses such as determining where to prioritize intersection safety investments. Interviews with staff at DVPRC indicate that the organization had many conversations during and after the 2020 uprising for racial justice regarding their role in perpetuating racial injustice, and have since

expanded equity planning activities with the support of the board. For instance, DVRPC has also initiated surveys and focus groups to better understand the mobility opportunities and choices of people of color.

Dispatches from Alternate Futures

Dispatches was initially prepared from the spring of 2019 through to the summer of 2020. More than the previous efforts, these scenarios resemble the idealized exploratory scenario structure (Schwartz, 1991). The scenarios are fully developed stories, built from a collection of key uncertainties. The presentation – news stories written from future dates – is designed to alert, engage, and enhance plausibility. The scenarios also include signposts to help in identifying which direction the region is headed. The long-range planning staff also developed videos for each scenario that they have used in public outreach. The publication does not include strategic or policy analysis, but the use of the scenarios in such analysis is included in *Connections 2050*.

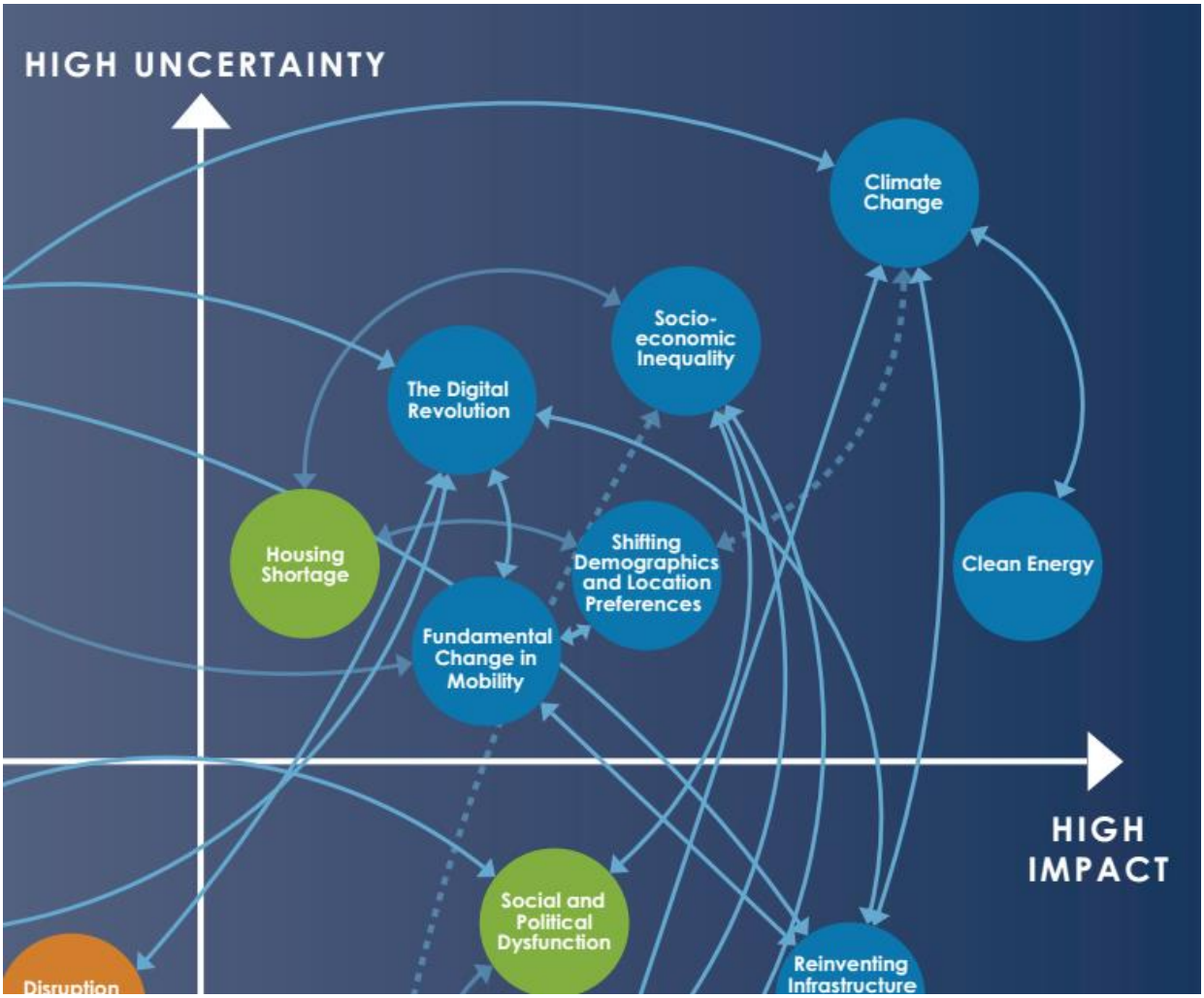

Figure 4.7: High uncertainty, high impact forces in Dispatches

As is typical in scenario planning, the stakeholders suggested critical forces impacting the region and then ranked each of the finalists in terms of the depth of uncertainty and the potential impact on the future of the region. The upper right quadrant of the chart with all the forces is shown in figure 7. The Futures Group included housing shortages and socio-economic inequality among the high impact/high uncertainty forces,

alongside forces related to climate change, changing technology, and demographics. From these forces, the long-range planning team crafted, with stakeholder feedback, four scenarios defined by three primary driving forces. Scenarios are first defined by either incremental or transformative changes in technology. They are additionally defined by whether political will and collective action are sufficiently powerful to address climate change and equity issues at the national level. Within the plan equity primarily refers to socio-economic equity but particular scenario stories touch on the linkages between socio-economic and racial equity. (DVRPC, 2020a).

Dispatches is primarily utilized to inform the DVRPC long-range plan. Since completing the scenarios, DVRPC has used the scenarios to guide four strategic discussions with the Futures Group and five strategy workshops with the general public. Workshop activities have included imagining threats and opportunities, crafting new scenario headlines, and suggesting strategies specific to each scenario. The five public workshops each had a particular topical focus including a February, 2021 workshop using the scenarios to examine strategies for equity and civic engagement. The workshops that took place prior to *Connections 2050* directly informed the strategic recommendations in the plan.

