# DEVELOP ROBUST AND RESILIENT STRATEGIES FOR AN UNCERTAIN FUTURE

CAMBRIDGE SYSTEMATICS

Plan Forward

Transportation is facing a rapidly changing landscape. New technologies like connected and autonomous vehicles (CAVs), transportation network companies (TNC's) like Uber and Lyft, and mobility as a service are poised to disrupt many aspects of the transportation industry. These changes mean that the future of transportation is less likely to look like its past – while global crises like the COVID-19 pandemic and climate change are making it even harder to predict what that future will be. With many possible outcomes, planning for the future amid this uncertainty can seem impossible, but there are several tools and processes that agencies can use to help prepare for and shape the future.

Planning for uncertainty helps us answer important questions about the future, such as:

- What will be the impacts of CAVs? Increased telework? Shared rides?
- What policies could have the most impact on congestion? Transit ridership? Emissions? Equity?
- Will my project still be a good idea to build, even if the future looks very different?
- Will my strategies, programs, or plans work no matter what the future holds?

## CURRENT STATE OF THE PRACTICE

### *Qualitative Scenario Planning*

Qualitative scenario planning is a process that considers how trends and drivers of change (e.g., urbanization, technology, globalization) will impact a community and its transportation system. With story-telling, collaboration and discussion, a few plausible future scenarios are developed to consider specific "what if" questions. This process can help agencies develop strategies and policies that hedge against a variety of futures and can also evolve over time. Additionally, this type of scenario-planning can be accomplished relatively quickly and affordably, taking advantage of easily accessible resources like local experts, questionnaires and surveys, and public engagement strategies.

However, the scenarios that result from qualitative scenario planning don't offer a detailed understanding of the impacts of different scenarios, and cannot provide an analysis of the interactions among different variables. For example, will the cost of buying an AV encourage how they are used? Will the proliferation of EV charging infrastructure impact land use decisions? With qualitative scenario planning, blanket assumptions are often made about these relationships to keep the scenarios internally consistent, but exploration of the interactions among different uncertain variables is not possible.

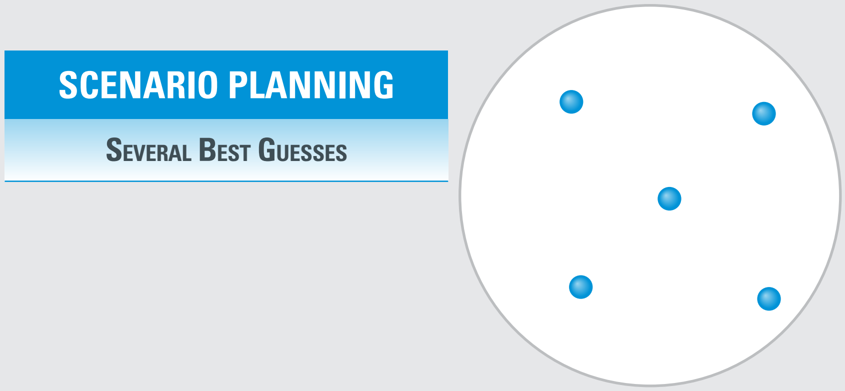
### *Quantitative Scenario Planning*

Travel demand models and other analytical tools can be used to provide more clarity about the potential impacts and effects of different scenarios. These methods use detailed quantitative assumptions as inputs – about land use, demographics, technology adoption rates, pace of climate change, comfort with sharing rides, etc. – to model how these trends could change when, where and how people travel.

Using these models, quantitative scenario planning can provide detailed insights into a wide range of potential impacts of these futures. Typical travel demand models can quantify the impacts to operational questions like congestion levels, transit ridership, and vehicle emissions. Other specialized tools can quantify impacts to land uses, revenues from a range of sources, and economic activity. One of the other major benefits of quantitative scenario planning is that agencies can more finely differentiate scenarios from one another, as it allows for the use of very specific assumptions. For example, this approach can quantify the difference in outcomes at very specific levels of CAV adoption (50% vs. 75%) and in different years through time. The results of these analyses can be used to understand the impacts (including unintended impacts) of different policy options like congestion pricing or EV subsidies; to prioritize transportation improvements; and/or to test the resiliency of various projects.

