WHAT COUNTS IN MOBILITY

Improving Planning Tools for a Multi-Modal Future

UEP FIELD PROJECTS 2020 REPORT

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for a Multi-Modal Future

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ACKNOWLEDGEMENTS

TEAM MEMBERS

Yingran Li received her BE in Urban and Rural Planning from Huazhong University of Science and Technology in 2019. She is currently pursuing an MA in Urban and Environmental Planning and Policy at Tufts University, with interests in urban renewal, transportation, and smart cities. Growing up in the Internet era, she has a strong interest in the application of big data in urban planning.

Sarah Saydun holds a BA in Human Services and International Affairs from Northeastern University, and is currently pursuing an MA in Urban and Environmental Policy and Planning from Tufts University. Sarah has spent over eight years working with youth in Out Of School Time programs in Boston, and comes to Tufts with an interest in community control over development. In her off time, you can probably find her making zines, tending to her plants, or reading speculative fiction.

Andrew Schloss is a student in the Tufts combined undergraduate-graduate program in Urban and Environmental Policy and Planning, where he is focusing his studies on climate change policy, mobility, and urban design. In addition to pursuing a MA, he is completing his BA in Political Science and Environmental Studies, with research interests in environmental policy, public opinion, and comparative democracy. Originally from Long Island, New York, Andrew is an avid swimmer, biker, and cook.

Hoai Tran holds a BS in Environmental Science, Geology from Northeastern University and currently pursues an MA in Urban and Environmental Planning and Policy at Tufts University. Her areas of focus at Tufts are transportation, climate change, and equitable planning. She is a seasoned MBTA user and is interested in policy changes that can improve transit service and access. Her hobbies include camping and eating cake.

Jess Wilson received her BA in Environmental Studies from Bates College in 2017 and worked at Boston University as an Environmental Research Assistant from 2017-2019. At Tufts UEP, the focus of her studies includes environmental policy and transportation analysis using GIS. As a bike commuter she is very interested in multimodal transportation, and conducted a spatial risk analysis of bike crashes in Cambridge, MA in Intro to GIS in Fall 2019. After graduation, she hopes to work as an environmental policy regulator or transportation analyst. Her hobbies include baking and running.

EXECUTIVE SUMMARY

Have you ever wondered why the MBTA Green Line trains run less frequently than the Red Line trains? Or why Route 128 has eight lanes, while the Mass Pike has six? Every decision about transit schedules, bike lanes, highway width, and bridge height is informed by a transportation model. Transportation engineers devised mathematical models to predict how many people would travel to a given location at a given time in space, to aid in this decision-making process. Transportation models predict the traffic volume of a given bridge, highway, or train, so that decision makers can make more informed decisions about where to allocate limited funds.

Now the dominant model in transportation planning, the four-step travel demand model was first developed in the 1950s as a way to more systematically plan for roadway expansion. It has since become widely embraced by planners in the field, and continues to shape Boston's regional transportation landscape. In the Greater Boston area, the Central Transportation Planning Staff (CTPS), staff to the Boston Region Metropolitan Planning Organization (MPO), uses their own version of the four-step model in order to predict traffic flow and patterns for the 97 cities and towns the MPO serves.

Transportation planning is undergoing a paradigm shift: away from car-centric planning and towards sustainable, multi-modal design. However, the four-step travel demand model has not evolved much with this change, which causes a disconnect between the predicted results of the model and the actual situation after construction. The model also doesn't support transportation agencies' multi-faceted planning goals. This can result in forecasts that overpredict for cars and underpredict for other modes, therefore justifying the production more status-quo, car-centric design, as opposed to encouraging planning for innovative, multi-modal

transportation solutions.

Goals and Methods

Models are used to make decisions about transportation projects that have major implications on the landscape of the future. However, most laypeople don't understand them, if they are even aware of them, and they largely lead to expanding roads and building highways. What if transportation advocates better understood this tool, in order to advocate for a more sustainable future, a future that included access to better transportation options?

The main purposes of this project are to:

   • Make the technical aspects of modeling more accessible to non-engineers;

   • Understand how models affect decision making; and to

   • Use that understanding to make recommendations for improvement to the model and to the transportation planning process as a whole.

To achieve these goals, we conducted a literature review and stakeholder interviews. In order to make recommendations for improving the CTPS's four-step model, we needed to understand the inputs, assumptions, and mechanics of the four-step model itself. We also needed to study the current transportation trends in the Boston area, as well as current and future planning goals in the region. We investigated the transportation-related agencies in the Greater Boston area to understand their roles in transportation planning and their use of the model. We also analyzed the Massachusetts State Implementation Plan, the Focus 40 Plan, and the Go Boston 2030 Plan, which promote the development of human-scaled and transit-centered solutions to combat transportation challenges and reject the

expansion of automobile infrastructure.

Analysis

A careful analysis of our literature review and stakeholder interviews, revealed several insights about how models fit into the transportation planning process. Our analysis includes an overview of how the model's forecasts are generated, CTPS's role in generating predictions, and project goals and assumptions that planning agencies and stakeholders can have. Depending on the project and the questions that need to be answered, the CTPS model can be used in various inquiries, such as air quality analyses, economic analyses, and conceptual studies.

The model's results are used by planners and policymakers to inform a project design, give new recommendations for policy changes, or justify recommendations that they had already planned to pursue prior to modeling. They treat the forecasts as a credible supplement for decisions, but that credibility is increasingly being questioned by planners and community members alike.

We conclude by highlighting weaknesses of the model, and suggestions for improvement, that arose from our interviews. The model does not have sufficient data to generate the most accurate prediction possible, so we recommend investing in better data collection, mainly for transit, biking, walking, and location-specific data. The results of the model can be skewed by inaccurate inputs, so we recommend increasing the transparency of the modeling process, improving community engagement around the use of the model, and letting these transparent and democratic processes make the model as objective as possible. Additionally, the model is only good at predicting the future as long as nothing changes. We suggest incorporating an iterative planning practice for modeling that allows us to evaluate the results from the beginning.

Overall, the travel demand model provides support

in making scientifically based decisions. However, we cannot ignore the dependence of its validity on high-quality data and outdated assumptions. Additionally, we must understand that the results of the model do not represent the only possible future. We must prepare more options outside of models that incorporate a holistic approach to make transportation planning more flexible and sustainable. Furthermore, transportation planners and policy makers should question the accuracy and reliability of model results. Transportation trends and patterns are dynamic, and a good model is able to adjust and incorporate fluctuations in space and time.

Recommendations

Based on the findings from our literature review and interviews, we recommend improvements to both the model itself, and to the transportation planning process as a whole. While we recognize that CTPS is ultimately responsible for improvements to the model, all of these recommendations are relevant to all stakeholders in the field.

Improvements to the model include:

   • Implementing a transportation model study

We recommend that CTPS implement a more in-depth assessment of the strengths and weaknesses of its modeling process; and conduct a feasibility study for integrating suggestions outlined in our report.

   • Acquiring more comprehensive and up-to-date data

Many of our interviewees pointed out that the accuracy of model predictions relies on the quality of data inputs, but much of the data used in the CTPS model are insufficient, overgeneralized, and outdated. If we rely on model forecasts to make important decisions about transportation planning, the data used to inform models need to be more comprehensive and representative of the community that any given project will serve.

Planners and engineers can use big data to complement traditional data collection methods, while working towards sharing data in collaboration with other actors in the transportation planning field.

• Implementing an iterative process

Iterative processes are widely used by designers, developers, and entrepreneurs to test and improve a product before finalizing it. Model forecasts could be developed through an iterative process by testing the forecast against reality, and then reevaluating inputs and assumptions used in order to improve the accuracy of the output. Our interviews suggested several strategies that CTPS could incorporate to consistently iterate and improve the way the model functions, including scenario planning, feedback loops, and back-casting; all of which are discussed in the analysis section of our report.

Improvements to the transportation planning process as a whole include:

• Committing to better understanding mobility through using interdisciplinary approaches and collecting qualitative data

Quantitative data are helpful, but they do not provide a complete picture of travel behavior. Actors involved in transportation planning – state agencies, regional planning organizations, municipalities, and advocacy groups – should prioritize using interdisciplinary approaches to data collection to achieve a more holistic picture of how, and why, people move. This sophisticated understanding of human mobility will allow states to better achieve their vision for a future with sustainable, human centered transportation solutions.

• Creating space to question model results

The modeling process has long been inaccessible to laypeople and advocates, and as a result, its predictions largely go unquestioned. We believe that you don't have to be a transportation engineer or planner to be able to critically engage with model forecasts and ensure their relevancy. Advocates should have the right to evaluate modeling results

when they are inconsistent with the community's understanding of reality and desired solutions.

• Improving the community engagement process

Transportation planning should not occur in a vacuum; decisions made by planners will ultimately have real impacts on communities. Therefore, having accurate representation of public experiences and travel preferences are crucial. Transportation planning agencies in the Boston area can, and should, work with community members to be a bigger part of the decision-making process: identifying problems; brainstorming solutions; and informing the prioritization of projects. The three-step community engagement process developed by the Greenlining Institute, which will be discussed in greater detail in the recommendations section of our report, is a feasible tool that municipalities and state agencies can utilize to improve community engagement and transportation equity.

• Better integrating public health needs into the modeling and planning process

There is no doubt that transportation policy will have an impact on public health. The pollution caused by traffic will affect people's respiratory function, and the 2020 outbreak of the Novel Coronavirus (COVID-19) has given us a wake-up call. We need to focus more on public health in contemporary transportation planning. Massachusetts does well in including healthcare priorities in transportation planning, but some recent projects in the Boston area show that there is still room for these initiatives to grow. With public health concerns integrated into the travel demand model and a holistic planning process, people can enjoy a more human scale transportation system.

We hope that this report provides some attainable next steps for improving the model and the transportation planning process as a whole.

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LIST OF ACRONYMS

BPDA: Boston Planning and Development Agency

COVID-19: Novel Coronavirus 2019

CTPS: Central Transportation Planning Staff

DCR: Department of Conservation and Recreation

DPU: Department of Public Utilities

EPA: Environmental Protection Agency

FHWA: Federal Highway Administration

FTA: Federal Transit Administration

IISC: Interaction Institute for Social Change

ITDP: Institute for Transportation and Development Policy

ITE: Institute of Transportation Engineers

MAGIC: Minuteman Advisory Group on Interlocal Coordination

MAPC: Metropolitan Area Planning Council

MassDOT: Massachusetts Department of Transportation

Massport: Massachusetts Port Authority

MBTA: Massachusetts Bay Transportation Authority

MOVES: Motor Vehicle Emissions Simulator

MPO: Metropolitan Planning Organization

MSRS: Massachusetts Safe Routes to School

RTAC: Regional Transportation Advisory Council

SIP: State Implementation Plan

SWAP: The SouthWest Advisory Planning Committee

TAZ: Traffic Analysis Zone

TDM: Travel Demand Model

TNC: The Transportation Network Company

TRIC: Three Rivers Interlocal Council

UEP: Urban and Environmental Policy and Planning

USDOT: U.S. Department of Transportation

1. INTRODUCTION
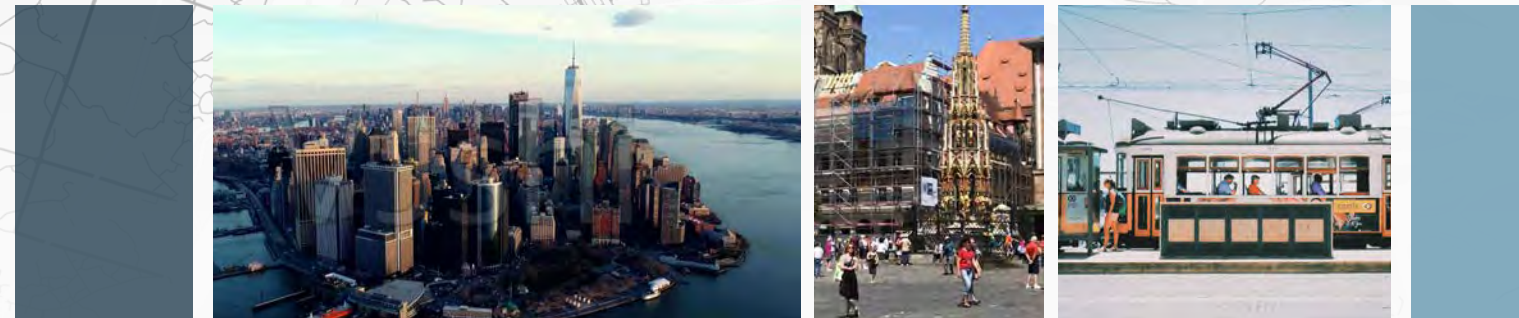
1.1 UEP Field Project Team and Community Partners

This study was conducted by a team of graduate students in the Urban and Environmental Policy and Planning (UEP) department of Tufts University, in the context of the Field Projects course, for the non-profit organization LivableStreets Alliance.

The student team includes Yingran Li, Sarah Saydun, Andrew Schloss, Hoai Tran, and Jess Wilson, who are all first-year MA/MS students.

LivableStreets Alliance is a transportation advocacy organization operating in the Metro Boston area. This project was supported by Ambar Johnson, Program Director at LivableStreets, and assisted by Ari Ofsevit, Boston Program Senior Associate at the Institute for Transportation and Development Policy (ITDP) and LivableStreets volunteer.

1.2 Project Goals and Research Questions

Our project has multiple purposes: to illuminate the mechanics of transportation modeling; understand how transportation models affect decision making; and to make the link explicit between transportation modeling and its impact on transportation policy. Our hope is that our report will help LivableStreets engage with transportation modeling in the future.

Specifically, we were tasked by LivableStreets to:

• Research the assumptions underlying the Central Transportation Planning Staff (CTPS) travel demand model used in the Metro Boston area, the inputs that go into that model, and some of the ways the model is used in local projects.

• Assess whether the model's inputs and assumptions could be improved to better reflect current and future transportation trends and promote equitable and accessible transportation.

• Make transportation modeling accessible and understandable to lay people so that community members can better participate in transportation planning that affects them.

In order to accomplish these goals, we conducted research through a literature review and interviews with key stakeholders in the Greater Boston Area's transportation planning community, as shown in Figure 1. Our main research questions were:

• How are transportation planning decisions made, and where do models fit into that process?

• What are the consequences of inaccurate modeling?

• What causes discrepancies between forecasts and post-construction traffic counts?

• How can community advocates be better equipped to challenge decisions informed by the transportation modeling process in the future?

• How can we change modeling to ensure that

Figure 1: Project goals logic map. *Created by Yingran Li.*

major capital projects better meet the needs of a rapidly evolving multi-modal future?

Our primary deliverable for this project is our report. Through our preliminary research (literature review and initial interviews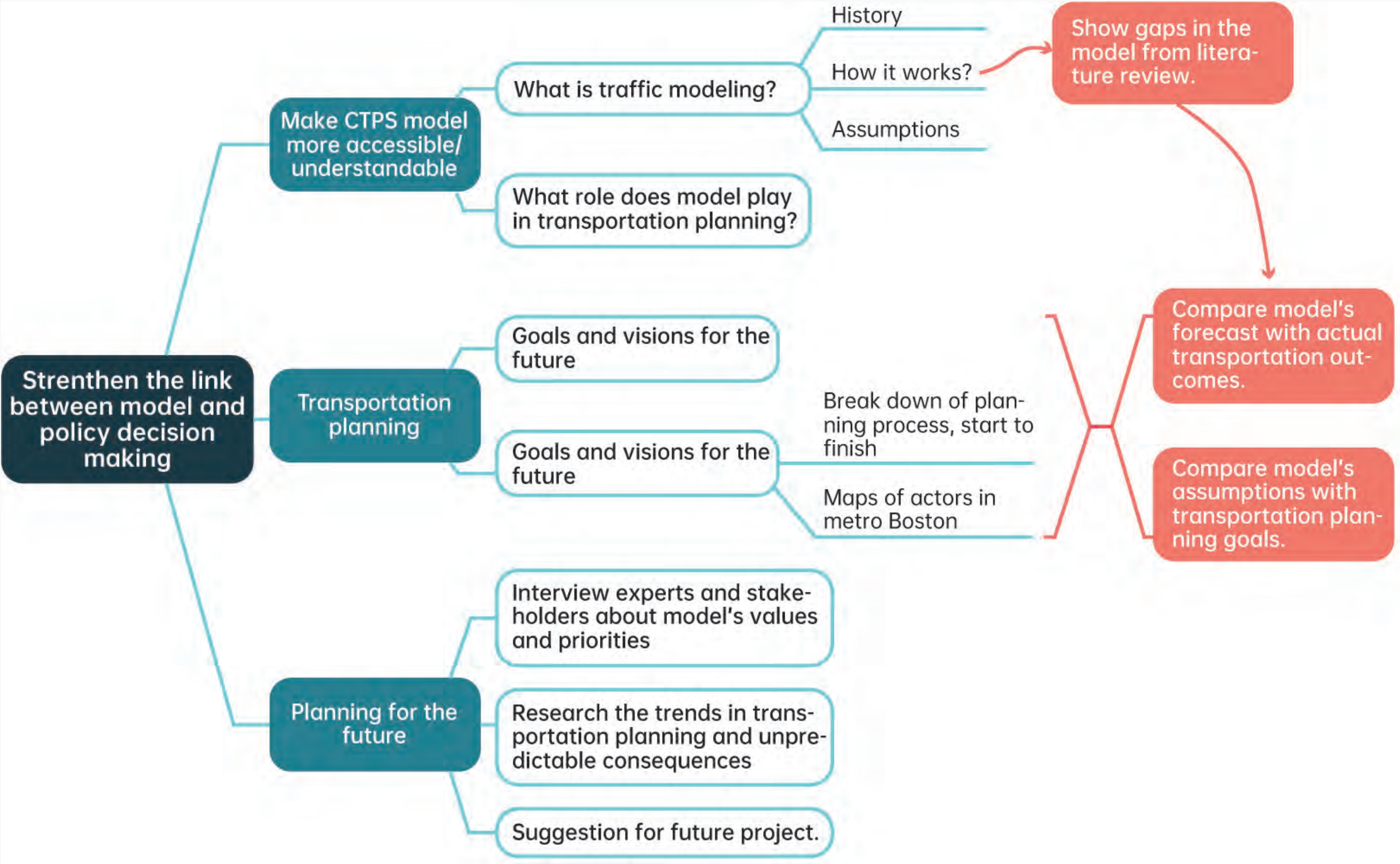 with transportation planning advocates), we found that information about transportation modeling does exist, but it is very technical and incredibly dense (Beimborn and Kennedy, 1995, updated 2006; Handy, 2008; Flyvbjerk et al., 2005; Parthasarathi and Levinson, 2008). Our goal was to synthesize this information in a way that's more accessible to readers from all backgrounds, and then map that understanding onto the specific context of the Boston Area Metropolitan Planning Organization (MPO) and the model used by CTPS. The Boston MPO is the regional transportation planning organization for 97 municipalities in Massachusetts which allocates federal and state funds to improving transportation infrastructure and funding new projects. CTPS performs this work under the direction of the MPO board (Boston MPO, 2020). The report includes a break-down of the process of transportation modeling, a more in-depth understanding of the mechanics of the CTPS model and how it is used to inform decisions about transportation in Metro Boston, and recommendations for improving the overall process. A glossary of terms and a one-page information sheet for advocates to bring to planning or community meetings is included in Appendix C.