Applying the Framework

Paradigmatic Case Analysis

The use of *Dispatches* is a paradigmatic case for applying the framework because of the quality of the plan and the direct inclusion of equity (Flyvbjerg, 2006). *Dispatches* is the product of a state-of-the-practice regional scenario planning process. The organization, and the planners on the project, have a long, well-respected history of scenario planning. They are also supported by a standing working group, an institution that might be unique for regional scenario planners. The process and products resemble idealized exploratory scenarios. *Dispatches* is also advantageous as a case because their commitment to equity is evident both outside and within the scenarios. The application of the framework would provide little insight if applied to a scenario plan that lacked any equity component.

The qualitative data for this case includes semi-structured interviews with DVRPC staff and stakeholders, review of planning documents, and participant observation. The interviews were collected over two periods of time. First, I completed twenty interviews in January of 2020. Though these interviews addressed racial equity they also explored perspectives on other topics of research interest such as the use of models and implementation. I completed another twelve interviews in July through September of 2022 – this time with a focus on racial equity. Through both visits, I conducted nineteen interviews with twelve different DVRPC staff, including all staff that were involved in scenario planning. I additionally conducted fourteen interviews with thirteen Futures Group members. Seven of those interviews were with individuals whom I identified in my stakeholder analysis (described below) to have professional interest in advancing equity.

Dispatches serves as the central document in my analysis. Associated with the report itself are the archived agendas, minutes, and slides. The *Connections 2045* and *Connections 2050* long-range plans inform and are informed by the scenarios. The long-range plans were examined primarily where they mentioned equity and/or scenarios. Finally, I explored the broader universe of DVRPC materials to better understand the organization's action and messaging around racial equity.

Observations were performed in person and remotely. When I was in Philadelphia completing interviews, I was offered a desk at DVRPC and the opportunity to sit in on some long-range planning meetings. I attended a Futures Group meeting in person during my first visit and three remotely following my second visit. I also

have attended three DVRPC board meetings online. The public posting of videos of some board and Futures Group meetings after the pandemic started has allowed me to view them at later dates.