However, there are limitations to this type of scenario planning. Similar to qualitative scenario planning, there are practical limits to the number of scenarios that can be tested based on how long the underlying models take to run. This limits the amount of the uncertainty space that can be analyzed with these methodologies. Additionally, the quantitative analysis is still based on assumptions about human behavior and travel choices that are in themselves inherently uncertain, so the results of each scenario will also be uncertain. For example, because we have no reliable observed data on how quickly people are likely to adopt shared CAVs, the models will still use 'best guess' assumptions that may ultimately not be accurate. To test a range of different input assumptions, models would need to be run hundreds or even thousands of times – something that these tools cannot do practically.

With so many uncertainties about so many variables affecting the transportation system, a wide range of futures is possible. This means that the actual future can fall anywhere in a large 'uncertainty space' that can't easily be covered by any analysis that considers a limited set of discrete scenarios. Understanding the relationships among variables helps to bring the uncertainty space into view.




## EMAT+TANDEM: TOOLS FOR AN UNCERTAIN FUTURE

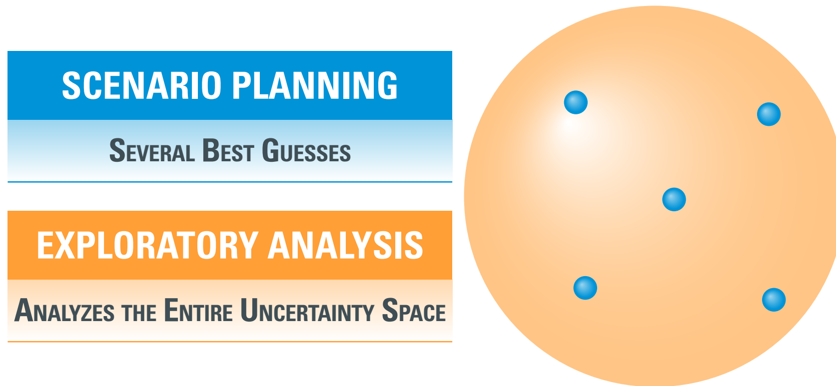
### *Deep uncertainty requires a different approach*

Qualitative and quantitative scenario planning can be effective at providing insight into a set of potential futures to answer "what if" questions about how the future might play out. However, both fall short in addressing the type of deep uncertainty that is currently facing the transportation system. Traditional tools produce reliable predictions because they are validated against actual events. Rapid change, extreme volatility, low consensus on problems, and the use of traditional scenario planning practices alone make this validation impossible. Therefore, they cannot provide a full understanding of what might potentially happen – the full extent of the uncertainty space is left unexplored.

As new technologies continue to advance and the full effects of the global pandemic are yet to be seen, the only certainty is uncertainty. As we enter a post-COVID-19 landscape of rapid technological development and demographic shifts, agencies require a new analytical strategy to prepare for the future.

## *What is exploratory modeling and analysis?*

In the face of this level of uncertainty, analysis of potential futures must be taken to the next step. Exploratory modeling and analysis (EMA) is a research methodology that uses computational experiments to analyze complex and uncertain systems.[1] Exploratory modeling does not aim to predict the future, but seeks to identify the conditions and thresholds where different outcomes occur. It is used when there is high uncertainty—where the future is unpredictable and there are many possible and plausible futures. In transportation planning, EMA can be used to identify decisions that are the most robust and resilient against thousands of possible futures.




Exploratory analysis should:

- » Identify the implications of uncertainty variables on the uncertainty space;
- » Help tell the story of how strategies may fare under different conditions;
- » Identify what can be done to mitigate the worst-case outcomes and encourage the best-case outcomes; and
- » Provide an analysis of sensitivities and vulnerabilities.