We hope that our investigation makes the transportation modeling process more transparent and will allow LivableStreets and their partners to more critically engage with decisions made based off of its forecasts. This will allow them to inform their public partners about modeling, and better advocate for the future of transportation that we all deserve.

1.3 Methods

Our methods include a Literature Review and a series of 11 stakeholder Interviews.

Literature Review

We conducted a literature review with the goal of better informing ourselves of the mechanics, inputs, and assumptions of transportation models currently being used in the transportation planning industry. The team also researched and reviewed future Massachusetts transportation goals for the next 10-20 years. The literature review helped to answer our research questions and informed the questions for the stakeholder interviews. Literature review topics included the following.

1. Transportation Modeling 101 - In order to better understand the effectiveness of the CTPS model, the team first studied the mechanics of the model: how it calculates trip generation; trip distribution; mode split; and trip assignment.

2. History of Transportation Models - We reviewed the creation of the model, and its original purpose, in order to understand how it is currently used. Increased automobile use in the 1950s led the US government to build the Interstate Highway System, and create the four-step travel demand model to plan appropriately for highway demand. Knowing this helps us understand some of the underlying assumptions of the model.

3. Trends in Transportation Modeling - The demands for different types of transportation infrastructure have shifted with time. The unique needs of various regions can dictate how models are designed and used. Exploring the trends in transportation modeling, therefore, helps us to better understand how it was historically used and how other models are incorporating modern variants, such as, among others, bicycle and pedestrian patterns, public transit and highway planning methods , and land-use forecasting.

4. Unpredictable Consequences of New

Trends - Transportation models may be using outdated assumptions as inputs, grounded in traffic patterns that were more applicable to the 1950s, than they are to our reality today. Travel demand modeling, by its very nature, cannot account for the impacts of emerging trends in transportation. We reviewed the increase in ridesharing, decrease in car ownership, incorporation of external costs into trip distribution (such as the value of time, and parking costs), increases in intersection or traffic delays, the shift in peak hours, and increase in climate change impacts as transportation trends with unpredictable consequences. These trends will influence how people travel, contributing to inherent uncertainty in travel demand forecasts.

5. Critiques of Modeling - We wanted to know how experts measure the effectiveness of transportation modeling and some of its weaknesses as a planning tool.

6. Massachusetts Transportation Goals - We reviewed documents published by Massachusetts state agencies that outlined transportation goals and visions for the future of transportation to assess if the CTPS model has the potential to be an adequate tool to hold decision makers accountable to those goals.

Stakeholder Interviews

We conducted eleven stakeholder interviews to uncover information specific to the CTPS travel demand model that could not be found in the literature. The stakeholder interview questions can be found in Appendix B. The team interviewed representatives from the Central Transportation Planning Staff (CTPS), Massachusetts Department of Transportation (MassDOT), Metropolitan Area Planning Council (MAPC), Massachusetts Bay Transportation Authority (MBTA), Emerald Network Initiative, Institute for Transportation and Development Policy (ITDP), WalkBoston, Boston Transportation Department, and Northeastern University. This core group of experts provided

critical insight into the mechanics of the model, its inputs and assumptions, and where modeling as a tool fits into the transportation planning process. An analysis of the stakeholder interviews and the literature review informed the team's recommendations.

2. BACKGROUND
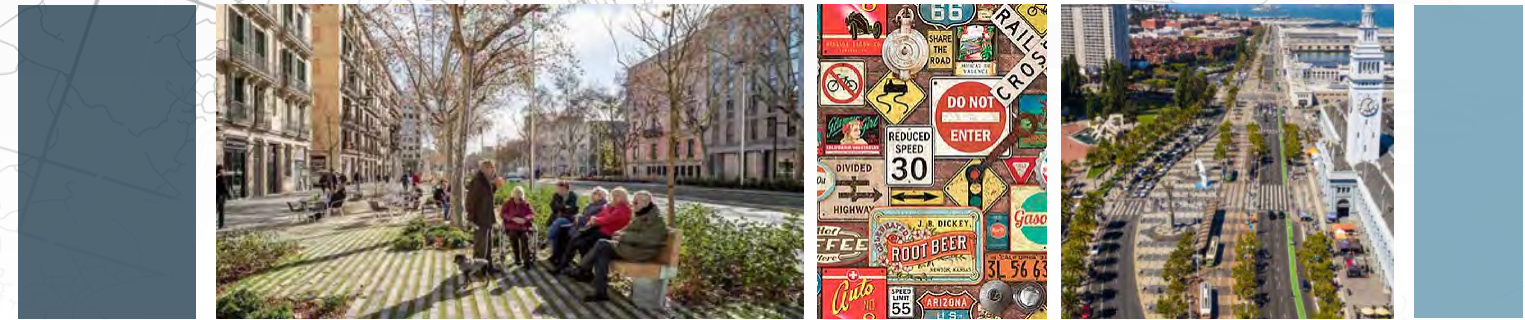
2.1 Partner Organization History

LivableStreets Alliance is a non-profit, Boston-based organization committed to transit equity and sustainability. They advocate for initiatives that create safe, affordable, and accessible transportation options for everyone in the Greater Boston Area. The organization's mission supports the growth and development of people-centered transportation systems, safe travel environments, and fostering connection between communities in Boston (LivableStreets 2020).

LivableStreets' advocacy is centered around the belief that equitable access to transportation and safe streets are integral to economic and social justice. Through their three priority programs – the Emerald Network, Vision Zero, and Better Buses – LivableStreets Alliance works with partner organizations throughout the region to reduce fatal traffic crashes, increase transit ridership, create greenways for active transportation, and build safer, more sustainable streets (LivableStreets, 2020). All three of these programs are underpinned by an organizational commitment to increasing public awareness and support for the region's goals, as outlined in plans such as GoBoston 2030, and continues to work on influencing legislators to improve street design.

In our initial meetings with LivableStreets, they used the Longfellow Bridge redesign as an example of how transportation modeling affects transportation projects. The Longfellow Bridge redesign used the

CTPS model to predict traffic volume. The prediction overestimated vehicular traffic volume along the bridge, and was used to justify widening automobile lanes, without including significant infrastructure for bikes or pedestrians. LivableStreets, along with other advocacy groups like the Boston Cyclists Union (BCU) and WalkBoston, formed a coalition to engage community perspective, and advocate for more bicycle- and pedestrian-friendly infrastructure. After completion of the Longfellow Bridge redesign, post-construction counts revealed significant discrepancies between predictions and observed traffic volume. The anticipated post-construction inbound vehicle count estimated 1,684 cars during the AM peak and 3,031 cars during the PM peak. The actual post-construction inbound vehicle count observed 580 cars during the AM peak and 1,063 cars during the PM peak. Outbound vehicle counts had comparable results (see Table 1 below). With this in mind, LivableStreets reached out to the Field Projects teaching team with the task of researching the assumptions and inputs of the CTPS model to see if the model could be improved to better reflect transportation trends and promote equitable and accessible transportation in the Metro Boston area (LivableStreets 2020).

Table 1. Anticipated and actual vehicle counts of the Longfellow Bridge redesign. *Source: MassDOT.*

massDOT — Massachusetts Department of Transportation — Data Download

	Pre-Construction	During Construction	Anticipated Post-Construction as of 2012 (CRB Model[1])	Anticipated Post-Construction as of 2018 (CTPS Model)	Actual Post Construction [Source: ATR counts taken week of September 17, 2018]
Inbound Vehicle Counts 6-9 AM peak, 3-6 PM peak Mon-Fri	2008 – 816 AM peak 2008 – 1,331 PM peak *Source: ABP counts 2012 – 1,615 AM peak 2012 – 3,255 PM peak 13,020 ADT *Source: CTPS	2016 – 895 AM peak 8,840 per day 2017 – 882 PM peak 9,246 per day *Source: ABP Counts, PM counts not taken	2017 720 AM peak 1,380 PM peak	2019 – 1,684 peak AM 2019 – 3,031 peak PM *Source: CTPS model run Jan 2018, projection, modeled with two lanes inbound and NWS Bridge & Tobin Bridge under construction	580 AM peak 1,063 PM peak 10,880 ADT
Outbound Vehicle Counts 6-9 AM peak, 3-6 PM peak Mon-Fri	2012 – 2,775 peak AM 2012 – 2,080 peak PM 12,985 per day *Source: CTPS	N/A – Outbound lanes closed to vehicular travel	2017 780 AM peak 700 PM peak	2019 – 2,121 peak AM 2019 – 1,019 peak PM *Source: CTPS model run Jan 2018, projection, modeled with two lanes inbound and NWS Bridge & Tobin Bridge under construction	442 AM peak 311 PM peak 7,612 ADT
Bicycle counts 7-9 AM peak, 4-6 PM peak Mon-Fri.	2011 – 221 Inbound AM 22 Outbound AM 2011 – 246 Inbound PM 182 Outbound PM *Source: ABP Counts	2013 – 256 Inbound AM 2013 – 85 Inbound PM *Source: ABP Counts, Out counts not taken 2017 – 1,226 (34.9% of all vehicles in AM peak) 2016 – 757 (25% of all vehicles in AM peak) *Source: City of Boston	N/A	N/A	Inbound[2] 392 AM Peak 181 PM Peak 1206 Daily Average Outbound[2] 90 AM Peak 281 PM Peak 937 Daily Average
Pedestrian counts 7-9 AM peak, 4-6 PM peak, Mon-Fri.	745 walkers/runners *Source: CRB Pedestrian+ Bicycle Study for Pathways + Vehicular Bridges, June 2010, data collected Tuesday, 5/11/10 from 4:30pm-6:30pm	N/A	N/A	N/A	Inbound 351 AM Peak 406 PM Peak 2,487 Daily Outbound 279 AM Peak 381 PM Peak 1,609 Daily

1.   Charles River Basin (CRB) model run assigned BU Bridge, Anderson Bridge, and Longfellow Bridge with final design lane configurations; no traffic growth was assumed
2.   Average daily bicycle counts include bicycles on sidewalk

2.2 Summary of Problem

Transportation models were developed in the mid-twentieth century as a way to plan for the large-scale roadway infrastructure of the era. They are generally useful tools for planning because they allow engineers and policy makers to understand the potential impacts of a project. Transportation models are meant to answer questions like, "if we built a new project here, how would the system respond?" or "what would happen to congestion if we added another lane to this street?" The forecasts from models help decision makers to assess all their options and make better-informed decisions (Buehler, 2014).

However, all models are imperfect tools and leave significant room for error. The presence of algorithmic bias, lack of accurate, up-to-date data, and lack of ability to precisely predict the future all affect the model's outputs. **Since transportation models were built in a transportation planning system heavily influenced by the automobile industry, they were not designed to predict multi-modal possibilities.** Transportation policies, priorities, and projects are all affected by this potential inaccuracy (Hartgen, 2013; Handy, 2008, Flyvbjerg et al, 2005; Parthasarathi and Levinson, 2010; Marsden and McDonald, 2017; Beimborn and Kennedy 2006).

Because of this, advocates question how well models can predict for futures that do not include automobiles, or that allow us to work towards goals outlined in plans like Go Boston 2030. Go Boston 2030, the transportation section of Boston's 2018 comprehensive plan Imagine Boston 2030, and other plans at the state level have explicitly outlined that providing walkable streets, increasing transit access, and preparing for climate change are main priorities for transportation planning in our region (Go Boston 2030, 2017).

While it has significant impacts on what kinds of projects get built, modeling is largely unknown to most members of the public and inaccessible to many members of the transportation planning field themselves. This gap in technical knowledge has limited LivableStreets Alliance's (and other transit equity advocates') ability to critically engage with decisions that are made based on the model's predictions.

As an organization whose advocacy promotes forward-thinking transportation solutions that have profound implications for equity and climate justice, LivableStreets can make better informed recommendations if they are able to access that information. Their mission includes work to ensure that transportation initiatives are in line with progressive visions for the future: promoting transit use, biking and walking, and reducing vehicular travel. In addition to their recent advocacy for the inclusion of bike lanes over the Longfellow Bridge, LivableStreets Alliance is engaging with plans for the Allston I-90 redesign to emphasize transit, bike, and pedestrian transportation accessibility. These projects have tremendous potential for the region to envision the future of sustainable, equitable transit design. Unfortunately, movements to build sustainable, walkable, and innovative transportation solutions are currently still overshadowed by highway expansion.

As the Boston region continues to expand, we are seeing more occasions where we have to make choices that will profoundly impact our landscapes. One of the basic assumptions of the four-step travel demand model, that automobiles are the preferred mode of travel, makes it unable to predict situations that would favor non-automobile modes of travel, therefore underestimating the effectiveness of alternative transportation policies. Additionally, transportation modeling is an inaccessible piece of the planning process, so in order to have an intentional participatory process, there needs to be more transparency.

LivableStreets and this project team believe in prioritizing sustainable transportation planning, which includes building infrastructure that reduces car use and promotes more equitable access to transit. A better understanding of what decisions the models inform, and how, as well as what factors lead to inaccuracy and uncertainty, will allow LivableStreets and their partners to more effectively advocate for better transit solutions in the future.

3. LITERATURE REVIEW

The student team conducted a literature review to better understand the mechanics of the four-step travel demand model, and its role in transportation planning. We explored the history and evolution of transportation modeling, trends in transportation planning, and critiques of the accuracy of model forecasts. The findings in the literature review are related to transportation modeling on a broad scale; more specific observations about the CTPS regional model and its relevance in planning in the Boston region are derived from the analysis of our interviews.

The literature review confirmed that transportation modeling is a complex process. We found evidence to suggest that the four-step travel demand model is an outdated, inflexible, and inaccurate tool. We reviewed some of the biases and assumptions embedded in transportation models that could be holding planners back from implementing innovative transportation solutions. However, we also discovered why transportation models are useful, and that there exists best practices and strategies for improving the transportation modeling process as a whole.

The literature review is broken out into six sections below: Transportation Modeling 101, History of Transportation Modeling, Trends in Modeling, Unpredictable Consequences of New Trends, Critiques of Modeling, and State Planning Goals.

3.1 Transportation Modeling 101

Models are a series of mathematical equations, usually used in a computer program, that are meant to represent (model) human behavior and predict the outcomes of specific transit projects. The predictions are used to inform the construction of transportation infrastructure, for example whether to add lanes to a road, construct a highway, add a transit link, or prioritize including bike lanes in a specific neighborhood.

Models are simplified representations of reality that assume relationships between a set of predetermined factors. As such, models have specific limitations that will be discussed further in this literature review.

The basic, widely used tool for transportation modeling is referred to as the four-step model, since it is broken down into four steps.

Step One: Trip Generation

Trip generation answers the question: "how many trips will there be?"

Information from land use, population, and economic forecasts is used to estimate the number of trips taken by a household. **It assumes that factors like household size, income level, and car ownership determine how many trips an individual makes a day.** It also assumes origins and destinations, such as workplaces, schools, and shopping locations. The estimates of individual trips per household are then

expanded to estimate the number of trips per Traffic Analysis Zone (TAZ) (defined in Glossary in Appendix C).

Step Two: Trip Distribution

Trip distribution answers the question: "where will people go?"

This step is concerned with how people decide to get from one place to another, and represents how trips are linked together from beginning to end. The most commonly used model to calculate trip distribution is the gravity model (defined in Glossary in Appendix C), which distributes trips from one zone to another based on zone size and distance to other zones.

Step Three: Mode Split/Auto Occupancy

Mode split answers the question: what mode of travel will people use?

The possibilities considered are automobile, bus, rapid transit, and (possibly, but not frequently) walking or bicycling. **The model compares "attractiveness" of using different modes, which is generally only calculated through the cost of using each mode, and the time it would take to get to a destination using each mode.** It generally does not include factors like pedestrian friendliness or safety concerns (Beimborn & Kennedy, 2006).

Step Four: Trip Assignment

Trip assignment answers the question: what routes will be used?

Once we know how many vehicular or transit trips will take place in a day, we need to know which routes they will travel on. Trip assignment predicts the path that people take from their origin to their destination.

A forecast from the model is a prediction of what kind of traffic demand will result from a project. Forecasts are then used as data with which to make decisions about the prioritization of transportation projects.

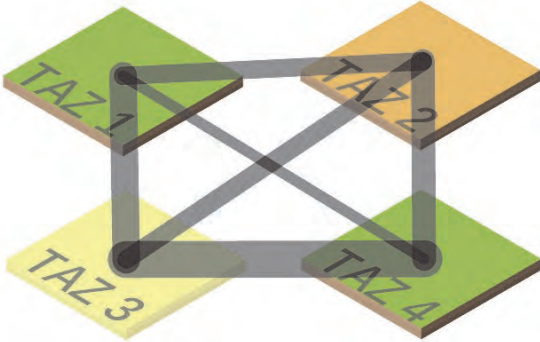Figure 2. Trip generation. *Created by Yingran Li.*

Figure 3. Trip distribution. *Created by Yingran Li.*

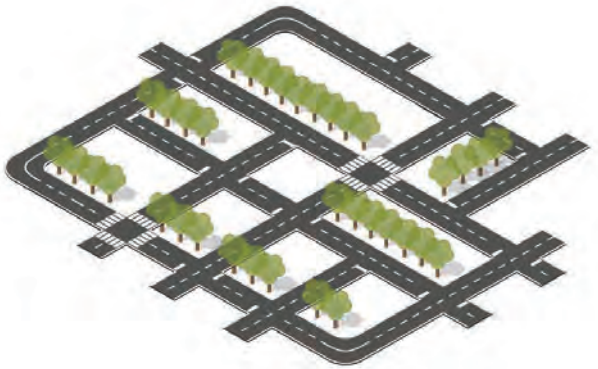Figure 4. Mode split. *Created by Yingran Li.*

Figure 5. Trip assignment. *Created by Yingran Li.*

Limitations of the Model

Although widely used to support decisions about transportation projects, the four-step model has limitations. Several considerations are not included in the calculations, as discussed and illustrated in Figure 6 below.