The data I collected was coded according to the equity framework. Each mention of equity planning was coded for the equity topic and the stage in the scenario planning process. I subsequently went through and assigned the data to each framework element to build summaries of what DVRPC did and how they did it. Finally, I synthesized these summaries relative to the practices indicated within the framework.

Finally, I performed a stakeholder analysis because having sufficient people of color and equity-oriented stakeholders as part of the scenario planning is necessary, albeit not sufficient, for deliberative equity. *Dispatches* identifies 108 individuals as members of the Futures Group. I researched each individual and the organization that they were named to represent through publicly available sources. I then assigned each Futures Group member to an organization type and to "sustainability focus areas". Organization types included: DVPRC, higher education, business services, planning advocates, etc. I derived the sustainability focus areas from Campbell's three Es: equity, economy, and environment (Campbell, 1996). Individuals could be assigned to none, one, or multiple of these categories if their professional profile indicated that they worked in or were interested in the focus area. While this paper is not about sustainability, I utilized the three Es because they provided a simple way to compare the number of equity-focused stakeholders with similarly broad interest categories.

Applying the Framework to the use of *Dispatches*

In applying the framework, the following section primarily summarizes how *Dispatches* is used to support racial equity planning through the lens of the five types of equity. In the process I touch on various stages of scenario planning. For the sake of brevity, I do not address all thirty combinations of equity type/planning stage (see Appendix B for complete summary). To conclude this section, I summarize how *Dispatches* is used and not used to promote racial equity planning outcomes.

Distributive

Distributional concerns are present throughout nearly all stages for creating and using *Dispatches*. In the early stages of the process, the Futures Group identified several forces related to distributional equity including the housing shortage and socioeconomic inequality. In determining which themes should advance into driving forces, the stakeholders elevated these two forces with five others as having the highest uncertainty and impact. Following exploratory scenario procedures, socio-economic inequality, was selected as one the of three structuring forces determining the scenarios, sharing an axis with climate change (Figure 8). Narratively, two of the scenarios are then defined by the presence of political will and collective action for greater equity and climate policy, while two of the scenarios are defined by the dominance of market forces and individual responsibility. The process, from analysis of forces through the development of scenarios created a space for

Futures Group members to discuss how socio-economic inequity is already impacting the region and the potential impact of different equity trajectories.

Figure 4.8: Key driving forces and the four scenarios in dispatches

The scenario narratives also highlight some of the potential external causes and solutions for racial inequity. Specifically *Dispatches*, in the introduction and the scenarios, indicates that socio-economic inequity and lack of government safety net programs exacerbates racial divisions. The scenario stories also indicate that social movements have the power to drive policies that address structural inequities, even citing Black Lives Matter at one point.

The strategic suggestions that resulted from several workshops included many suggestions for equitable transportation, housing, schools, and technology policies. While the strategic suggestions, which are often less

than a full sentence, are too brief to determine clear normative goals for these policy areas, their inclusion suggests an appetite for redistribution strategies.

A clear shortfall in terms of distributional equity is in terms of evaluation. *Dispatches* plan does include several quantitative and qualitative summaries of the scenarios. None of the quantitative indicators can serve as either direct or distributional measures of racial equity. Nor are the scenarios geographically specific in a manner that would enable opportunity mapping. The scenario indicators do include the percentage change in non-white and low-income households from 2015-2040, but they do not assess the distribution of any benefits or burdens between the white and non-white population. The plan also includes the percentage change in low, medium, and high-income households. This provides a sense of growing or shirking poverty, but also fails to capture the quality of those lives. Additionally, none of the specific policies were evaluated systematically for their impacts on any of the regional priorities. Rather the plan advanced those strategies that received the most up-votes from individuals the any strategy workshops.