## *What is EMAT+Tandem?*

EMAT is a set of open-source exploratory modeling and analysis tools, originally developed for the Federal Highway Administration's Travel Model Improvement Program by Cambridge Systematics, Inc. (CS). These advanced tools offer the capability to study thousands of scenarios in a fraction of the time it takes a traditional model to run. To build on the power of EMAT and make its outputs more accessible, CS developed Tandem, a web-based dashboard that allows a user to visualize and interact with the wide range of possible futures generated by EMAT.

By running thousands of scenarios relatively quickly, EMAT+Tandem can help you understand the interactions among variables by exploring the relationship among policy decisions, projects, build scenarios and performance metrics. These insights equip you to make long-term decisions that account for uncertainty, help prevent project obsolescence, save time and make the most out of your investments.

Example Strategies For Evaluation:

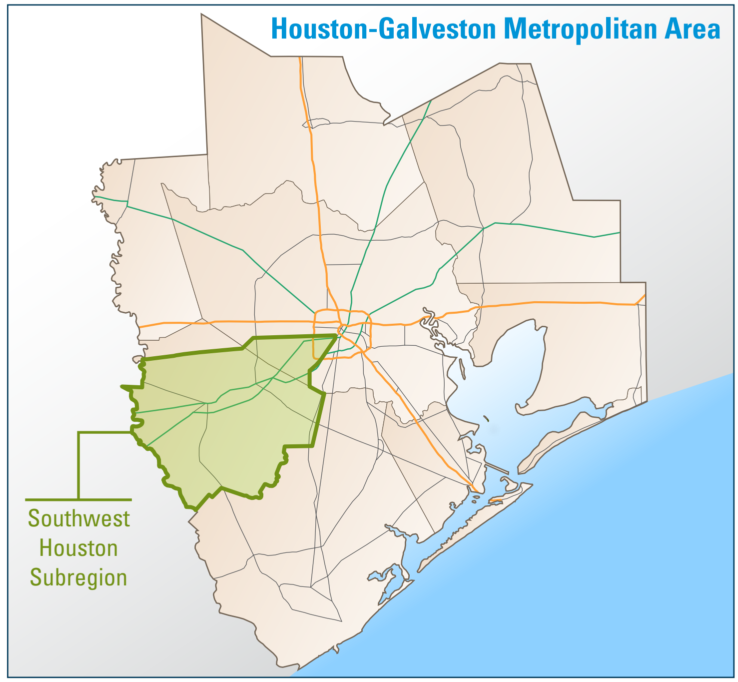
- » Highway Capacity Expansion
- » Managed Lanes and/or toll policies, including CAV lanes
- » Transit Expansion
- » Transit frequency, fare, or travel time improvements
- » Travel demand management policies such as encouraging telecommuting, increasing parking costs, etc.
- » Transit Oriented Development or other land-use policies

Try it for yourself! Check out the EMAT+Tandem demo dashboard here: https://tandem.camsys.xyz

1 Bankes S., Walker W.E., Kwakkel J.H. (2013) Exploratory Modeling and Analysis. In: Gass S.I., Fu M.C. (eds) Encyclopedia of Operations Research and Management Science. Springer, Boston, MA. https://doi.org/10.1007/978-1-4419-1153-7_314

## HELPING TXDOT UNDERSTAND AND REACT TO CHANGE: A CASE STUDY

The southwestern portion of the Houston region is facing major shifts in population growth, demographic characteristics, land use, transportation networks and travel behavior. For the Texas Department of Transportation (TxDOT) Houston District, CS was part of the team that helped evaluate the subregion's long term future, define the major drivers influencing transportation and TxDOT's outlook, and determine how the agency will plan for an uncertain future within the region and subregion.