Step One: Trip Generation

Trip generation is used to estimate how many trips an individual will make. However, travel behavior is complex and dependent on many factors, making it hard to predict.

Factors that could affect number of trips, that are generally not accounted for in a regional transportation model, include:

• Detailed trip purposes: For example, shopping for groceries is different from shopping for furniture. One can be done on foot, while the other requires a vehicle.

• Trip chaining: trips that are made during the day (that don't begin at home or at work, but perhaps go from work to the grocery store and then back home) are not accurately accounted for.

• Quality of transit service

• Personal and/or perceived safety

This lack of variables sensitive to transit and walking leads to gaps in knowledge about demand for transit and pedestrian use.

Step Two: Trip Distribution

As mentioned above, the most commonly used model to calculate trip distribution is the gravity model (see definition in Glossary in Appendix C). The gravity model relies on a measurement of the distance between zones, which is almost always based on vehicular travel times rather than transit times. This excludes travel patterns of households that rely on local transit routes.

Additionally, the model does not incorporate feedback loops in order to inform inputs and improve predictions. Feedback loops are processes in which the outputs of a system are circled back in and used as inputs, in order to improve the final output. (see expanded definition in Glossary in Appendix C) for changes in congestion caused by changes in road capacity. Changes in congestion affect travel time and this leads to inaccuracy in travel time prediction.

The four-step model does not account for the complex socio-economic-cultural factors that affect trip distribution. People's socio-economic background, activities such as daycare drop-off and pick-up, second and third jobs over a 24-hour period, work-from-home jobs, and proximity to friends and relatives affect trip distribution. Additionally, they do not include how technological advances, like the internet, have affected how people coordinate their activities. In other words, people are much more complicated than what can be seen in a census tract.

Step Three: Mode Split/Auto Occupancy

In order to determine the choice of different modes of travel, calculations are made to compare their "attractiveness". The basic four-step model assumes that people will choose modes based on two factors: time and cost of travel. But parking costs at destination, preference for public transit even it takes more time, and preference for bike commuting, are not taken into account. As with other assumptions made during the four-step modeling process, the limited set of assumptions on which predictions are made leave out important detail and nuance that are needed to be accurate.

Step Four: Trip Assignment

Most four-step models are not able to account for induced demand (see definition in Glossary in Appendix C). Induced demand is the idea that increased capacity on roadways will encourage people to drive more, thus leading to more congestion on the road. Therefore, perhaps counterintuitively, adding lanes to roadways

is not an effective way to reduce congestion. When a roadway is expanded, traffic increases to meet capacity, leading to more cars on the road and increased (not decreased) congestion. Trip assignment does not account for this factor.

The implications for these exclusions, and for other shortcomings of the four-step model, will be discussed further in the "critiques" section of this literature review.

Figure 6. Missing factors in model. *Created by Yingran Li.*

3.2 History of Travel Demand Model

Planning in the 1950s was fueled by the rapid increase in accessibility of the automobile. The U.S. Federal Government incentivized highway building through the Federal Aid Highway Act of 1956 , resulting in the Interstate Highway System that connects many urban areas in the U.S. The four-step travel demand model was designed to facilitate these highway projects (Buehler, 2014). This model gradually matured after more than 20 years of theoretical development and became

the mainstream model of transportation planning throughout the ensuing fifty years. CTPS developed their own version of the four-step model in order to better predict traffic flow and patterns for the 97 cities and towns served by the MPO region. However, due to changes in travel behavior, demographics, automobile dependence, and new directions in transportation planning, the limitations of the widely used four-step model are becoming more evident and relevant.

A timeline of the evolution of the four-step model is

included below.
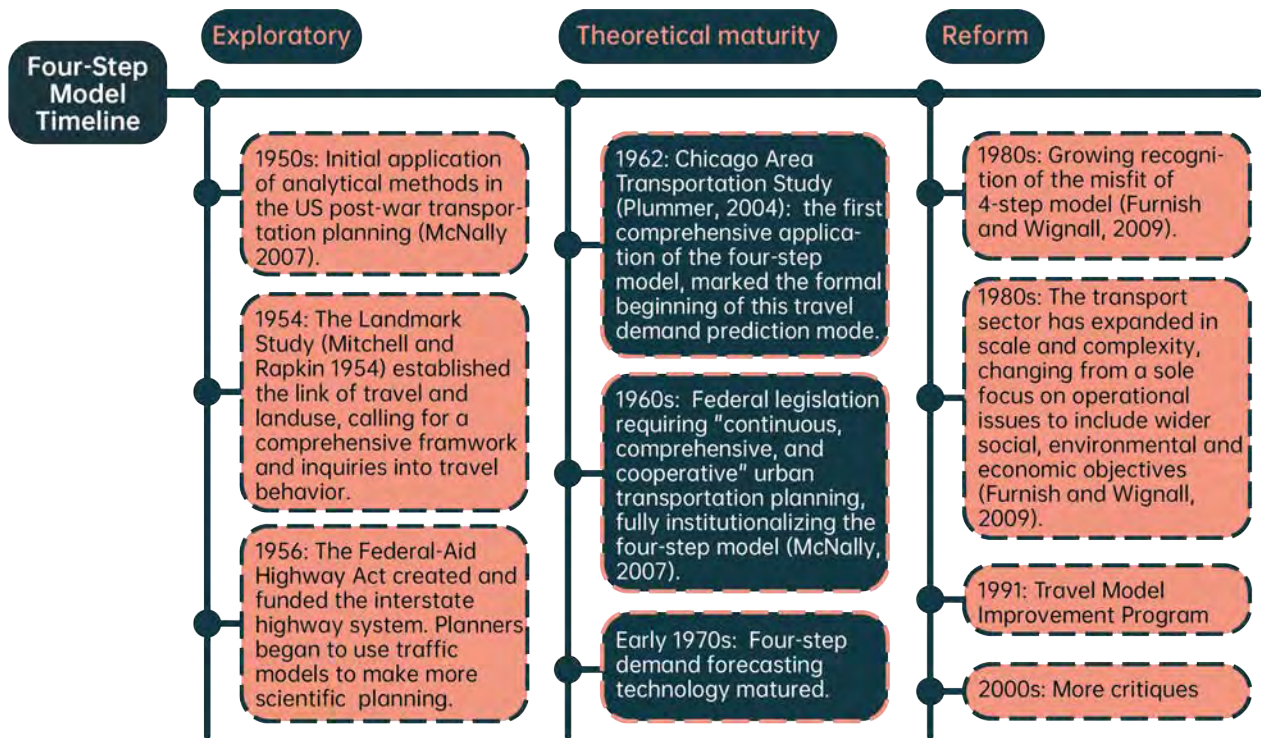
Figure 7. The timeline of the four-step travel demand model. *Created by Yingran Li.*

3.3 Modeling Trends

Scholars and practitioners assert that transportation planners are continuing to use the four-step model even though there are newer and more complex activity- and agent-based models. Unlike the four-step model, activity-based models use disaggregated, individual-level trip data rather than zone-level data (Castiglione et al, 2015), and agent-based models are more flexible and able to incorporate the decision making process of travelers rather than just using the destination and origin information (Yang and Morton, 2012)(See Glossary in Appendix C). However, practitioners also recognize current trends in practice and are researching ways to integrate these trends into the four-step model.

In 1964, Ira Lowry developed A Model of Metropolis, which simulated land-use changes as a result of urban renewal and slum clearance programs. By incorporating residential and activity patterns into

his model, based on these changes, Lowry was able to his land-use model with a trip-based travel model to "produce a set of network flows." (Iacono et al, 2008: 325-7) Since then, the integration of land use and transport has essentially remained unchanged (Moeckel et al., 2018). In theory, modelers integrate land use needs and transportation analyses at a micro scale. The microsimulation model replicates individual behaviors and decisions, trying to make connections between land uses and individual travel. However, the microscopic integration of land use and transport never became operational. There has been a growing trend of using microsimulation and introducing more complexities into once-simple models (Moeckel et al., 2018).

Kii et al. (2016) identified new requirements for integrated land-use and transport models to be inclusive of climate change mitigation, energy scarcity, social conflicts, and new technologies such as autonomous vehicles or shared mobility

services. Also, new trends such as telework and driverless vehicles have the potential to substantially influence land use patterns.

Besides integrating external factors into the model, some experts suggest that the model also needs to change internally. De Jong (2014) mentioned in the context of freight transportation, that mode choice is entered as an input without considering trade volumes. An external variable is shipment size, which may explain why small shipment sizes typically travel by road and larger shipments are more likely to be transported by rail or water. It is worth studying and exploring whether this applies to human transport where mode choice is entered as an internal variable. Hunt et al. (2005) argued that for the demographic data input, current models fail to include some significant demographic components such as age. Households are analyzed as an aggregate and the decisions of an individual are therefore not represented as independent units.

In addition to improving the four-step model, developing other isolated models as supplementary tools is another direction taken by transportation planners and critics of the current modeling. Increased public interest in factors such as public health, the environment, and the social benefits of walking has propelled the need to model pedestrian movement. A pedestrian volume model emerged as a result of such interest. Raford et al. (2006) listed the fundamental differences between pedestrian volume modeling and vehicular modeling:

   • Pedestrian trips are less homogenous than vehicle trips in terms of journey purpose and their route choices are less well defined;

   • Pedestrian trips are usually built into overall trips that include other modes like transit;

   • A pedestrian network is more difficult to define than a vehicular one because there are numerous pathways available to pedestrians that are not available to cars;

   • Pedestrians can make multiple intermediate stops that cars cannot (based on traffic, parking availability, etc.).

All the aforementioned authors concluded that more research is needed before pedestrian volume modeling becomes a standard. When that time comes, then pedestrian simulations "as a decision support system and scenario planning tool for urban planning may be realized." (Raford, 2006, p. 13)

More recently, there has been a more coordinated effort from state Departments of Transportation to improve and simplify models so that they better reflect shifting priorities and are not as time-intensive to run. Working together with research organizations, transportation agencies are revisiting travel demand models and investigating ways to better incorporate other modes of travel in addition to vehicular use when making traffic forecasts (NCHRP at 50 Years, 2012).

3.4 Unpredictable Consequences of New Trends

Models assume that population growth occurs spatially in a certain way, that income and household size will follow specific trends, or that income or household size impacts decision making in a certain way. But they cannot plan for unpredictable consequences of new trends that affect the way people travel, such as changes in technology, natural disasters, or a large employer opening up in a specific part of town (Parthasarathi & Levinson, 2010). Some of these trends with unpredictable consequences in Boston include, but are not limited to, an increase in ridesharing, a decrease in car purchases among younger generations, incorporating external costs into trip distribution, intersection or traffic delays, a shift in peak travel hours, changes in population and demographics, fluctuations in economic, modal, and land-use forecasting, and climate change. The

literature reviewed is a sample of information from these topics and is reflective of trends in the Metro Boston area.

A study by Sun and Yin (2017) that analyzed over 17,000 transportation journal articles from 1990 to 2015 identified the following emerging trends: sustainable development, non-motorized mobility, travel behavior, and human-centered research. This study suggests that transportation planning is becoming less automobile-centric and more people- and environment-centric (Sun and Yin, 2017).

Resilient Modes of Mobility

Figure 8. Environmentally friendly and people centric modes. *Source: David Soto. Why Transportation Must be a Part of Resilience Planning in Puerto Rico, 2019*

Conversely, Zhang (2005) studied the extent of automobile dependence in Boston, MA, Portland, OR, and Houston, TX in order to better understand the current shift away from driving towards travel choice accessibility. Zhang's study revealed that automobile dependence was associated with employment status, and that an unemployed person was more dependent than a part-time worker, and a part-time worker was more dependent than a full-time worker. According to this study, in Boston, automobile dependence for traveling 10 or more miles was much lower than for traveling two or fewer miles, which was likely due to transit reliability. The study points out that an increased trend of driving for short-distance travel illustrates increasing automobile dependence. The study also found that the level of automobile ownership does not correlate with the level of automobile dependence, and that work-based transportation and land-use initiatives (e.g. densification) would help to reduce automobile dependence (Zhang, 2005).

In terms of unpredictable consequences of climate change, Chang et al. (2010) conducted a study of river flood-induced travel disruptions in Portland, Oregon. Through the impact assessment method of combining various climate change and transportation models, they were able to study the impact that road closures would have on travel. Vehicle miles traveled were not impacted significantly by the road closures, but vehicle hours delay was impacted significantly. The implications of these findings are that transportation planners must take into account the impact of increased traffic delays due to climate change related events (Chang et al., 2010).

When it comes to the impact of climate change on transportation engineering, Meyer (2008) outlined short and long-term implications from temperature change, precipitation, sea level rise, storm frequency, and wind. Meyer stressed that planners should incorporate risk assessments into designing for a US transportation system affected by climate change (Meyer 2008). Boston's "Climate Ready" Mapm Explorer illustrates the risk posed from stormwater flooding, coastal flooding, and heat intensity due to climate change (Figure 9).
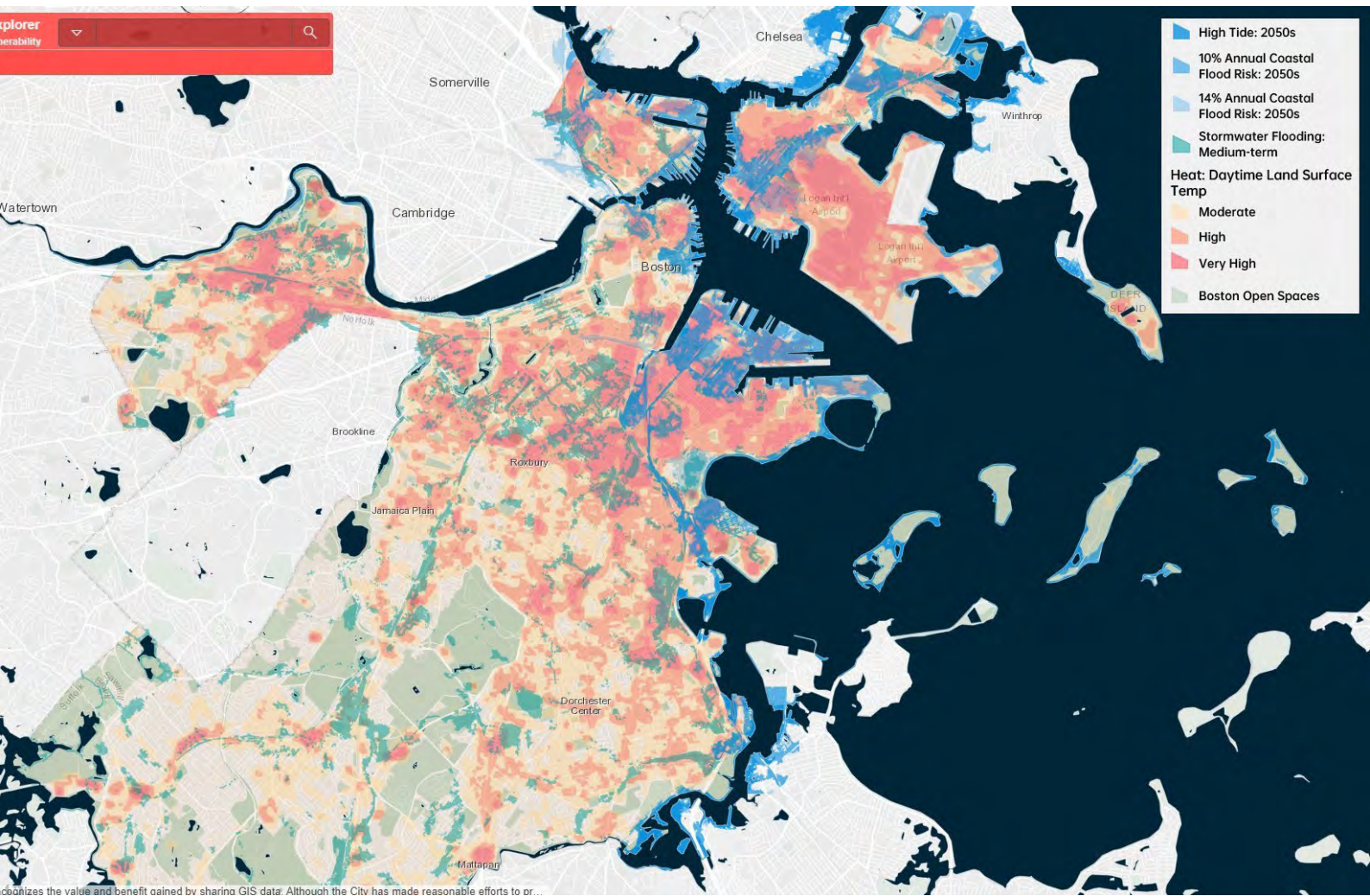
Figure 9. Climate Ready Boston map. *Source: Boston.gov*

Accordingly, design considerations for short-term climate change impacts in Boston included those relating to increased storm surge and sea level rise. Considerations for the long term included temperature changes and wind impacts on transportation infrastructure (Climate Ready Boston, 2020). Meyer pressed that there is a gap in the impacts of climate change on transportation infrastructure, and that land use and transportation planning must be closely aligned in the future to address these needs (Meyer, 2008).

In regard to trends in ridesharing, a study by Xu et al. (2015) proposed a new transportation model that reflected changes in transportation modeling due to ridesharing and congestion. Their results showed

that congestion levels were impacted by the price of ridesharing, and more specifically, that an increase in the price of ridesharing (within a specific range) decreased traffic congestion. Additionally, the study found that ridesharing increases as congestion increases.