Deliberative

In determining the degree to which the use of *Dispatches* advanced deliberative equity, I primarily use the stakeholder analysis, because the development of a diverse and representative stakeholder group is central to equitable deliberations. Specifically, I look to my assignment of sustainability focus areas according to their online presence. I found the Futures Group included 11 equity-oriented stakeholders, 27 environmentally oriented stakeholders, and 26 economy-oriented stakeholders. While there is doubtlessly a large margin of error in assessing an individual's priorities based on their online presence, the relative paucity of equity-oriented stakeholders is significant enough to overcome any hesitations that I would have in drawing conclusions from this analysis. Even though equity made it into *Dispatches* as a driving force, the presence of equity voices was limited. This is particularly concerning when the utilizing of randomized breakout groups could create groups without one of these voices.

My concern for the lack of racial equity voices in the room was reinforced by the lack of racial diversity as well. Four of the external stakeholders I spoke with, including one that I did not identify as equity-oriented, indicated concern regarding the lack of racial diversity in the Futures Group session that they attended. This observation is affirmed by DVRPC staff that indicated they tried to recruit greater diversity and had fallen short of their targets. In recent Futures Group meetings that I attended, diversity has increased from earlier ones.

Procedural

Given the relative lack of equity-oriented stakeholders and BIPOC people in the Futures Group, DVRPC can elevate the voices and racial equity priorities through procedural structures. One way of doing this is by reminding stakeholders that racial equity is a regional priority in all stages of the planning process. In the initial scenario planning meeting, the Futures Group were instructed to focus on themes, forces, and scenarios impacting that could, "impact the region's ability to achieve its vision" (DVRPC, 2019). The DVRPC staff leading the exercises were consistent in reminding the Futures Group of that full vision, including the equity component, before each workshop. As the vision shifted in *Connections 2050* to equity as a cross cutting concern, messaging shifted accordingly (DVRPC, 2020d). The number of slides and the depth of description used to reintroduce the vision varied from one meeting to the next and they never provided a clear definition of equity goals or target populations to guide the stakeholders.

Each stakeholder was left to define equity according to their own perspective and to prioritize equity within the workshop exercises according to their interests. For instance, at one of the workshops, the breakout

groups were instructed to provide strategic recommendations for advancing regional priorities within each scenario. The volume and specificity of equity recommendations varied tremendously from one breakout group to the next, as detailed more in the section on outcomes. The interests and priorities of the randomly assigned breakout group members may have contributed to this variance. In interviews with stakeholders, when I asked them about the issues in Philadelphia that kept them up at night, some spoke at length about the region's deep inequities. Others didn't mention any related topic. DVRPC could have mitigated this effect by requiring each group to suggest a certain number of equity-oriented policies.

Procedural equity also includes community engagement procedures and the extent to which impacted communities beyond the stakeholders understood and contributed to the scenario planning. The DVRPC process did not engage external stakeholders until *Dispatches* was a finished document. They then presented the scenarios in videos at strategy workshops in which they hosted breakout groups to determine strategies for each scenario. While I am unable to determine from my data the extent to which community members feel that they understood and contributed to this particular exercise, they clearly played no role in the earlier stages.

Epistemic

Epistemic equity was not a part of the creation or use of dispatches. In order to promote epistemic equity, we would expect DVPRC to partner with BIPOC community members in co-designing all stages of the scenario process. Rather, the scenario planning process was designed and guided by DVRPC planners according to their own research into scenario planning. The lack of epistemic equity is unsurprising given that it would demand radically inclusive revision of scenario planning.

Restorative

The *Dispatches* plan and its later use provide no evidence of promoting restorative equity. In *Dispatches* "Equity is defined as, "the just and fair inclusion in a society where everyone can participate, prosper, and reach their full potential" (DVRPC, 2020a, p. 15). This definition appears to suggest a "sufficiency standard" in which achieving equity is defined by each individual possessing sufficient access to goods and opportunities to fully participate in society (Martens, 2017). While this does not preclude restorative elements, few places elsewhere in the *Dispatches* suggest such a standard. The only mention of restitution occurs in the *People Power* scenario, in which a fictional former public official says, "We had a lot of difficult and honest conversations around systemic racism, social justice, and reconciliation; and how the rules of the game, economic and otherwise, really shape outcomes" (DVRPC, 2020a, p. 50) Though the two more equitable scenarios include a variety of federal policies, none of them are explicitly oriented toward restoring communities after racialized harm. This is in contrast to the Reconnecting Communities Pilot Program initiated by the actual federal government just two years after completion of the scenarios. Similarly, the policies suggested through the strategic exercise include pushing for more equitable transportation, housing, schools, and technology; but no policies suggest addressing past harms.