The effort, known as the Sustainable Mobility Alternatives for Regional Transportation (SMART) Study, began with identifying major drivers that contribute to the deep uncertainty of the future transportation system. Some examples include:

- CAVs
- Shared mobility
- Transit expansion
- Growth/energy sector
- Micromobility
- Telecommuting
- E-commerce
- Population distribution and growth

EMAT+Tandem were applied in conjunction with a version of Houston-Galveston Area Council's trip-based travel demand model (TDM) to quantitatively evaluate the transportation system under the entire range of potential futures. The TDM was updated to include additional sensitivities related to CAVs, shared mobility, micromobility, telecommuting, and e-commerce. The updated TDM and EMAT incorporated as inputs various levels of the following uncertainty variables:

- Share of households owning CAVs
- Share of households willing to utilize shared-ride services
- Change in fares and wait times of shared-ride services
- Transit expansion including increased micromobility
- Level of telecommuting and e-commerce
- Four varying land-use scenarios: base case, urbanization, suburbanization, and high growth.

Utilizing Tandem's visualizations and algorithms, CS assessed the interactions among the uncertainty variables and the performance metric outputs. The feature score table shown in the figure on the next page provides insight into which uncertainties are relatively more important in determining the values of each performance metric. The higher the number (and more yellow) the greater the influence of that factor, while the lower the number (and more blue) the less the influence. The findings indicated that demographic distributions have the largest influence on many of the performance metrics while the transit network expansion had the lowest influence on the metrics.

| | Share of CAVs | Share of Rideshare | Rideshare Level of Service | Demographic Distribution | Transit Network | Telecommuting and E-Commerce |
|---|---|---|---|---|---|---|
| Subregion Person Trips | 0.25 | 0.24 | 0.16 | 0.12 | 0.08 | 0.15 |
| Subregion Vehicle Trips | 0.13 | 0.12 | 0.32 | 0.22 | 0.04 | 0.16 |
| Subregion VMT | 0.21 | 0.11 | 0.18 | 0.29 | 0.06 | 0.15 |
| Subregion VHT | 0.17 | 0.11 | 0.16 | 0.32 | 0.06 | 0.17 |
| Subregion Average Speed | 0.14 | 0.10 | 0.19 | 0.35 | 0.06 | 0.16 |
| Average Trip Length | 0.35 | 0.15 | 0.11 | 0.21 | 0.05 | 0.13 |
| CAV Mode Share | 0.60 | 0.09 | 0.10 | 0.07 | 0.04 | 0.10 |
| Non-CAV Mode Share | 0.60 | 0.09 | 0.10 | 0.08 | 0.04 | 0.08 |
| Transit Mode Share | 0.19 | 0.14 | 0.30 | 0.18 | 0.05 | 0.14 |
| Rideshare Mode Share | 0.11 | 0.16 | 0.48 | 0.09 | 0.05 | 0.13 |
| Region Transit Ridership | 0.13 | 0.13 | 0.17 | 0.21 | 0.12 | 0.24 |

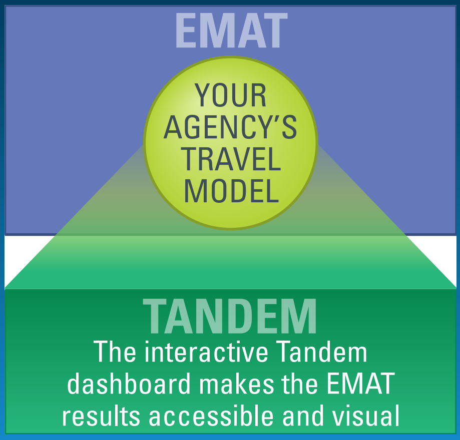
Tandem was also utilized to pinpoint corridors where high congestion will occur if certain futures were to materialize. For example, Tandem identified that the Rosenberg to central Houston corridor is likely to have high travel times if high population growth occurs in suburban and outlying areas, but may continue to have low congestion in many other possible futures.