This study has implications for any city experiencing high levels of congestion, as it shows that the ridesharing movement can have an impact on city congestion, which transportation models need to recognize (Xu et al., 2015).

An additional new trend with unpredictable consequences is outlined in an article by Ways and Burbank (2005) of the Federal Highway Administration. The authors advocate for scenario

planning, or flexible planning for future trends and uncertainties (Schoemaker, 1995), alongside transportation planning, which incorporates public input and community values into future plans. Additionally, scenario planning aims to educate community members on transportation trends to reduce uncertainty and confusion surrounding transportation planning. By involving the public, scenario planning empowers transportation advocates and community members to build consensus, recognize regional transportation tradeoffs, and incorporate the public's perspective in order to strengthen transportation planning for the future (Ways and Burbank, 2005).

The presence of new trends with unpredictable consequences highlights the precariousness of using transportation models to predict the future.

3.5 Critiques of Modeling

Model forecasts can have significant impacts on which transportation projects are funded, prioritized, and executed. This has profound implications for the future of a city or town, since projects shape landscapes for decades. Models are seen as an important tool in the planning process, as they provide planners and policy makers with quantitative data with which they can make informed decisions. However, critics of the four-step model question its accuracy, note that forecasts are biased toward overstatement, and can be manipulated by political agendas to prioritize specific projects over others (Hartgen, 2013; Handy, 2008, Flyvbjerg et al, 2005; Parthasarathi and Levinson, 2010; Marsden and McDonald, 2017; Beimborn and Kennedy 2006). **The idea that models are technical, and therefore objective and correct, is misleading.**

In fact, transportation models can create incorrect information at any stage of the four-step process. Indeed, there is a lot of potential for transportation

models to be significantly inaccurate. In a study of over 200 projects worldwide, Flyvbjerg et al. found that estimates used by planners of transportation infrastructure development are "highly, systematically, and significantly misleading" (Flyvbjerg et al, 2005). Another study conducted by Parthasarathi and Levinson used a sample of recently-completed projects in Minnesota to measure accuracy of modeling forecasts. They found that a lack of incorporation of significant shifts in personal preferences and social changes into models led to inaccuracies in travel demand estimations (Parthasarathi & Levinson, 2010).

Many problems associated with transportation models are caused not only by their potential for inaccurate forecasting, but also by their use and interpretation, which can be manipulated by policy makers and urban planners. Hartgen suggests that forecasts are subjective exercises that are susceptible to being influenced by political agendas, with the potential to be designed in a way that projects a favorable light on certain potential outcomes, while disadvantaging others. He also notes the potential for federal funding to favor highway expansion, encouraging "megaprojects" to move forward (Hartgen, 2013). Additionally, despite their inherent uncertainty, forecasts can be presented with certainty, leading to misunderstandings about the implications of the forecasts, which leads to misguided decisions (Handy, 2008). The consequences of making planning decisions based on inaccurate forecasting are multifaceted, including wasting scarce resources, and targeting out-of-date goals (Flyvbjerg et al, 2005)

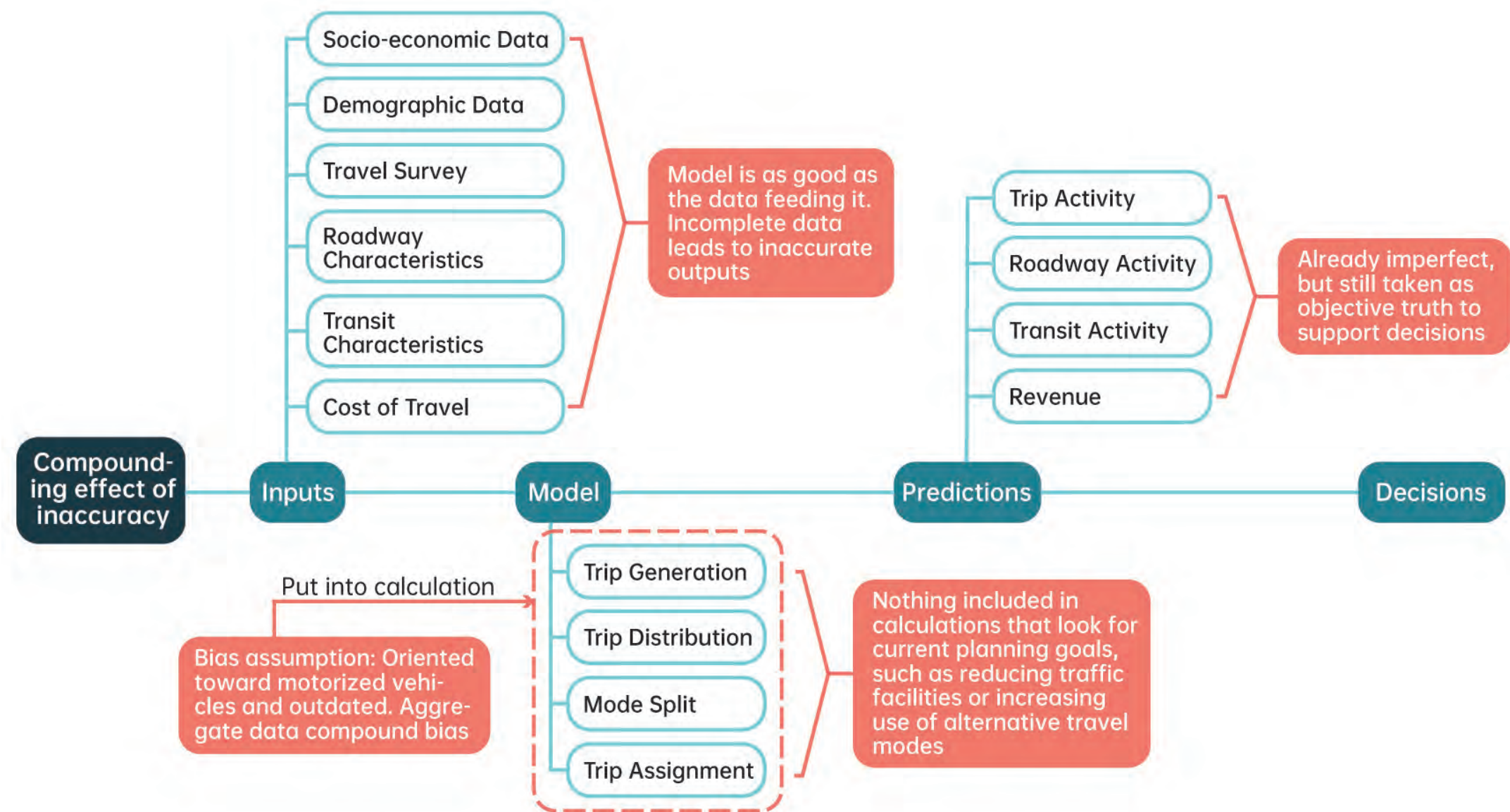The compounding effect of this inaccuracy is depicted below.

Figure 10: Compounding effect of inaccuracy. *Created by Yingran Li*

As previously mentioned, the first step in a four-step model is trip generation. Trip generation is based on traffic counts and demographic and geographical data. Such data are often outdated and incomplete: accuracy of traffic counts and travel surveys are extremely variable, demographic and geographical data are often not up to date. Demographic data change especially fast. For example, as cities face rapid expansion and displacement caused by gentrification, people have been forced to move quickly; changes in lifestyle and trends in immigration also affect demographic information. Forecasters quote this as a main source

of uncertainty in road traffic forecasting (Flyvbjerg et al., 2005; Hartgen, 2013).

Additionally, transportation models are developed by people who -- consciously or unconsciously -- embed their own assumptions and ideas about future conditions. Models are inherently limited by the assumptions that engineers, planners, or policy makers include in the transportation modeling process.

Models have assumptions explicitly included in the equations they use. This creates a weakness that makes models insensitive to solutions that stimulate

non-automobile modes of travel. Transportation modeling has only been recently updated from planning for highways, to address transit, pedestrian traffic, land use, and air quality issues. **As a result, there tends to be a trend that overestimates demand for roadways and underestimates the potential success of alternative transportation solutions (Beimborn and Kennedy, 2006).**

The assumption that automobiles are the preferred mode of travel could make today's transportation models unable to predict situations that would favor non-automobile modes of travel, therefore underestimating

the effectiveness of alternative transportation policies. Since models were not originally intended to incorporate these issues, they might not do so well at handling predictions (Beimborn and Kennedy 2006). These factors make it difficult to predict future conditions without bias.

Models often incorporate bias that favors automobile transport and tend to ignore or undercount (and therefore, undervalue) nonmotorized transportation improvements (Stopher and Greaves, 2007). Critics suggest that there is a tendency to overvalue highway capacity expansion, and de-emphasize alternative solutions to transportation problems. The impacts cumulate in such a way that they significantly shift policy and planning efforts towards the automobile and away from alternative forms of transportation, resulting in more vehicular travel and placing "an undue economic burden on consumers and the economy" (Comprehensive Transport Planning, TDM encyclopedia).

While the accuracy with which models can replicate real world conditions has improved, they are still limited in utility, as they represent just one single way of accounting for all possible outcomes. **Conventional transportation models tend to be useful for analyzing current conditions, forecasting the effect of future 'business as usual' strategies and for testing the performance of network improvement options (Furnish and Wignall, 2009). They are not, however, good at predicting the future if the goal is to change behavior or plan for a different future.**

Scholars and advocates are calling on transportation professionals to adapt transportation models to reflect the wider range of needs and goals (Furnish and Wignall, 2009). In her analysis of changing trends in technical aspects of regional transportation, Handy

found that goals that have performance measures that can be forecast using transportation models get the most weight in the process. As a result, congestion relief may still be driving the planning process, despite the adoption of a broader range of goals, simply because of the entrenched use of transportation models to forecast system performance (Handy, 2008). **If new goals are truly important, new planning tools are needed.**

A comprehensive list of problems with contemporary models and suggestions with how to fix them is included below.

Table 2. Improving transportation models.
Source: Transport Model Improvements, Victoria Transport Policy Institute (VTPI), 2019.

Factor	Problems With Current Models	Appropriate Correction
Accessibility	Most transportation models primarily evaluate mobility (movement), and fail to reflect accessibility (people's ability to obtained desired goods and activities).	Develop multi-modal models which indicate the quality of nonmotorized and transit travel, and integrated transportation/land use models which indicate accessibility.
Modes considered	Most current models only consider automobile and public transit.	Expand models to evaluate other modes, including walking and cycling.
Travel Data	Travel surveys often undercount short trips, nonmotorized travel, off peak travel, etc.	Improve travel surveys to provide more comprehensive information on travel activity.
Generated traffic and induced travel	Traffic models apply the same travel time to value all travel, regardless of conditions.	Vary travel time and cost values to reflect travel conditions, such as discomfort and delay.
Qualitative impacts	Focus on quantitative factors such as speed and user fees, and undervalues qualitative factors such as convenience and comfort. Level of service ratings are provided for roadway conditions, but not other modes.	Develop multi-modal level of service rating systems to help evaluate walking, cycling, and public transit travel conditions, in order to identify problems and trade-offs between automobile traffic and other modes.
Self-fulfilling prophecies	Modeled traffic projections are often reported as if they are unavoidable. This creates self-fulfilling prophecies of increased roadway capacity, generated traffic, increased traffic problems, and sprawl.	Report travel demand as a variable (for example, "traffic will grow %20 if current policies continue, %10 if parking fees average 1$ per day, and %0 if parking fees average 3$ per day") rather than a fixed value ("traffic will grow %20").
Transportation diversity	Models often underestimate the benefits of improved travel options, particularly those used by marginalized groups.	Recognize the various benefits that result from improving accessibility options.
Impacts on land use	Models often fail to identify how transport decisions will affect land use patterns, how this affects accessibility and strategic planning objectives.	Develop integrated transportation and land use planning models which predict how transport decisions affect land use patterns and how land use decisions affect accessibility.

3.6 Massachusetts Planning Goals

In order to understand if the travel demand model is a good tool to make decisions that represent the public's vision of the future of transportation, we wanted to get a better sense of how that vision is communicated by different actors. **While transportation modeling often over represents the need for automobile infrastructure, Massachusetts' state transportation goals reflect very different priorities. This disparity is important for us to consider because it puts the very role of transportation modeling in the transportation planning decision making** process into question. If these outcomes are inconsistent with the state's stated goals, will these goals still be met?

Several different actors have control over transportation planning in the region. These include the federal government, which funds federal and Interstate highways, the Commonwealth of Massachusetts and its Department of Transportation (MassDOT), the Massachusetts Department of Conservation and Recreation (DCR), the Metropolitan Planning Organization (MPO), which implements transportation projects in the Metro Area, and the 97 municipalities that make up the Metro Area.
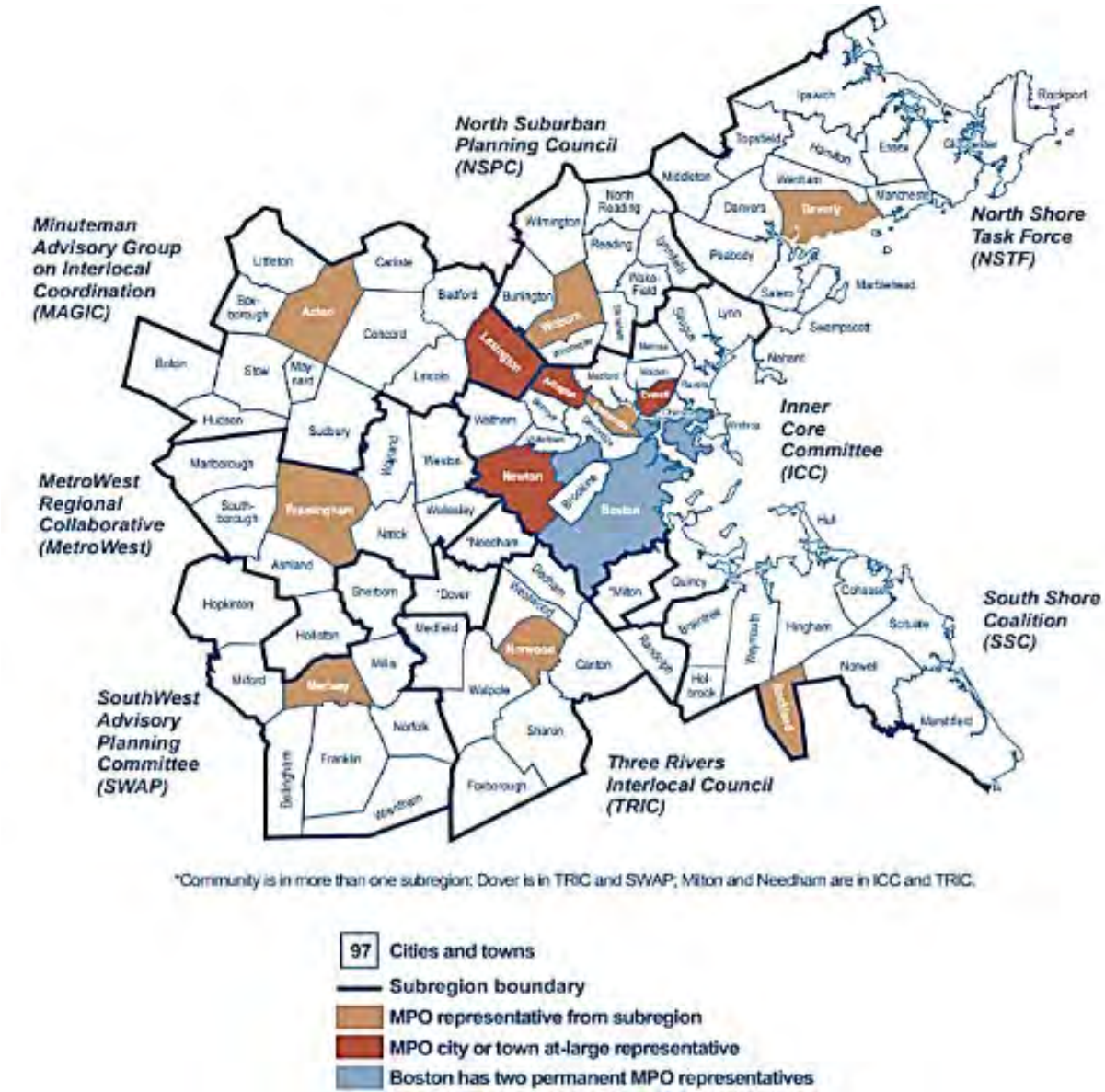

Figure 11. Massachusetts municipalities within the Boston Region Metropolitan Planning Organization (MPO). *Source: Central Transportation Planning Staff (CTPS)*

The region includes Boston, Cambridge, Somerville at its center. Likewise, some quasi-governmental agencies are also involved. These include the Massachusetts Bay Transportation Authority (MBTA) and MassPort. Each level of government is led by actors representing different constituencies and political interests. This disparate structure allows for specificity in the planning process but can also lead to interagency conflict and the clash, diffusion, or dilution of goals.

We reviewed several planning documents, including Go Boston 2030 and Focus 40, to get a better sense of the way transportation agencies communicate their vision for the future of transportation. The language used in these reports indicate that MassDOT and the City of Boston have embraced moving away from car-centric design, and toward infrastructure that supports a multi-modal future. They specifically commit to reducing car travel, increasing transit accessibility, and making streets safer for walkers and bikers, among other things. However, as discussed in the previous section, the four-step travel demand model generally over-predicts for cars, which can lead to car-centric design. It is important, then, to note the inconsistency between the language used to communicate statewide transportation planning goals (human-scaled and transit-centered solutions), and the tools that are used to achieve these goals. **Forward thinking goals call for updated, innovative tools.**

A main priority for MassDOT is the current State Implementation Plan (SIP) (Massachusetts Department of Transportation, n.d.). This is a regulation implemented by MassDOT to achieve the goal of completing four main projects. These include (1) the Green Line Extension to Medford, (2) the Green Line Extension to Union Square, Somerville, (3) upgrading the MBTA Fairmount Commuter Rail line, and (4) constructing 1,000 new parking spaces near rail stations. Most of these are complete or

near completion. **We can glean from the SIP that MassDOT prioritizes human scale transportation solutions and urbanism in its reports and language. The goal behind this is to "reduce certain air pollutants in eastern Massachusetts (Massachusetts Department of Transportation, n.d.). This is an important finding because it denotes that plans inconsistent with these values are inconsistent with the overarching state planning goals to curb emissions.**

Another feature of the MassDOT transportation planning is the MBTA Focus 40 plan (MBTA, 2019). This plan begins with four goals of sustainability, equity and affordable housing, livability, and economic competitiveness (Ibid). Likewise, the plan has identified several "priority places" to focus efforts in their future development. These include major employment growth centers like Kendall Square, Cambridge, South Boston and the Waterfront, the Longwood Medical Area, and Logan Airport, all places where transportation links can be improved. The MBTA also identified communities in the inner core that are underserved by transit. These include Everett, Revere, Chelsea, Roxbury, Mattapan, Dorchester, South Boston, and Brighton. Finally, the MBTA identified "urban gateways," denser edge nodes where improving connection could benefit the region. These include Waltham, Framingham, Lynn, Salem, Lawrence, Lowell, Haverhill, and Brockton among others. It is important to denote the MBTA's stated goals of sustainability and "improving mobility options for all- regardless of income or ability…" (MBTA, 2019).