The racial equity outcomes of Dispatches

In applying the framework to *Dispatches*, I address each of the scenario planning outcomes. I want to place the spotlight on the outcome that is an apparent priority in DVRPC's use of the scenarios: strategic guidance. In developing and since completing the scenarios, DVRPC conducted four Futures Group workshops oriented towards strategic recommendations. In a December, 2020 workshop Futures Group members were assigned to breakout groups to brainstorm lists of strategies for achieving the regional vision in each scenario. The

slides reminded the stakeholders of the vision for an equitable, resilient, and sustainable region, though the terms were never defined. Each group was then assigned to develop strategies for one scenario and prioritize their top five. Included in the top twenty suggested strategies were: promote equitable transportation, expand transit, discounted transportation passes & credits, and affordable communications infrastructure & devices. (DVRPC, 2020c)

DVRPC also conducted five strategic workshops with the general public in the lead up to *Connections 2050* that followed the same format as the Futures Group workshop. In addition to the usual slide reminding community members of the vision, each workshop focused on a different theme, including a February 2021 workshop focused on equity and civic engagement (DVRPC, 2020d). The introduction to *Connections 2050* cites the ten universal recommendations from these exercises which include building equitable communities, enhancing transit, expanding public outreach, equitable access to developing technologies, and affordable housing. Contingent strategies assigned to specific scenarios include strengthening public health, equitably improving education, equitable transportation, and empowering community-led solutions (DVRPC, 2021a).

For the most recent reexamination of the scenarios, the Futures Group has reconvened but public outreach has not yet started. In a January, 2023 workshop each breakout group was assigned one focus area (community, environment, economy, and transportation) and one of the scenarios. They were again reminded of the regional vision, including equity as one of the three cross cutting values. Over the course of two sessions, each of the groups crafted new headlines, named challenges & opportunities, suggested adaptive strategies, and assigned a transportation budget across twelve different priority investments (adding up to 100%). Equity was not an investment category even as resiliency was. The degree to which breakout groups suggested equity strategies varied widely across groups. For some focus area/strategy combinations, the breakout group suggested no equity strategies. Others were vague: "equity in technology is challenging". Still others suggested very specific strategies such as "Citizens council evaluating data to identify efficiencies, increase transparency, incorporate equity" and wrote in their own equity investment category (DVRPC, 2023).

Neither organizational learning nor community learning appear to be priority outcomes in the conduct of the scenario planning process. For strong organizational learning, leadership at all levels should be involved throughout. For organizational learning regarding racial equity, that organizational leadership should share the room with members of impacted communities and equity leaders so that those experiences can inform the shared development of driving forces. Neither of those groups were thoroughly represented in the scenario development process. Though many DVRPC staff participated, including the deputy executive director, the executive director and the board were not involved in the process. They were informed of the scenarios at regular intervals. This differs considerably from the private sector, where the company board is often central to scenario development in that sector (Schwartz, 1991). They learned of the scenarios and implications after their completion. Additionally, my stakeholder analysis, covered previously, indicates a relative lack of equity-oriented stakeholders. While the Futures Group members may have learned about equity by exploring it as a driving force, the composition of the Futures group during the development of *Dispatches* did not constitute a favorable setting for organization learning regarding racial equity.

Similarly, the modes of public engagement around *Dispatches* do not favor community learning regarding regional dynamics. DVRPC did not involve the general public in the scenarios until late in the process. The Futures Group had already determined trends and driving forces, and provided input on the scenario stories. The public only learned of the scenarios in the consideration of strategic interventions. Such late exposure to the scenarios, even with a compelling report and videos, would not indicate an opportunity to deeply learn about the forces shaping equity or any other outcome in the region, as the learning component of scenarios is often linked to the process of collectively working through their development. In fact, the public engagement around scenarios was directed towards discussions of strategy, reinforcing the centrality of that outcome.