The results of this study will allow TxDOT to explore the full uncertainty space by evaluating the relationship between the major drivers of change and key performance metrics. This analysis will provide TxDOT with the quantitative analytics to support formulation of projects and policies that will lead to a robust and resilient transportation system under a range of potential futures.

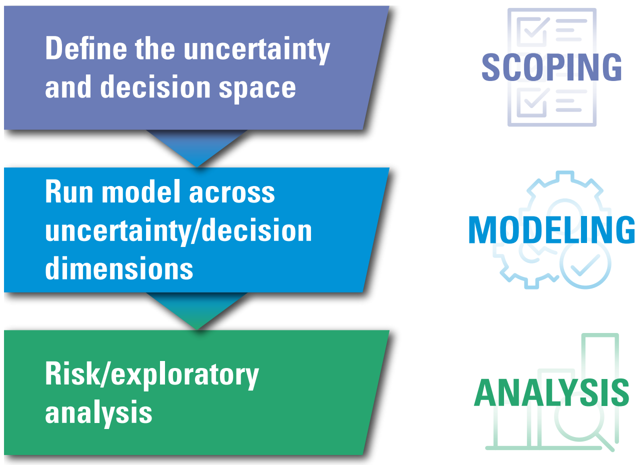
## HOW DOES IT WORK?

EMAT integrates with a core model, which can be your agency's travel demand model, simulation model, a sketch-planning model, or any other model of interest. It automates a variety of modeling processes, aggregates and tracks performance measures, and provides a variety of exploratory modeling features. Tandem wraps the entire package, providing an interactive interface that allows a user to easily visualize the model outputs across the uncertainty space, without worrying about the technical implementation details.

EMAT+Tandem helps expand the capabilities of your agency's rigorously calibrated and validated travel demand and simulation models. EMAT acts as a wrapper around these travel models, allowing them to produce performance metric results for thousands of futures in weeks, versus months or years.



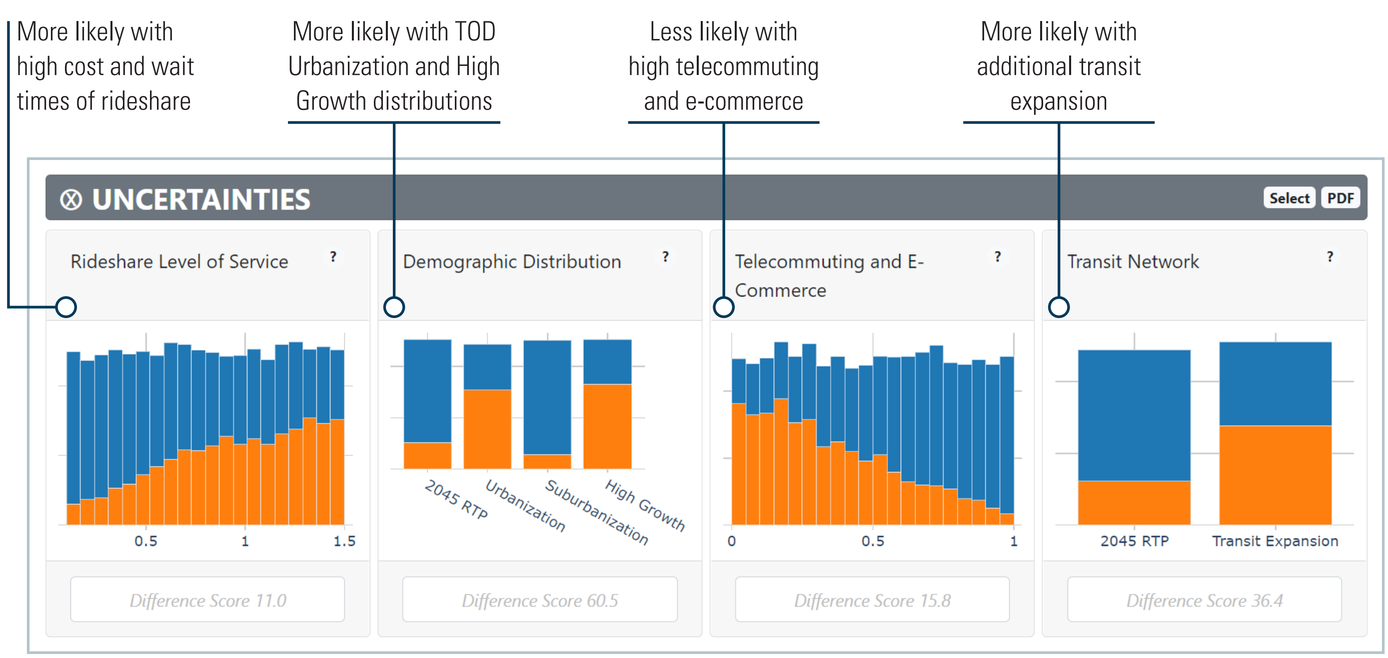
*Here are the three major steps to working with EMAT+Tandem:*