These goals were prioritized because they were identified as part of what the MBTA refers to as "innovative engagement processes" that supplement sophisticated data analysis (MBTA, 2019). **This is particularly pertinent because it shows that any transportation planning that is inconsistent with these goals is inconsistent with what the people of this region want from their**

government and transportation infrastructure.

We need to keep these goals at the forefront of the project prioritization process, and treat them as data that are just as important as a model forecast. **If the outcomes of the model are inconsistent with goals outlined in state plans, how are we holding ourselves accountable to achieving**

the sustainable, multi-modal futures the people and planners of the Commonwealth are prescribing? If transportation modeling better reflected benchmarks for these goals, it would help the transportation planning sector better work together to carry out transportation solutions as outlined in state plans.
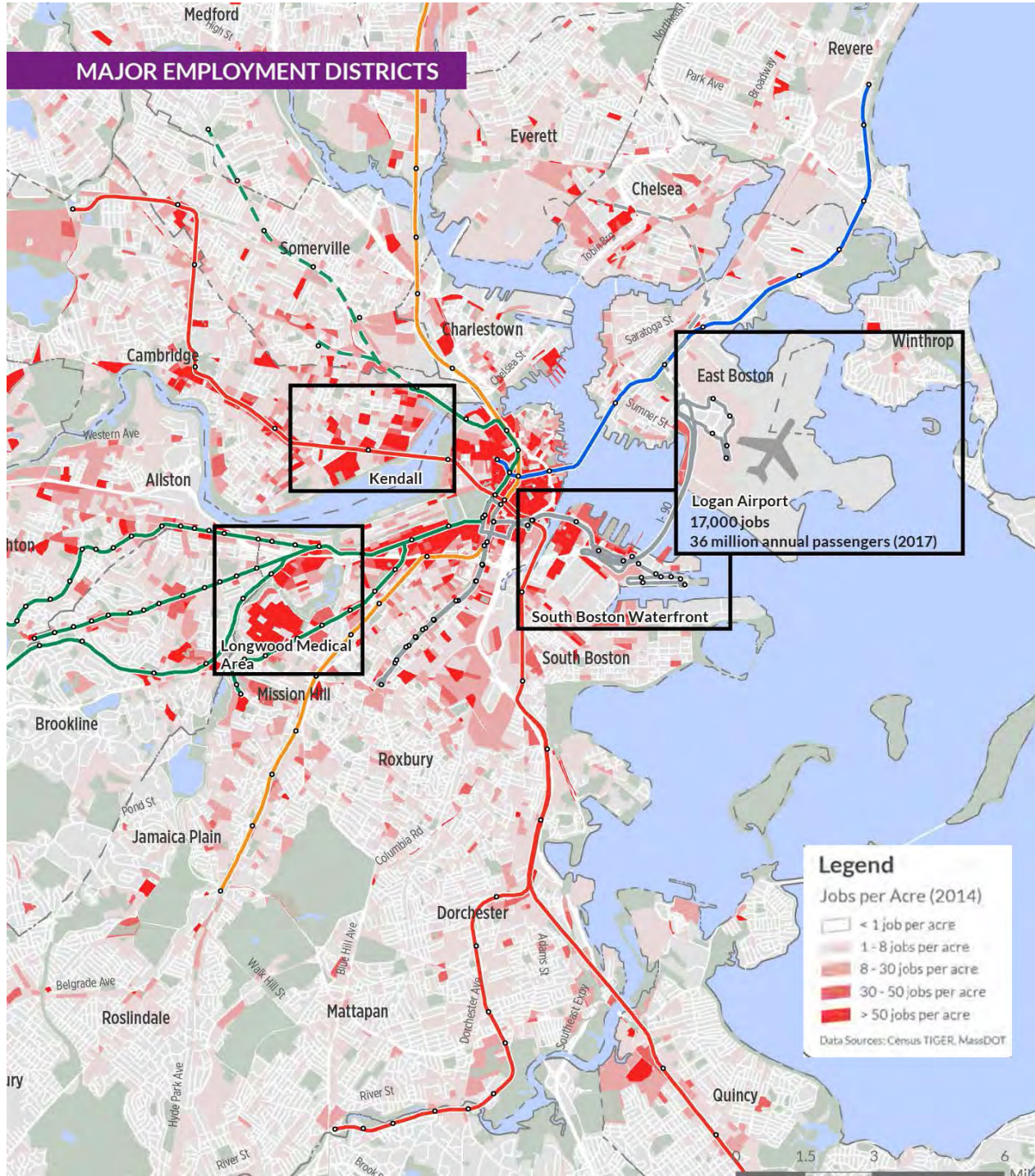

Figure 12. Priority places in Focus 40. *Source: Massachusetts Bay Transportation Authority (MBTA).*

4. INTERVIEW ANALYSIS AND FINDINGS

Our data are primarily sourced from interviews with transportation advocates, engineers, and planners, from agencies such as CTPS, the Boston Transportation Department, MAPC, and WalkBoston, among others. Our analysis required a careful assessment of the language being used by the interviewees. We coded and analyzed the transcripts of each of the interviews to identify relevant and novel truths about transportation modeling.

This section starts with an assessment of all of the actors who engage with travel demand models throughout the transportation planning process. A network analysis map of these actors, seen in Figure 13, displays the intricate web of relations between organizations and stakeholders that makes transportation planning possible. It is clear from this figure that transportation planning a complex process involving a multitude of different players. The purpose of this map is not to illustrate the power dynamics or hierarchy of the process, but instead is to show how the planning process relies on the input from various different sectors in order to make a cohesive product. By showing this map, it is clear that every organization listed has the power and opportunity to hold others accountable in the planning process, and only through a cohesive and holistic effort can the planning process succeed. We provide insight into how forecasts are generated and used, as we understood from our interviews. A

short list of inputs used, why specific inputs might be used at different times, and how assumptions are incorporated into the CTPS model, are all outlined in Figure 16. We discuss some weaknesses inherent in using the model, as well as some suggestions to address those weaknesses, and some key questions for transportation advocates to ask when engaging with model forecasts. We hope that the details we discuss in our analysis reveal a clearer path for transportation advocates to critically engage with the modeling process, and hold the sector accountable for achieving the goals outlined in the Massachusetts Planning Goals section of our literature review.

Our interviews revealed that opinions on the efficacy and necessity of transportation modeling landed on a spectrum: from believing that it is integral to planning and decision making, to asserting that it is completely irrelevant and unnecessary. Some opinions were more in the middle: expressing faith that with improvements, the model can be a great asset to transportation planning in our region. We do believe that no matter where stakeholders – state agencies, regional planning organizations, advocacy groups -- land on this spectrum, they all have the ability and responsibility to make the modeling process better.

4. INTERVIEW ANALYSIS AND FINDINGS

Figure 13. Network analysis map of actors in the transportation planning process. *Created by Yingran Li.*

4.1 How model forecasts are generated

Our interviews indicate that a project is conceived when a city, town, or locality identifies a problem, or set of problems, that need to be addressed. There is a specific process whereby cities and towns submit proposals to state agencies, such as the MBTA, for review and approval. Then, the transit agency, such as the MBTA, MassDOT, or FHWA, often prioritize addressing these problems based on political goals and funding availability.

Based on its own priorities, a state agency like MassDOT might favor projects that move toward multimodal transportation in urban areas and try to encourage municipalities to submit transportation improvement plans that incorporate ways of doing that. The MBTA, on the other hand, might feel more pressure to juggle many competing priorities, like reducing its debt while addressing a long line of repair and service improvement projects. This need to maximize efficiency while being fiscally responsible, likely influences the projects that get prioritized in their process. That also means that agencies like the MBTA face constant political pressure for many of its problems for riders, employers, local officials, and the general public. They have a legitimate need to invest in better infrastructure, but because of their strict financial restrictions, their budget spending is under constant scrutiny.

Projects also rely on political support. Indeed, the goals of any given transportation agency are greatly influenced by local officials and the cities and towns they serve, as they should be representing the voice of the public.

Once a project begins to move through the pipeline, these agencies work with a municipality, such as the City of Boston or the City of Cambridge, and their stakeholders to strategize and create a vision, typically an ideal solution that is also achievable. The
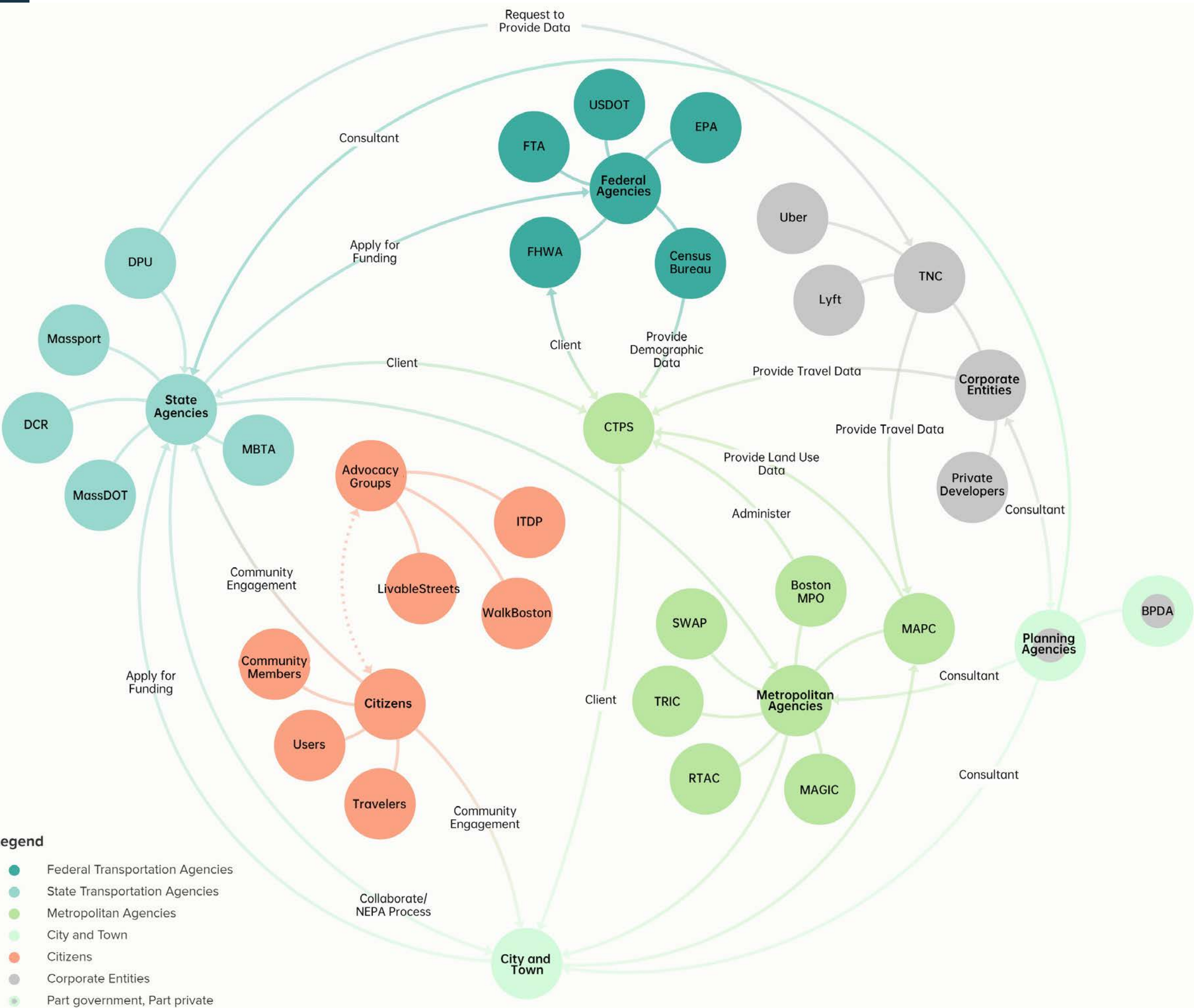
agency partners with CTPS to generate predictions of how traffic will respond to the proposed project, in order to assess if the project is feasible. The relationship between the agencies and CTPS has been described by CTPS staff as a client-consultant relationship, where the state and federal agencies are the client and CTPS is the consultant.

Transportation engineers from CTPS will run the travel demand model to generate a set of predictions about how traffic will change as a result
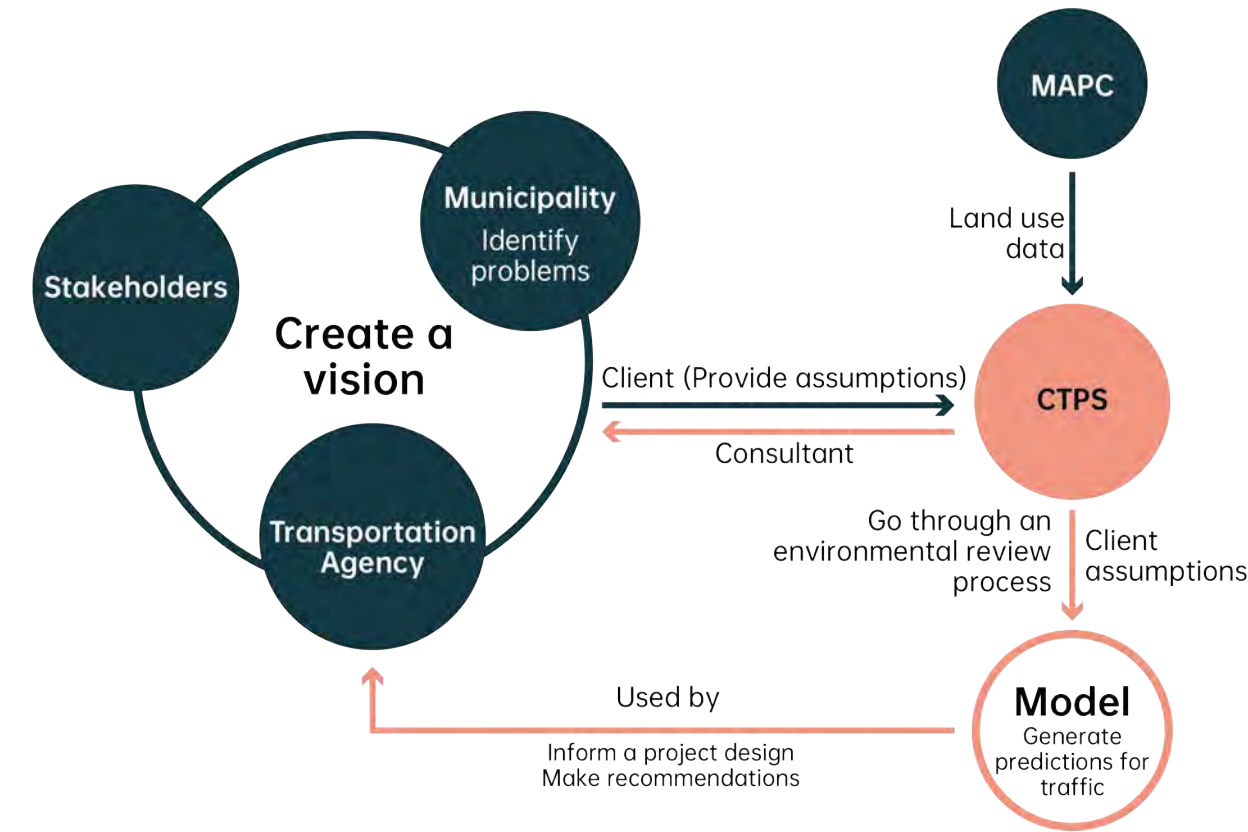

Figure 14. Transportation project decision-making process. *Created by Yingran Li.*

Table 3. Fixed and Project-Specific Assumptions. *Created by Sarah Saydun.*

Fixed assumptions	Project-specific assumptions
The automobile is the preferred mode of travel	
Traffic will always grow every year	
People decide which mode they will use mainly based off trip cost and time it takes to make a trip using that mode	The frequency and quality of transit service
	The price of gas
Things are going to look relatively the same in 30 years, meaning, no major environmental or cultural events will happen, and no improvements to transit, bike, or pedestrian infrastructure will occur between now and 30 years from now	The price of transit fares

of the identified project. Several components are collected and used as inputs; mainly, specific sets of data and assumptions.

Some assumptions are fixed, and some are specific to each project.

Fixed assumptions exist for several reasons. Some of them are a result of the way the model is built, for example, that mode choice is determined by cost and time. Others come out of the state's long-range transportation plan, which is a fiscally constrained document and grounds which projects are approved. Changes made to those assumptions would require a federal review. Project-specific assumptions are generally handed down by municipalities and state agencies. Interviewees made sure to point out that even though CTPS operates the model, they are still consultants, and the decisions about which project-specific assumptions are used are made by planners and policy makers.