How does DVRPC use Dispatches to promote racial equity?

When considered against the history of public sector scenario planning, *Dispatches* represents an advance in terms of planning for racial equity. Throughout the planning process the DVRPC staff consistently reminded the Futures Group of the regional vision, which includes a racial equity principle. The eventual plan *Dispatches* document identifies socio-economic equity as a driving force and acknowledges, at times, the manner in which socio-economic and racial equity are intertwined. DVRPC additionally used *Dispatches* to produce several equity-oriented strategic recommendations. While many of these strategic recommendations were vague, they were refined by planners into more concrete strategies in *Connections 2050*. These strategies are largely oriented toward redistribution, and the plan appears to suggest a sufficiency standard for that redistribution.

The DVRPC staff demonstrated concern for deliberative equity but failed to recruit a sufficiently diverse and equity-oriented stakeholder group. The diversity of the Futures Group is increasing, but they may also wish to institute some procedures to increase the focus on racial equity within deliberations. DVRPC could have considered creating an equity specific working group in order to elevate these voices. Such a working group could ensure that this perspective is highlighted in all stages of scenario development and strategic analysis. The DVRPC staff could also consider how to revise the breakout group prompts to ensure that each group considers the equity dimensions of their suggestions. Similar approaches could also increase focus on DVRPC's other two cross-cutting principles.

To get the most of the scenarios they will need tools that can map the distributional outcomes of scenarios and proposed policies. DVRPC already possesses tools that can speak to distributional concerns such as their Indicators of Potential Disadvantage map that they utilize in equity and environmental justice analyses, and the UrbanSim land use microsimulation model. If DVRPC brought such a tool into their scenario process, then they could test interventions and investments across scenarios to determine their equity impacts. Otherwise it might be better to instead deepen the qualitative analysis of racial equity.

I do not argue that DVRPC must engage in solely equity-centered scenarios, though I believe that such a process would be informative. Nor am I arguing that *Dispatches* should have focused on racial inequality rather than socio-economic inequality, though a deep examination of the latter must involve the former. Rather, DVRPC has put forth three cross cutting principles in *Connections 2050:* equity, resilience, and sustainability. Each of these principles can find their way into all DVRPC activities, including scenario planning. While the above framework and analysis can provide a starting point for DVRPC and like-minded organizations, the most important voices should come from the BIPOC peoples and other marginalized communities. The long-range planning and the community engagement team should consider how they can reach out to community members not as stakeholders, but as potential co-creators of a new, more epistemically equitable scenario planning process – one that addresses the forces, uncertainties, and aspirations that already percolate within these communities.

Conclusions

Scenario planning and racial equity planning, after decades of development down separate tracks, do appear to be in the process of meeting. Regional planning organizations are attempting to determine how all their plans and programs can support racial equity principles. For scenario planners, using scenarios to support racial equity planning has been a tentative process, in part because there are no concrete guides to aid in thinking through the problem. In this paper, my framework provides direction for using scenario planning for just such a purpose. This framework builds on the five types of racial equity, a six-stage hybrid scenario

process, and the three outcomes of public sector scenario planning. Applying the framework to the use of *Dispatches*, a leading state-of-the-practice scenario plan, demonstrates how far scenario planning has come in term of promoting equitable strategy in an uncertain future, and also how much more planners can do to fully include BIPOC voices and assess the efficacy of racial equity strategies.

A central limitation of this research is that it remains a largely theoretical exercise. I developed the framework from the literature, my own experience, and a deep look into the use of *Dispatches* for equity planning. But I remain limited by my own perspective. As a white, male planning scholar, I do what I can to learn how to advance equity planning, but I can never experience planning processes and outcomes from the perspective of BIPOC community members. More so, the use of scenarios for racial equity planning should not emerge from the minds of any single individual, but rather from the many perspectives of those impacted by the outcomes of scenario planning.