> "Understanding the master plans is an important piece because land use provides the foundation for trip generation."
>
> – CTPS employee

Then, the assumptions inform what types of input would be incorporated into the model. MAPC, which works closely with CTPS, will perform land-use forecasts based on current conditions and on the assumptions that have been given to them by the project engineers. For example, if the MBTA plans to change its transit service over the next 10 to 15 years, MAPC will forecast how land use will change as a result of those proposals and generate a series of different scenarios. Conversely, this step also considers how changes in land-use patterns in the future will impact the transportation system. CTPS will then feed this data into its model as one set of inputs that will generate travel times and accessibility measures that can be fed back into the land-use model to understand how land use could reallocate. **Several planners pointed out that these results only provide a static snapshot of the future based on one very specific moment in time. They do not provide fluid scenarios that would account for an ever-changing transportation system.**

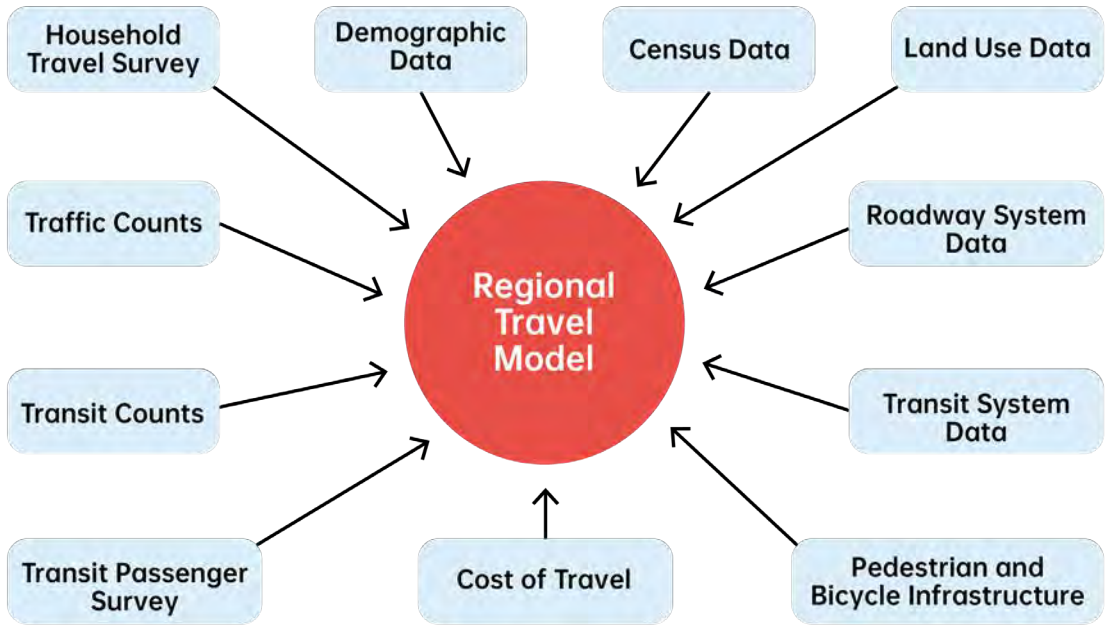Data sets that are consistently used as inputs include:

Figure 15: Inputs for the Regional Travel Demand Model. *Adapted from CTPS, Boston Regional MPO's presentation titled: Regional Travel Modeling Conducted by the Boston Region MPO, March 25, 2020.*

Depending on the project and the questions that need to be answered, engineers can also link the CTPS model to other models. The regional travel demand model can be used in air quality analyses, corridor studies, long range plans, construction impacts, and transit projects. For example, to determine the air quality and greenhouse gas emission estimate from different transportation sectors or projects, the CTPS model can be linked to MOVES2014b, the latest version of the Motor Vehicle Emissions Simulator (MOVES), used by the

U.S. Environmental Protection Agency (EPA). It can also be linked with economic analysis tools to predict financial implications. The model is not only used for transportation projects; CTPS can also use it to do scenario planning and conceptual studies. The economic analysis tool can be helpful in predicting sensitivity to changes in gas prices and estimated revenue based on the number of vehicles on the road. Ultimately, the assumptions and inputs will vary depending on the type and purpose of the project.
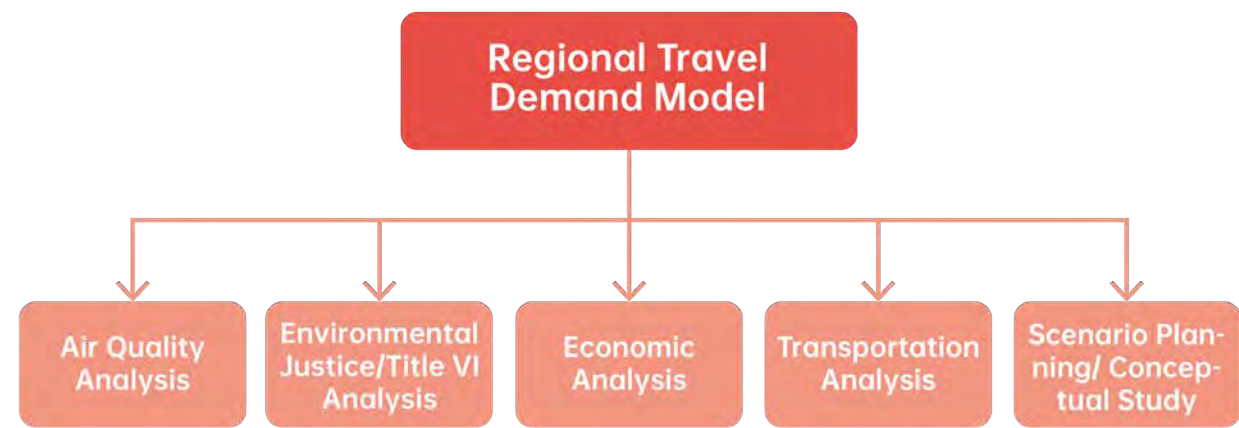

Figure 16. Application of the travel demand model. *Created by Yingran Li*

4.2 How model forecasts are used

According to interviewees from MAPC, CTPS, and ITDP, models allow planners and policy makers to make evidence-based decisions. They are seen, by some, as the best tool available to predict future behavior and therefore are confident in their reasoning for prioritizing one project over another.

> "The modeling becomes essential to make sure that we're understanding trends, so our decision making is informed. Because these things are not always intuitive."
>
> – ITDP employee

Once the model has finished running through its assumptions and inputs, the planners and policymakers on the project team would use those

results to either inform a project design, make new recommendations for policy changes, or justify recommendations that they had already planned to pursue prior to modeling. Interviewees who were more critical of using models in planning processes suggested that with some major projects, the state uses the model to defend its rationale for projects that it had already prioritized and deemed feasible, even if they are not accurate. Others emphasized that forecasts from models are needed to lend credibility to their decisions. While all of our interviewees stressed the importance of using data to inform big planning decisions, not all of them see forecasts from models as a credible source , due to their potential to yield inaccurate results.

> "It's usually when trying to justify an expenditure or comparing projects against each other that a decision is made on which project will take priority."
>
> – Member of the 128 Business Council

4.3 Weaknesses and suggestions for improvement

Evidence from our literature review and interviews confirm that the CTPS model is good at examining the outcomes of projects on regional flow, like what would happen after adding interchanges to an interstate system. However, we also found some critical weaknesses that impact its accuracy. Many

of the critiques we heard during interviews were consistent with the critiques we highlighted in our literature review.

For example, the CTPS model does not do well at predicting for other modes, such as transit ridership, bicyclists, or pedestrians. It generally overpredicts for cars, and underpredicts for other modes. **This is significant because these important numbers on which decisions are made are biased towards cars and will justify road expansion while de-emphasizing the legitimacy of options that improve infrastructure for other modes or purposes.** Some explanations for this gap and suggestions for improving them, that arose from our interviews, are outlined below.

Table 4: Weakness and suggestion for CTPS model. *Created by Sarah Saydun.*

Weakness	Suggestions for improvement	Desired Outcome and explanation
1. Insufficient data for accurate predictions	Invest in better data collection	Better understanding of how people move, and why, leads to more accurate predictions. Can reduce possibility of over or underpredicting for specific modes.
2. Results are dependent on the quality of inputs	Increase transparency and improve community engagement processes	Community members have a say in which inputs are used, leading to outputs more representative of current travel patterns and community needs.
3. Inability of modeling process to see a different future	Incorporate iterative planning practices	Allows for more course correction and leads to more accurate predictions
4. Limited scope of outputs	Integrate a process to review forecasts: build in room for questioning results, and use feedback loops	Results are not taken at face value, which ultimately improves accuracy of output

Weakness 1: Insufficient data for accurate predictions

Much of the data used as inputs are outdated and incomplete. **If the inputs for any algorithm are biased, incomplete, or outdated, the output will also be biased, incomplete, or outdated, no matter how much one tweaks the algorithm.**

The Decennial Census is only conducted every ten

years, and aside from issues that arise with using old data in a rapidly changing region, there are also concerns about the Census's ability to fully represent the demographics of any area. The American Community Survey can be used to supplement missing information from the Census, but it still does not provide a complete picture of who is traveling, how they travel, and why. Regions change so quickly, and each suffers from very specific issues.

All of our interviewees were well aware of the shortcomings of using data from these sources, but some expressed a sentiment that suggested "we are doing the best we can with what we have".

Additionally, models are run for a project that will be completed in ten to fifteen years. By the time the project is complete, the data that were used to predict the future is likely irrelevant. We address this further in the suggestion for Weakness #3.

Suggestion 1: Invest in better data collection

"As an industry, if we do not get better at data gathering, we're going to continue to roll the dice with a lot of these projects."

– Member of the 128 Business Council

If models need to be accurate in order to inform project prioritization, the data used as inputs must also be accurate. It is important to invest resources in better understanding of how people move, and why. This is especially true for historically ignored modes, like transit, bikes, and walking. It also has significant implications for using location-specific data, instead of depending on data that span urban, suburban, and rural areas, as transportation infrastructure looks very different in all of these areas. Without commitment to up-to-date, spatially specific, information from the start, model forecasts will fall short.

We recognize that, while flawed, using sources like The Census and The American Community Survey, are essential and there's no real replacement for them. However, much of these data might not actually very useful for the specific conclusions that transportation planners are trying to make. We urge CTPS, MAPC, MBTA, and MassDOT to be more creative about data collection and analysis, expand its breadth of data sources and ability to draw connections based on a sophisticated understanding of the intersectionality of travel behavior, in order to

make better informed decisions.

Weakness 2: Results are dependent on the quality of inputs

The model forecast can be skewed by the inputs used in any given situation. For example, when choosing to forecast a scenario where transit headways were 20-30 minutes (instead of 5-10 minutes), there is potential for low transit ridership to be predicted. That prediction can then be used as a means to justify not building transit. But if the input were 5-10 minutes, the model could have produced a higher prediction for ridership, and been used as a justification to build transit.

Given the history of the travel demand models and their grounding in highway development, interviewees expressed a hesitation with using predictions about transit produced by the CTPS model. **The historical focus on vehicular traffic and highway expansion has contributed to the assumption that transit ridership will not significantly increase. As a result, it is possible that projects that expand transit infrastructure could be doomed from the start.** Therefore, the concern here is not solely about the model, but also the inputs that are fed into it.

Suggestion 2: Increase transparency and improve community engagement processes

More sustained and meaningful community engagement is needed in order to keep policy relevant and goals at the center of planning.

Information on what inputs, assumptions, and calibration techniques were used for any given project are hard to find. **There should be more transparency throughout the entire planning process, so community members and advocates can understand why a model predicted what it did, and push for more accurate forecasts.**

"Treating the community more like a client has worked really well"

– Member of the 128 Business Council

The public engagement process, as it was described to us in our interviews, begins once the model has already been run, and decisions have already been made about project design. Citizens and advocacy groups, of course, can push back on the project or question the arguments for the decision rationale in public meetings, as they have in the past. Planners and engineers can either return to the model and modify some of its inputs or they can simply defend the decisions based on the model outputs. **However, this is not a "true" engagement process, rather, it is a one-way information session with room for questions and answers.**

Other engagement opportunities currently include public comment processes that occur later in planning stages; using the MPO as a forum for towns to become more involved in the process and share information because land use forecasting is the foundation for the model inputs. Many advocates emphasized that all of these opportunities occur too late in the process.

"CTPS could have a public meeting before running the model and say "We're going to run this model to answer this question. Here are our inputs and assumptions. What do you think is missing?". Then, they could come back after the model has been run and say: "Does this match your version of reality?"

– LivableStreets Alliance volunteer

It is interesting to note that there was not consensus among our interviewees around who was responsible for improving community engagement, or at what point in the process the public should be involved. We heard from some advocates that CTPS can, and should, do a better job of involving community members at the beginning stages of

the modeling process, before the model is even run. Others pointed out that the client, such as the MBTA, is ultimately the party responsible for facilitating public outreach, not CTPS. While we believe that whichever state agency is responsible for the project should be planning the community engagement process, we do think that there is room for better representing community voice in the modeling process. Recommendations for how to design that process are at the end of the report.

It is also important to note, here, the strides being made by the MBTA to do more meaningful community outreach, and the efforts of CTPS to better understand data about non-vehicular modes of travel. The Better Bus Project and Focus 40 were both specifically called out in interviews as projects that pushed the needle forward. We hope this report serves as further encouragement to dig deeper on these efforts.

Weakness 3: Inability of the modeling process to see a different future

"For regional planning, modeling assumptions rarely include new rail service in the future or more bus service, beyond what is in the state agencies' five-year capital plans. We're assuming that the transportation system in thirty or forty years will largely look like it does today. I think that will always be a critique; that we're not assuming more change. An approach that includes multiple future scenarios would be better."

– MAPC Employee

The model is good at predicting the future as long as nothing changes. But if planners are trying to encourage shifts in behavior, like becoming less dependent on automobiles, or increasing pedestrian travel, they can't depend on the status quo.

Additionally, since the model is cumbersome and

expensive to run, projections are not updated as frequently as they should be. **For example, the model is run with an assumption that transit costs $2/ride and generates a forecast based on that assumption. If anything occurs after this to affect fares, like a policy change wherein fare prices increase or decrease, that will likely have some effect on actual ridership numbers. That policy change, and subsequent rider change, might not be reflected in the prediction in time to adjust the project outcomes.**

Similarly, the forecast represents a snapshot of demand during one specific period of time. This means that the model does not account for induced demand very well, and is unable to take radical shifts in behavior, like sustained preference for a different mode, into account.

All of these shortcomings skew the model's predictions -- historically, and even today, its major flaw is over-predicting for vehicular traffic.

Suggestion 3: Incorporate iterative planning practices

Interaction Design   **Interface Design**

Ideate → Prototype → Build → Analyze
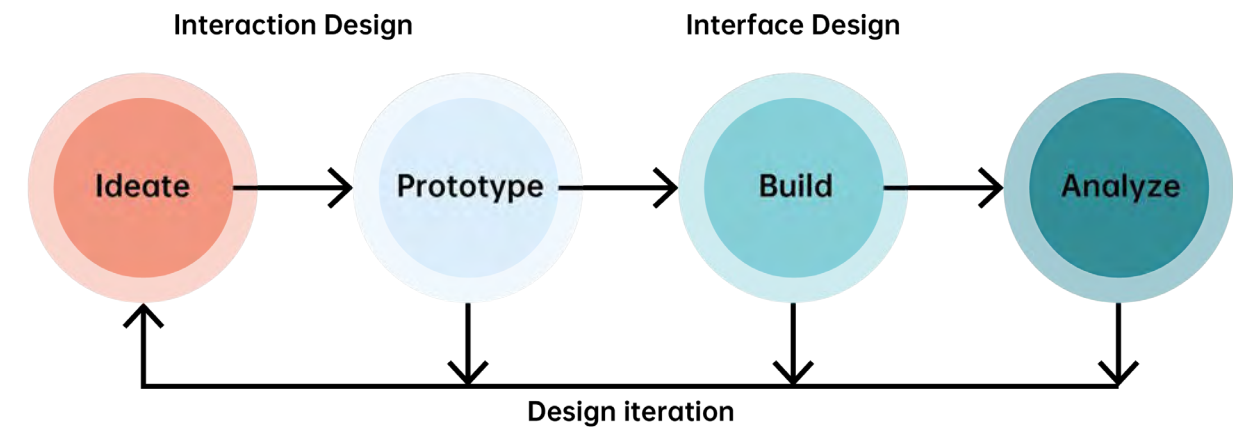
Design iteration

Figure 17. Iterative design process. *Adapted from ZURB.com*

CTPS could incorporate to consistently iterate and improve the way the model functions: scenario planning; feedback loops; and back-casting; which are briefly discussed below.

Scenario planning identifies several different

Many interviewees suggested that the process could be treated more like working with a hypothesis. Before running the model, a range of possible outcomes should be identified based on what is already known about transportation trends in the region. Once forecasts have been generated, they should be interrogated and compared against that range of possible outcomes. If the forecast does not land within that range, there should be a process to reevaluate the inputs and assumptions that were used at the beginning of the inquiry to figure out what went wrong. It could simply have been that there was an error in the calculations: a misplaced decimal or number; or it could be that the inputs were not reflective of reality.

This could also be thought of as an iterative process. Iterative processes are widely used by designers, developers, and entrepreneurs to test and improve a design, concept, or product before finalizing it. It starts with a prototype, which then is tested, adjusted, and redesigned. Each new design is informed by an analysis of the prior.

Our interviews suggested several strategies that

realities that could happen in the future. To generate land use forecasts, for example, the MAPC uses two scenarios: "Status Quo" and "Stronger Region". The Status Quo scenario uses current trends to make its predictions. The Stronger Region scenario

uses aspirational goals, like aggressive housing production to retain and attract a more substantial workforce, to inform its predictions. MAPC then uses this range of possible outcomes to inform the scenario it adopts. Transportation modeling could incorporate this process by forecasting for several different scenarios based on different assumptions.

A feedback loop is a process in which the outputs of a system are circled back and used as inputs, in order to create a better service or product. The community engagement process could incorporate feedback looks by using consumer feedback (in this case, the transit user, cyclist, or pedestrian) to inform inputs and improve prediction. CTPS could also use it to improve the model's ability to predict for cyclist and pedestrian use.

While forecasting involves predicting the future based on current trends, **back-casting** works backwards from a desired future outcome, and predicts which variables might need to exist in order to achieve that desired future. This could be used to better incorporate state planning goals. A similar process, widely used by climate scientists, tests model accuracy by running a particular climate model "backwards" to see if it predicts well for recorded carbon levels from 10 or 20 years ago. If the model did not predict accurately, technicians will compare results and tweak the model accordingly to improve its accuracy.

Weakness 4: Limited scope of outputs

One model output is a simplistic snapshot of one precise point in time. This becomes one vision of the future, but it doesn't account for the multitude of future possibilities.

Because it is a regional model, it is not sensitive or relevant to traffic patterns and demands at a small neighborhood level. So far, there is also no method to count bicycle and pedestrian patterns. Historically, the focus has strictly been on vehicular

travel, so there has been some improvement regarding the inclusion of bike and pedestrian projects, but that information is still superficial and needs improvements. The CTPS model was not built to consider recently reemerging travel mode trends such as an increase in biking and walking. The conditions that were built into the model no longer apply to the modern transportation system. By assuming that there has not been a rise in more sustainable modes of travel, the outputs continue to skew towards more vehicular ownership and travel.

> "Oftentimes, roadway expansion projects are based on status quo trends and development, and if you just keep on doing the same thing, you have to ask: Is what we're doing working, or should we try something different? And if we're going to try something different, then that model may not be relevant to us."
>
> – ITDP employee

Many interviewees emphasized the importance of identifying the priorities of every project. One interviewee highlighted the importance of urging agencies to start their planning process by saying: what's really important to us? If human-scaled and transit-oriented solutions are truly the priority, as outlined in Massachusetts state plans, how are we designing and working with tools, like the regional travel demand model, to achieve these solutions?

If we know the four-step model is good at overestimating vehicular traffic, but we also know that we need to get cars off the road, is using this model the best way to encourage said behavior shifts? This doesn't mean we have to throw the model out of the window completely, but there is room to utilize the model to make it consider options other than road expansion. If the goal is to reduce congestion, bus lanes could potentially achieve that, instead of adding another lane. **It is possible to ask different questions, put in different inputs, plan for different scenarios.**
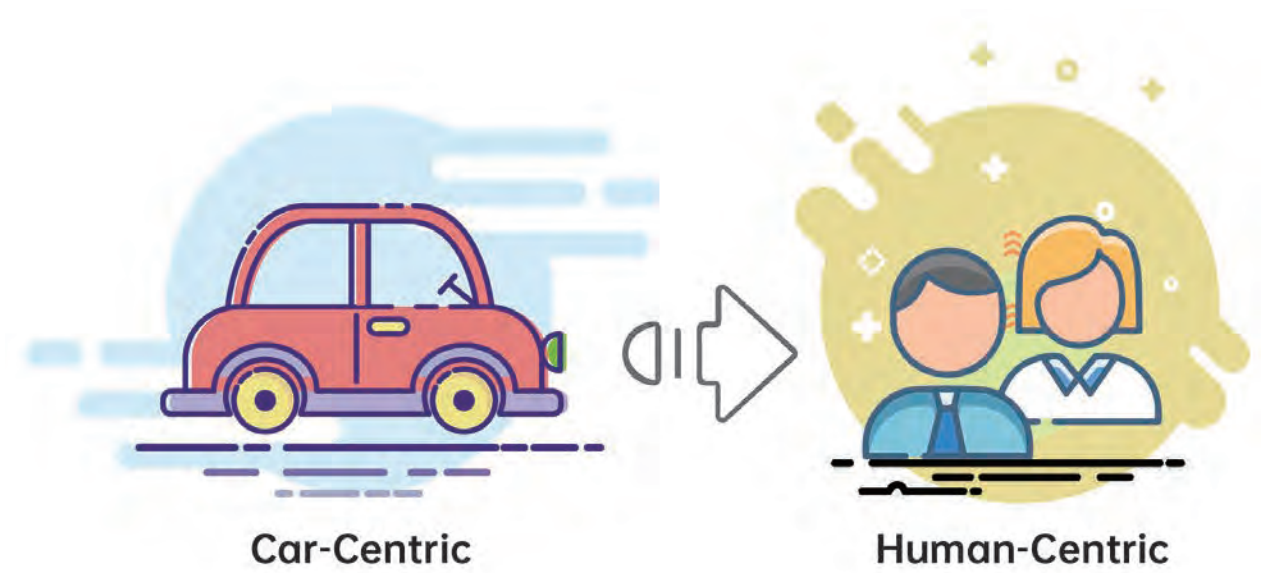
Figure 18. Shift to human-centric transportation planning. *Created by Yingran Li*

No matter what method you use, predicting the future is hard, if not impossible. Our interviews certainly emphasized the importance of having data with which to make informed decisions. However, a model is only as accurate as its assumptions. Model forecasts can be manipulated like statistics – it is possible to come to any conclusion depending on what numbers are used, and how. This is not an indictment of models or statistics, but simply a call for process improvements that align the tools we use with the goals we have. This will allow state agencies to better benchmark and achieve their goals in the future.

5. RECOMMENDATIONS
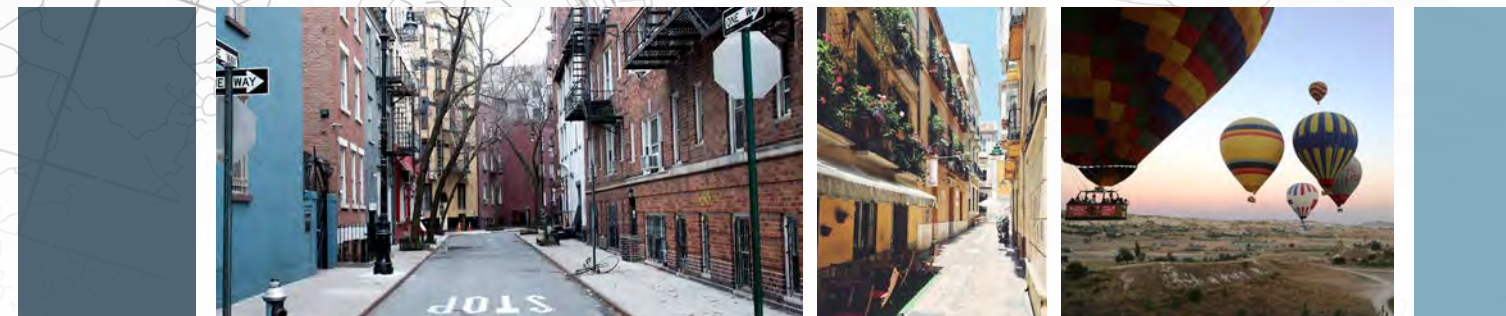
Our research illuminated several specific ways to ensure that transportation planning becomes more democratic and yields more representative, human scaled solutions in the future. In this section, we lay out seven recommendations that fall into two general categories: recommendations to improve the model itself; and recommendations to improve the transportation planning process as a whole.

Recommendations for model improvement include:

  • Implementing a transportation model study

  • Acquiring more comprehensive and up-to-date data

  • Incorporating an iterative process

Recommendations for planning process improvement include:

  • Utilization of interdisciplinary approaches and investment in qualitative data collection

  • Creating space to question modeling results

  • Improving the community engagement process

  • Better integrating public health needs into modeling and the planning process.

5.1 Implement a Transportation Model Study

First and foremost, in order to best utilize the findings of this report, we recommend that CTPS implement a more in-depth study to assess its modeling process. How feasible is it to integrate suggestions outlined in our report (such as: integrating more accurate, user-generated data; introducing better feedback loops; and methods to correct for auto-centric bias)? Is an entirely new modeling methodology needed to reflect and advance the multi-modal goals laid out in plans like GoBoston 2030? Our report just begins to scratch the surface of these questions. CTPS is best poised to answer them through a more systematic analysis of their own process.

5.2 Acquire More Comprehensive and Up-to-Date Data

There was one recurring theme within our interviews: the quality of data impacts the quality of model results. Much of the data used to generate trips are insufficient, overgeneralized, and outdated. If no data exists for bicycle or pedestrian behavior, how are we to expect the model can predict for changes in bicycle or pedestrian behavior as a result of a proposed project?

Likewise, much of the data used to generate trips for the model are sourced from a nationwide, and largely non-urban context. In order to get more accurate trip generation and potentially more favorable and human-scale transportation planning solutions, CTPS, municipal bodies, and advocates

alike may find it advantageous to shift their focus towards acquiring better data. These data would be more robust, more localized, and more detailed.

An area for consideration is looking into the data informing the ITE Trip Generation Manual, which is informed by data as outdated as twenty years old and generalized for national transportation data. If trips are generated in the model using more accurate data more narrowly tailored to represent the Boston region, we may see improvement. This manual, which is sourced from nationwide data, lacks comprehensive data for specific urban contexts, like the Greater Boston area. We are aware that MAPC is already working to remedy this data deficiency, but more mobilization around this is needed to prioritize collecting these data.

Another possible method to fix the lack of data would be to wade into the world of "big data." Using cellphone data or rideshare data to inform trip generation would give transportation planners and engineers a more accurate and current sense of where, when, and how people travel throughout the region. While this does raise some significant questions of scope, cost, and most pressingly, privacy, exploring the availability and relevance of big data to inform transportation planning is worthwhile.

Figure 19. Individuals are data sources. *Source: Ilija Mihajlovic. What is Big Data? Let's answer this question!*

Another possibility would be to work towards more collaboration and data sharing in the transportation planning field.

Advocates, planners, and community members may encourage governmental agencies, universities, and other research institutions to collect more bicycle and pedestrian data to inform model trip generation.

5.3 Incorporate an Iterative Process

One question that came up several times in our research was what methods, if any, are engineers using to ensure the accuracy of transportation models? As discussed in the analysis section of this report, applying an iterative process is a common and effective tool used by other fields in ensuring a process' integrity. In other fields that use models, like climate science, iterative updating processes are vital to promoting an accurate, up to date model. We recommend that transportation planners and engineers work towards implementing these processes. Taking current data, assumptions, and outcomes and testing it against model predictions is vital to getting the most accurate data outputs for future projects.

This assertion also reflects our previously stated assessments regarding the scientific method. We firmly believe that knowledge is created by vigorously testing and retesting hypotheses and claims. Model results should be observed and treated as hypotheses that require constant testing. To exempt transportation modeling from this level of scientific modeling is dangerous and yields even more skepticism.

5.4 Commit to Better Understanding Mobility Through Using Interdisciplinary Approaches and Collecting Qualitative Data

Much of the data collected through surveys, cell phone tracking, or traditional counts, are quantitative in nature. Quantitative data do not provide a complete enough picture on which to base planning decisions. The transportation system does

not exist in a purely quantitative vacuum and could benefit from an interdisciplinary approach. While the metrics that models project are helpful to make transportation recommendations, our transportation system is not just a series of inputs, conveyances, and outputs; nor is it merely a series of onramps, roads, and exits. Roads are also the trees alongside them. They are linked to the people who drive, walk, bike, and meander through them. They are shaped by the experiences of these people.

Quantitative data should be a part of a more holistic planning process, which includes community input and qualitative information. Several of our interviewees suggested that the transportation planning process would benefit from incorporating qualitative research methods and analysis.

Aesthetics, local history, emotions, personal and community knowledge and values, and ecological factors, among others, are all very closely related to our transportation systems. When recommendations are reduced to a model's projections, these vital factors are left out.

The transportation planning sector can take cues from innovative social science techniques for collecting qualitative data that can be used as a complement to quantitative data. For example, qualitative GIS is an emerging field comprised of geographers, planners, and sociologists, using mixed methods to understand and convey people's lived experiences of space. One study, conducted by Flamm, Keenan, and Meenar, used self-response survey and spatial analysis tools to assess the emotional experience of cyclists during their daily commutes. Their methodology produced detailed, geo-referenced data to illuminate emotional reactions along a traveler's route that influences their behavior. Their results underscore the importance of using qualitative data to add more insight into to travel behavior, beyond traditional measures like household income, demographics,

Figure 20. Creative placemaking in transportation. *Source: Noah Macmillan*

and vehicle ownership. They conclude by asserting that understanding the link between emotions and transportation environments is a crucial component to meaningful and sustainable planning efforts (Flamm, Keenan and Meenar, 2019).

Of course, we recognize that no set of data can ever be fully representative of any given population. **We recommend that CTPS collaborate with other experts in the field to find more sophisticated links between the data they have, and the assumptions they make about what those data say about mobility.**

Additionally, opening up the planning process also underscores an opportunity for communities to engage in data production.

5.5 Create Space to Question Model Results

At the start of this study, many of us were unfamiliar with transportation modeling. We were told by many community members and planners that the modeling process was a "black box": mysterious; confusing; and too complicated for community members to engage with.

While much of this sentiment remains, we found

that understanding the model and its role in the transportation planning process is not outside the realm of possibility.

Laypeople, community members, and advocates can understand the model's role in transportation planning and its results. They should have an active role in interpreting and refining model forecasts in order to plan for a more inclusive and sustainable future.

This understanding is incredibly important because it means that anyone can be engaged, informed, and involved in the transportation planning process. While we may not have the computers and software to operate and manipulate the transportation model, we can see the planning process as a series of analyses and decisions that we can understand and comment on.

Trusting one hypothesis or the results of one

process to prove a result is inconsistent with the scientific method. Knowledge and objectivity are constructed by illustrating repeated accuracy and validity. Transportation modeling has debatably not met this standard. Following the same logic to inform transportation planning could even be considered arbitrary or irrational, the legal disqualifiers for justifying government action. A holistic analysis is absolutely necessary, and part of this is understanding that modeling is an imperfect process.

LivableStreets and other advocates should question modeling results when they are inconsistent with the community's desired solution. In order to properly and noticeably question these results, a more robust community process is needed.

Questions advocates can ask when encountering model forecasts:

Table 5: Questions prepared for advocates. *Created by Sarah Saydun.*

Question to ask:	Reason for asking:
What specific inputs were used when running the model?	If the 2010 census was used instead of the 2020 census, it could produce inaccurate results. Or, if rural land use inputs were used for an urban setting, it could produce inaccurate results. It is important that the most relevant and accurate data are used.
What options did the model account for?	If, for example, road expansion was included as an option, but transit improvement was not, that could yield high traffic volume predictions.
What are you using as your level of service?	If the headway for transit is too long, it can yield low ridership predictions.
Does this reflect what we know of current reality of ridership?	If the forecast is severely over or under current reality, it could be a sign that something went wrong in the modeling process and it needs to be reassessed.

5.6 Improve the Community Engagement Process

Our interviews illustrated a top-down hierarchical planning process for transportation. Concerns from advocates and community members over their lack

of power in this process were largely confirmed by these findings. Better accounting for a community planning process is integral to ensuring equitable transportation solutions for the future.

Transparency in government is incredibly important,

especially in this field. Transportation affects us all and has a major role in everyone's day-to-day activities. Behind-the-scenes planning is detrimental to the democratic process, especially at a local level, where many of these decisions are being made. **Transportation is a field in which community knowledge is vital to determining the outcome that is best representative of the public interest.**

Processes to account for community input in transportation solutions are the Boston area is strong, and have continued to grow in recent years. In 2017, the MBTA released the new Youth Pass as a result of years of youth advocacy groups campaigning for dependable and affordable transportation options for younger riders. These efforts proved successful through the usage of community and youth-led surveys, interviews, petitions, and reports expressing the need for improving the current MBTA Student Pass. Young people built alliances with organizations, who aided

in increasing publicity exposure, launching a public education campaign, and engaging with public officials. Finally, they created relationships with champions within the MBTA by meeting regularly with officials who were willing to aid in their efforts (Transportation for America, 2018).

Similarly, in the development of the City of Boston's future transportation report, "Go Boston 2030," the Interaction Institute for Social Change (IISC) designed the research process to include a rigorous public engagement process. IISC collected over 5,000 questions from Bostonians through the following submission portals: text, email, handwritten cards, social media, digital media, by driving an interactive glass truck and a pop-up bike trailer around Boston's neighborhoods, by enlisting the help of 80 partners from city and non-profit organizations, and by holding events throughout the city. Go Boston 2030 additionally hosted three roundtable discussions open to the public to discuss challenges facing the

Figure 21. Interactive glass truck. *Source: ISSC, Go Boston 2018 ,2030*

transportation system (IISC, 2020).

In both instances, transportation advocates in Boston worked with community members to identify

problems, brainstorm solutions, and engage with public policy makers to ensure that community members were heard and mobility was improved. This process of community engagement can be

broken down into digestible pieces and applied to a theoretical framework developed by the Greenlining Institute. These steps include:

Step 1: Determining community's mobility needs: engage in conversations about mobility equity with the community, and hold brainstorming sessions around local needs.

Step 2: Conducting an equity analysis of mobility

Mobility Equity Framework

- Step One: Identify the mobility needs of a specific low-income community of color.
- Step Two: Conduct the mobility equity analysis to prioritize transportation modes that best meet those needs while maximizing benefits and minimizing burdens.
- Step Three: Place decision-making power in the hands of the local community.

projects: prioritize projects that best meet the needs of the community, as articulated by the community, and draft project proposals to advocate for these projects.

Step 3: Strengthening community decision making power: value the experience and intellect of community members by including their vote. (Creger et al. 2018).

Figure 22. Mobility equity framework. *Source: The Greenlining Institute, 2018*

The first step requires that community advocates, local organizations, and policy representatives prioritize collecting local knowledge by making the sessions accessible. This includes holding forums in locations that are physically accessible, located within the community they are trying to serve, and held online for people who cannot physically attend; ensuring that several sessions are held at several different times in the day; and providing food, childcare, and translation for attendees. Organizers of these public meetings should do their best to understand the most appropriate way to publicize meetings within the community as well.

The second step requires that the community members vocalize and advocate for certain mobility services or agendas that are not being served currently. Whether this is through a town hall, virtually, or through in-person question and answer sessions, it is vital that the project team reaches as many people as possible to get a full understanding of the problems and challenges that transportation users are facing. Once these problems are made

clear, advocacy organizations must prioritize projects that meet the needs of the group, and help the community to draft proposals, petitions, or engage policy makers to ensure that the implications of a beneficial project are understood and prioritized.

The third step requires that community members are not just solicited for their input, but also have power in decision making: to meet with local policy makers and to vote for projects that will enhance their mobility and the mobility of their neighbors.

Not only should these three steps be strengthened in the entire planning process, they can also be applied to the CTPS modeling process. CTPS can work with state agencies and advocacy organizations to engage the public, connect with public policy champions, and create space early in the process to ensure that inputs and assumptions are inclusive and representative of community voice before the model is run. The Greater Boston area is rich with transportation advocates, and this process is very doable for fair and just transportation planning to take place. **The**

CTPS model results must be questioned, and the model process must be made accessible, transparent, and open so that community members and advocacy organizations have a say in mobility changes that directly affect them and their community.