My limited perspective also opens an opportunity for further research that is more broadly inclusive of BIPOC communities. Initial follow up research could present this framework to racial equity and justice advocates to determine what resonates with them and what is less meaningful. From there, I would refine or rework the framework. In following such a research approach, I would necessarily be limited to consulting those advocates that have already engaged in scenario planning. They are the only ones with sufficient experience to comment on the process.

A more inclusive, albeit more resource-intensive approach, would engage advocates and the communities that they represent directly in regional scenarios for racial equity. The process would still resemble either exploratory scenarios, or the hybrid approach that I suggest, but substantively the scenarios would focus on understanding those forces determining racial equity outcomes. This could take place under the auspices of the MPO or in a separate process if the MPO is not interested. Building scenarios in this way would support a more inductive process for using of scenarios in equity planning. Suggestions for framework elements and equity practices would come from the participating community members. Only then would it make sense to introduce the framework I presented in this paper and attempt to reconcile the theoretical approach with the community-driven approach.

In the long run, I am interested in what more radically inclusive scenarios might look like. Rather than professional planners or myself determining how to translate a pre-selected scenario process to community members, community representatives would co-design scenario planning from their perspectives. The results that they reach might look quite different from scenario planning as it has been practiced in planning. But the process should be more meaningful to BIPOC communities as they craft and tell multiple stories born of their own worldviews and touching on their own concerns.

A second crucial limitation of this research was the lack of perspectives far from the DVRPC planning process. Though some of the Futures Group stakeholders I spoke with were critical towards *Dispatches* with respect to equity, they were all participating members of the Futures Group. They were invested in the process and also in the privileged position of being able to dedicate workday hours towards creative exercises without direct remuneration. Their responses are likely to differ from those that stopped engaging because they did not believe it to be a good use of their time or those many equity and justice advocates throughout the Philadelphia region that were never asked to participate. Such an outsider perspective may have informed more strident critiques of DVRPC scenario planning. Or advocates may have expressed that DVRPC activities are simply of little relevance to the transformations they promote. My focus within the planning process resembles much of the previous research on regional scenario planning. Future research into regional scenario planning and equity should look beyond organizational boundaries to gain a more inclusive perspective.

Finally, there is a separate opportunity for future research on how to apply scenarios towards more equitable outcomes in later stages of the planning process. In particular, scenarios could inform required MPO equity analysis. As mentioned previously, the existing regulations leave room for going beyond the minimum and that could include examining equity through the lens of multiple futures. On the technical side, the research would focus on how scenarios are translated to modeling processes and the results analyzed to ensure that the MPO plan to promote equity is robust to outside forces. Researchers should also track how MPO staff and boards are translating scenarios equity-oriented scenarios into policies and project prioritization. In the end, the ultimate measure on the use of scenarios for equity planning will not be in applying any idealized framework. Rather, it will be whether equitably developed scenarios actually lead to more equitable regional policy outcomes.

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Appendix A: The Equity Planning Framework with Specific Recommendations