5.7 Integrate Public Health Needs into Modeling and the Planning Process

The 2020 outbreak of the Novel Coronavirus (COVID-19) has highlighted another factor underexplored by contemporary transportation planning. As we addressed in our recommendations, concerns about public health have touched every aspect of everyday life, including transportation for essential workers. Massachusetts has made significant headway in this area, but the outbreak of COVID-19 places public health concerns in the spotlight. How is the healthcare infrastructure and

emergency needs this outbreak brought to the forefront being accounted for in the transportation planning process?

Numerous studies and articles highlight the importance of assessing the public health implications of our transportation planning. The American Public Health Association has found a significant link between transportation policy and public health (American Public Health Association, 2020). In this study, the association wrote that pollution from roadways is linked with decreased respiratory function and cardiovascular problems.

For these reasons, transportation planning and policy should be reframed by advocates and community members as a public health issue. Targeting transportation modeling to better reflect this connection is a good place to start. This framing was successful in passing many of the significant federal environmental laws of the 1970s, such as the Clean Water Act, Clean Air Act, and Resource Conservation and Recovery Act.
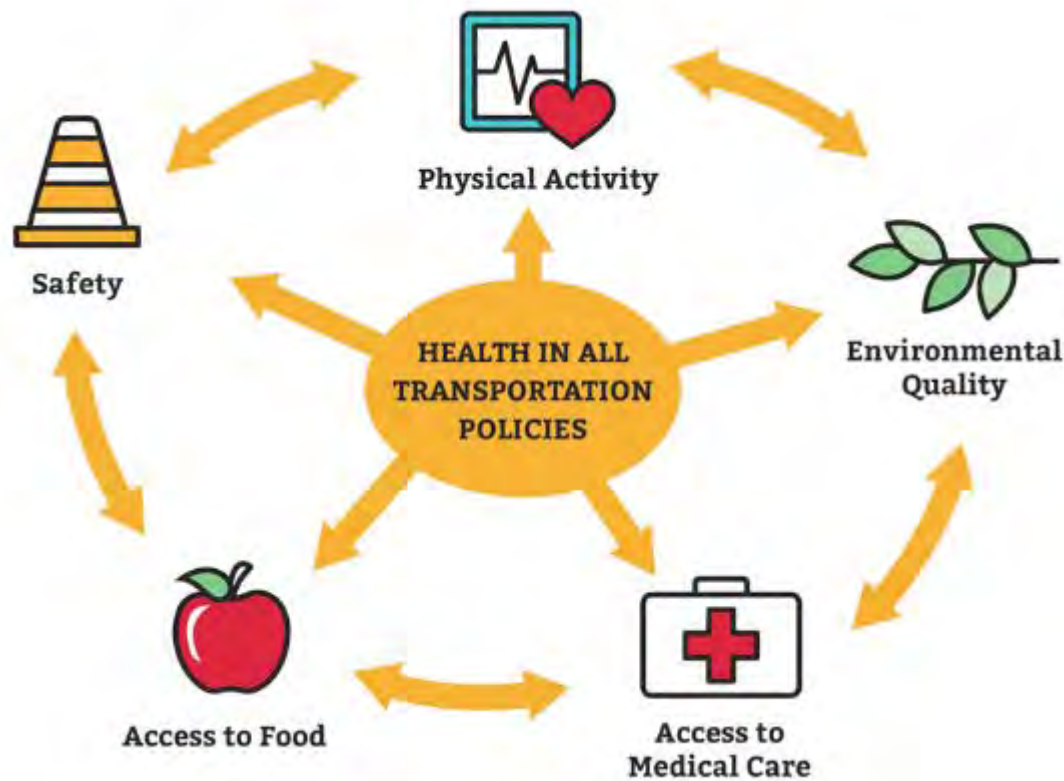

Figure 23. Health & Transportation. *Source: Metroplan Orlando*

Implementing this framework by including healthcare priorities in the Boston region's transportation planning has already been successful. In 2009, Governor Deval Patrick signed the Transportation Reform Act of 2009, which linked statewide public health and transportation goals by prioritizing complete streets, promoting cycling and walking, and improving interagency collaboration to engender healthy transportation solutions (Center for Healthcare Strategies 1-6). In 2010, MassDOT issued guidance promoting a "healthy" approach to transportation planning called "GreenDOT." Under this guidance, all MassDot projects must incorporate public transit, walkways, or bicycle paths (Sneider, 2013). **However, some recent projects in the Boston area, including the Longfellow Bridge replacement, show that there is still room for these initiatives to grow.**

To further implement this reframing, public health could be more explicitly included in Boston's transportation modeling. In "The integrated transport and health impact modeling tool in Nashville, Tennessee, USA: Implementation steps and lessons learned," Whitfeld et al. studied the Integrated Transport and Health Model in Nashville,

TN, a model that attempted to adapt Nashville's transportation systems to be more advantageous to public health (Whitfield et al., 2017). They suggested that this model was successful in Nashville by potentially saving the region between $10 and 63 million and between 24 and 123 lives a year. The Nashville model, as observed by Whitfeld et al., is one that can be adapted to serve the people of the Boston region. As shown by this example, goals and integrating them into an entirely new model can have powerful outcomes.

With public health concerns integrated into the transportation model and a more holistic planning process in which public health concerns are included, the Boston region can better work towards this reframing and prioritization.

Prioritizing public health goes hand-in-hand with constructing more human scale transportation solutions. If planners, engineers, advocates, and community members work to accomplish this, along with improving the planning process and data integration, our transportation system will be healthier, more equitable, and more sustainable.

6. CONCLUSIONGS AND AREAS FOR FUTURE RESEARCH
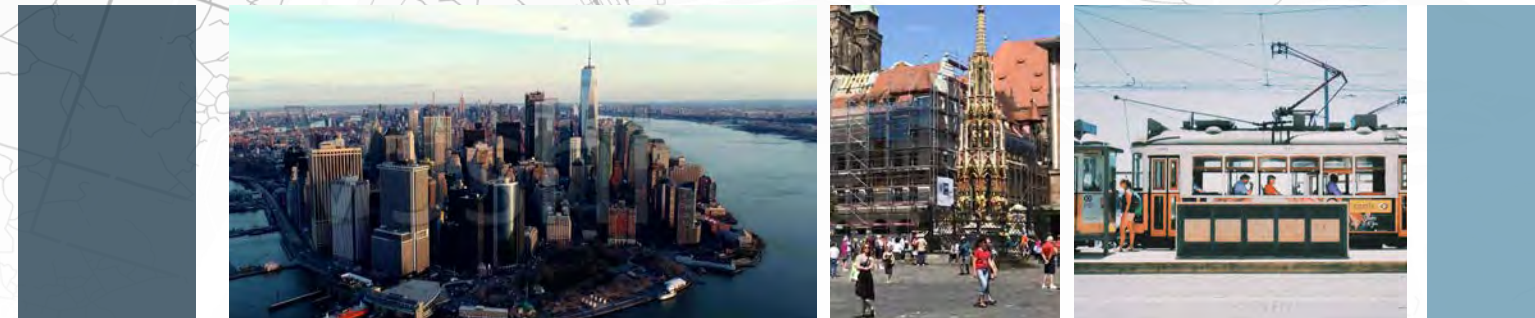
In this report, we outline how transportation modeling is used as a tool for engineers, policy makers, and planners to inform transportation planning decisions. There is a fundamental need by many in these fields to have concrete, objective, numerical data to bolster policy and development recommendations. However, we also learned that transportation modeling is imperfect. Lack of accurate, up-to-date data, the presence of algorithmic bias, and the potential for outputs to be skewed by inputs, all contribute to the model's inaccuracy.

The modeling process is complex but not impenetrable. While we may not have the computers and engineering knowledge to conduct transportation modeling, understanding the role, outcomes, and potential inaccuracies of transportation modeling is possible.

We have also learned that transportation modeling is just one piece of a larger, more holistic policy and planning process. There are multiple steps involved in this process where community interests, political pressure, and institutional advocacy are possible. **These are the steps in which community actors and advocates have some power to influence and fight for advantageous policy recommendations.**

A large data deficit exists in this field. Much of the data being used to generate trips in this model is

outdated by up to twenty years. Much of these data are used for and by transportation systems all over the United States. While this does allow for a degree of uniformity in nationwide transportation planning, it does not allow for more accurate and realistic trip generation in exceptional areas. Unlike the Boston region, the country as a whole is far less dense and far more automobile centric. Using these data for trip generation skews model outputs for this region.

Another feature of this data deficit is a lack of significant and accurate bicycle, pedestrian, and transit ridership data. How can we get better, more accurate, and representative data on bicycle, pedestrian, and transit mobility? Are there localities or institutions who are succeeding in collecting and analyzing these data?

The interviews that we conducted underscored repeatedly that the outputs of transportation models are only as good as their inputs. Robust, holistic data will lead to more robust, holistic recommendations; biased or incomplete data will lead to skewed recommendations. Without up to date, widely sampled, and nuanced data inputs, the outputs of transportation models will yield unsatisfactory, less viable policy recommendations.

There are still multiple questions remaining that will supplement these findings. Are these alternatives to transportation modeling that planners and policy makers can use to make accurate and successful

mobility solutions? Are there localities and regions that are innovating the transportation planning process, and how are they approaching these solutions?

There are more macro-scale questions to ask about the fundamental structure of our political system. Our interviews suggested that cities and towns rely on growth to fund their infrastructure expansion and maintenance. Is this really what is best for our localities? Further studies can explore the need for growth to support municipal budgets and solutions for remedying this.

Additionally, our interviews highlighted the federal environmental review process under the National Environmental Policy Act (NEPA). While congestion is seen as a fundamental threat and road expansion and widening are seen as universal remedies to this, is this really what is best for the greater good of society and the environment?

Ultimately, several questions remain: Can policy makers, planners, engineers, and stakeholders demystify the transportation planning process? Can we in fact get more complete and accurate data to put into these models? Is a truly public, equitable planning process possible? We hope that the answer is a resounding, "yes!" But will those with more power in this field allow for this? Exploring the answer to these questions is important.

We conclude this study with hope. We have highlighted several challenges communities face in their quest to seek the transportation solutions they need. However, these challenges are supplemented and underscored by opportunities for policy makers, planners, engineers, advocates, bikers, passengers, walkers, and drivers to improve our roads, systems, data collection, planning processes, and cities at large.

APPENDICES

Appendix A: Research Questions

Guiding research questions

• What causes discrepancies between forecasts and reality?

• How are transportation planning decisions made, and where do models fit into that process?

• What are the consequences of inaccurate modeling?

• How can community advocates be better equipped to challenge decisions informed by the modeling process in the future?

• Can we change modeling to ensure major capital projects better meet the needs of a rapidly evolving multi-modal future?

Stage 1: Literature Review

• Understanding the model: What are the basics of traffic modeling? What is its purpose?

• Relationship between model and decision making: What is the transportation planning process? Where does modeling fit into decision making?

• Connection to aspirations: What are goals and visions for the future of transportation? How do basic assumptions map onto those aspirations?

Stage 2: Stakeholder Interviews

• Understanding the model: What causes discrepancies between predictions and post construction counts?

• Understanding the model: What are specific mechanics? (inputs, data sources, algorithm?)

• Relationship between model and decision making: How do forecasts from models affect decision making? Who or what else is considered in project design?

• Connection to aspirations: Is model flexible? How does it change/get updated?

Appendix B: Interview Questions

• How do you interact with traffic models and forecasts? Do you interact with the CTPS traffic demand model?

• Can you tell us about the transportation project planning process from start to finish?

• Can you explain, to the best of your knowledge, the main data being used as inputs into the CTPS model, and what sources the data are being pulled from?

• What is your sense of how accurate this model is at predicting traffic flow?

• Is there a sub-regional model that is used specifically for local projects?

• What are the geographic bounds of the regional model?

• What types of algorithms are used for what situations? Are there different ones based on the situation?

• Are there different levels of accuracy based on use at different scales?

• Is there a good balance between complexity and simplicity in aggregation for forecasting?

• Does CTPS use a land-use/transport integrated model

• What can be done to improve accuracy?

• Are there metrics for evaluating forecast accuracy? What do you think those metrics should be?

• How are forecasts from the model calibrated?

• Can you evaluate the algorithm of the model? When is it updated, and why?

• Do the most recent updates reflect current transportation goals?

• How are project design and approval affected by model forecasts?

• Who interacts with the forecasts, and how?

• How are aspirations and goals from state plans and city plans integrated into modeling and forecasting?

• How do model forecasts influence the prioritization of projects?

• What regions have comparable planning processes? Any places you've looked at for inspiration on best practices?

• Is there anyone else you think we should talk to about this?

Appendix C: Glossary

Activity-based model (ABM): An ABM simulates individual and household transportation decisions that compose their daily travel itinerary to predict whether, where, when, and how this travel occurs.

Agent-based model: an agent-based model aggregates the collective actions of a group of individuals within a system, rather than as individual actors.

Back-casting: While forecasting involves predicting the future based on current trends, back-casting works backwards from a desired future outcome, and predicts which variables might need to exist in order to achieve that desired future. This could be used to better incorporate state planning goals. A similar process, widely used by climate scientists, tests model accuracy by running a particular climate model "backwards" to see if it predicts well for recorded carbon levels from 10 or 20 years ago. If the model did not predict accurately, technicians will compare results and tweak the model accordingly to improve its accuracy.

Centroids: Imaginary points within zones from which all departing trips are assumed to originate and at which all arriving trips are assumed to terminate.

Equilibrium: In the trip assignment step, the traffic flow distributed to the urban road network is the result of the interaction between the two mechanisms until the balance. One mechanism is that people

try to minimize their travel costs by choosing the best route. Another mechanism is that the road service level of the roads will influence people's choices.

Feedback loop: a process in which the outputs of a system are circled back and used as inputs, in order to create a better service or product. The community

engagement process could incorporate feedback looks by using consumer feedback to inform inputs and improve prediction.

Gravity model: A function used in the trip distribution model. The traditional approach to this has been to assume that the amount of travel between two zones is represented by a 'gravity' function incorporating the scale of the activity in each zone and the difficulty (or 'impedance') in traveling between them. (Furnish and Wignall 2009)

Induced demand: the idea that increased capacity on roadways will encourage people to drive more, thus leading to more congestion on the road. When a roadway is expanded, traffic increases to meet capacity, leading to more cars on the road and increased (not decreased) congestion.

Input: data used to inform model results

Mode split: The use of modes for movement between zones. (Furnish and Wignall 2009)

Scenario Planning: flexible planning for future trends and uncertainties.

Traffic Analysis Zone (TAZ): In order to facilitate the analysis, transportation planning usually divides the

planning area into several zones.

Transit: public transportation system, sometimes called "public transit," using public transport, such as buses and railways, to carry a large number of passengers.

Transportation model: Transportation model is a mathematical model that reflects the relationship

between traffic demand, land use and traffic network. Based on traffic survey data, it can be used for traffic demand forecast and traffic analysis. 4-step traffic demand model is a classical and dominant term of travel demand model, which

includes trip generation, trip distribution, mode choice, and trip assignment models.

Travel impedance: Time and costs spent on the road during the trip, which are the basis for road users to choose their travel path.

Trip assignment: the transportation method that has been chosen for movement between zones

Trip distribution: The amount of movement between each zone pair converted by each zone's travel amount predicted by the trip generation model (Furnish and Wignall 2009)

Trip generation: The amount of travel generated by or attracted to different land-use type zones. The basis for this is the observed level of current trip attraction and generation (Furnish and Wignall 2009)

Appendix D: Source of Figures and Tables

Figures

Cover Page (Left to Right): Unsplash.com. Government technology (https://www.govtech.com/fs/Redesigning-Roads-Taking-a-Look-at-the-Complete-Streets-Movement.html). Howard Stein Hudson (https://www.hshassoc.com/our-work/private-development/tontine-crescent-boston/). Unsplash.com

Background Map on Cover Page and Chapter Pages: Etsy. https://www.etsy.com/sg-en/listing/684897151/boston-city-map-digital-download-black

Chapter Heading: Unsplash.com

Report Layout: Yingran Li

Inside Page of Executive Summary: Unsplash.com

Figure 1: Yingran Li

Figure 2: Yingran Li

Figure 3: Yingran Li

Figure 4: Yingran Li

Figure 5: Yingran Li

Figure 6: Yingran Li

Figure 7: Yingran Li

Figure 8: David Soto. Why Transportation Must be a Part of Resilience Planning in Puerto Rico, 2019. https://medium.com/planblog/why-transportation-must-be-a-part-of-resilience-planning-in-puerto-rico-b2382e4db1b

Figure 9: Boston. gov. https://www.boston.gov/departments/environment/climate-ready-boston-map-explorer

Figure 10: Yingran Li

Figure 11: Central Transportation Planning Staff (CTPS). https://www.ctps.org/mpo

Figure 12: Massachusetts Bay Transportation Authority (MBTA). https://www.mbtafocus40.com

Figure 13: Yingran Li

Figure 14: Yingran Li

Figure 15: CTPS, Boston Regional MPO's presentation titled: Regional Travel Modeling Conducted by the Boston Region MPO, March 25, 2020

Figure 16: Yingran Li

Figure 17: ZURB.com

Figure 18: Yingran Li

Figure 19: Ilija Mihajlovic. What is Big Data? Let's answer this question! https://towardsdatascience.com/what-is-big-data-lets-answer-this-question-933b94709caf

Figure 20: Noah Macmillan. https://smartgrowthamerica.org/beautiful-animations-illuminate-power-creative-placemaking/

Figure 21: ISSC, Go Boston 2030, 2018. http://interactioninstitute.org/go-boston-2030/

Figure 22: The Greenlining Institute, 2018. https://greenlining.org/wp-content/uploads/2019/01/MobilityEquityFramework_8.5x11_v_GLI_Print_Endnotes-march-2018.pdf

Figure 23: Metroplan Orlando. https://metroplanorlando.org/programs-resources/health-transportation/

Tables

Table 1: MassDOT

Table 2: Transport Model Improvements, Victoria Transport Policy Institute (VTPI), 2019, https://www.vtpi.org/tdm/tdm125.htm

Table 3: Sarah Saydun

Table 4: Sarah Saydun

Table 5: Sarah Saydun

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