	Stakeholders and Goals	Trends, constraints, and issues	Driving forces	Intervention Options	Scenarios	Test & Evaluation
Distributive	Equity defined a priori as cross cutting principle; define equity priority population and goals	Trends and issues identified based on impacts on racialized distribution of goods and opportunities	Driving forces prioritized are those with high uncertainty and high impact on the racialized distribution of goods and opportunities	Select interventions aimed at generating fairer distribution of goods and opportunities	Each scenario explores the impacts of the scenario stories on racialized and other marginalized populations; person-oriented narratives illustrate impacts	Evaluation tools are able to measure the distribution of key measures between socio-demographic groups;
Deliberative	Proportional or greater representation of BIPOC people and equity leaders	Trends that matter to BIPOC people and equity leaders in the room	BIPOC people and equity leaders among stakeholders lead in assessing the potential impact of driving forces on racial equity concerns	BIPOC people and equity leaders among stakeholders lead in determining potential interventions	BIPOC people and equity leaders among stakeholders help to author scenario stories and person-oriented narratives reflecting their experience	BIPOC people and equity leaders among stakeholders develop lead in developing criteria and assessing outcomes
Procedural	Direct community input from members of affected communities	Remind stakeholders of equity priority in selecting trends; Engage broader BIPOC communities in trends and issues that matter to them	Remind stakeholders of equity priority in driving forces; Engage broader BIPOC communities in assessing the potential impact of driving forces on racial equity concerns	Remind stakeholders of equity priority in interventions; Engage broader BIPOC in determining potential interventions	Remind stakeholders of equity priority in scenarios; Engage broader BIPOC communities in scenario stories and person-oriented narratives reflecting their experience	Engage broader BIPOC communities in developing criteria and assessing outcomes
Epistemic	BIPOC community members co-design scenario process	BIPOC community members define what counts as trends and issues	BIPOC community members define what counts as a driving force impacting their wellbeing	BIPOC community members determine intervention – not required to be typical MPO strategies	BIPOC community members co-authors of scenario stories	BIPOC community defines assessment procedures in line with community knowledge practices
Restorative	Reparation or related restorative efforts set as goal	Research trends related to historic harms done to BIPOC communities	Driving forces include durable historic and present structures enforcing inequality	Suggested interventions include reparations and other policies to redress past harms	Scenarios illustrate continued influence of past harms as driving force as well as potential of (external to region) reparatory efforts	Evaluation tools able to aid measure restorative impacts; restoration criteria for "successful" policy within scenarios

Appendix B: DVRPC's use of *Dispatches* with respect to racial equity

	Stakeholders and Goals	Trends, constraints, and issues	Driving forces	Intervention Options	Scenarios	Test & Evaluation
Distributive	Equity is vaguely defined in *Dispatches*; clear distributive goals in governing long-range plan.	Socio-economic equity and housing costs identified as important trends.	Socio-economic equity selected as one of the key driving forces.	Strategy suggestions include those designed to address socio-economic and racial inequities.	Scenarios link socio-economic inequity to racial inequity; scenario highlight how driving forces lead to different distributional outcomes.	Evaluation metrics unable to assess equity impacts.
Deliberative	BIPOC community members and equity-oriented stakeholders present but not proportionate.	BIPOC community members and equity-oriented stakeholders present but not proportionate; no special effort to elevate their voice	BIPOC community members and equity-oriented stakeholders present but not proportionate; no special effort to elevate their voice	BIPOC community members and equity-oriented stakeholders present but not proportionate; no special effort to elevate their voice	Scenarios include personal narratives but not of those reflect explicit perspectives of BIPOC community members	BIPOC community members and equity-oriented stakeholders present but not proportionate; no special effort to elevate their voice
Procedural	Stakeholders reminded of regional equity principle at outset. No direct community engagement from members of affected communities.	Stakeholders reminded of regional equity principle in selection of trends. No direct community engagement from members of affected communities.	Stakeholders reminded of regional equity principle in selection of forces. No direct community engagement from members of affected communities.	Stakeholders reminded of regional equity principle in selection of strategies. Community outreach performed around strategy including workshop on equity.	Stakeholders reminded of regional equity principle in refining scenarios. No direct community engagement from members of affected communities.	Community outreach performed around strategy including workshop on equity.
Epistemic	No evidence of co-design or BIPOC community led knowledge processes.	No evidence of co-design or BIPOC community led knowledge processes.	No evidence of co-design or BIPOC community led knowledge processes.	No evidence of co-design or BIPOC community led knowledge processes.	No evidence of co-design or BIPOC community led knowledge processes.	No evidence of co-design or BIPOC community led knowledge processes.
Restorative	Goals from long-range plans and definition in *Dispatches* suggest redistribution, possibly sufficiency standards. No setting of restorative goals.	Socio-economic inequity names as historic force enforcing racial divisions. No other mention of historic racial inequities.	Role of market v. government and degree of political will tied to historic driving forces for racial inequity. But those ties are not explored through *Dispatches*.	No restorative interventions considered	One scenario makes mention of conversations around systemic racism and need for reconciliation; no other mentions.	Scenarios and strategies not evaluated for redistribution impacts.