**1. Scoping**—In the first step of working with EMAT, you define your scenario inputs. What questions are you trying to answer? Why are you running the model? What are you trying to achieve? After identifying the strategies you want to evaluate, performance measures are established to test those strategies. The next step in scoping is defining the uncertainties or risk factors that could affect your strategies, which could include land use development patterns, CAVs, changes in telecommuting or any other uncertainties that can be represented in the model.

**2. Modeling**—For modeling, uncertainties are converted to inputs or variables within your core model. EMAT runs the core model a set number of times, depending on how many variables are being evaluated, systematically varying the model inputs and variables across the full range of their possibilities. EMAT takes the core model's outputs and creates a new model out of those results. This process results in a set of meta-models; models of the core model that can be used for future analysis. The key benefit of the meta-models is that they only take microseconds to run, producing measures comprehensively and quickly across the uncertainty space. After the meta-models are developed, EMAT runs a simulation of the meta-models, producing thousands of scenarios in a fraction of the time it takes the core model to produce just one model run.

**3. Analysis**—Tandem is the web-based dashboard that visualizes the results of the meta-model runs and the simulation of thousands of scenarios. Tandem offers a range of visualization capabilities, including interactive scatterplots, histograms, and optimization algorithms, that can be used to more fully understand the impact of the different uncertainty variables. The figure below of the TxDOT SMART Study Tandem dashboard, highlights, in orange, all scenarios that achieve more than 975,000 transit riders per day. As shown, transit ridership is more likely to be high when population lives closer to transit and the urban core or with high regional population growth, while transit will unlikely reach it's target ridership with the base demographic scenario or with high suburbanization. Transit ridership is also influenced by levels of telecommuting and attractiveness of shared ride services.



## HOW DOES EMAT+TANDEM HELP IMPROVE THE TRAVEL DEMAND MODELING PROCESS?

**You can embrace uncertainty, rather than pretend you can minimize it.** Single point forecasts, plausible scenarios and traditional models don't fully capture the range of possibilities. Computing limitations often cause us to ignore the uncertainty so it is left unaccounted for. EMAT can create thousands of potential scenarios relatively quickly, capturing a range of potential futures.

**You can visualize the potential.** Tandem provides a user-friendly dashboard to select data ranges and visualize performance metrics through scatterplots and histograms. These interactive visualizations are critical for enabling planners to comprehensively evaluate a policy or project under the full set of potential futures.

**You can maximize your budget.** Automated procedures decreases the labor hours and resources required by an analyst to set up, run, and summarize model outputs. EMAT+Tandem features automated capability to run a large set of core model runs, estimate meta-models from the core run outputs, run the simulation of the meta-models to produce thousands of scenarios, and produce visualizations of the outputs.

## HOW DOES EMAT+TANDEM HELP IMPROVE THE PLANNING PROCESS?

**You can tell the story.** The powerful visualization capabilities within Tandem allow transportation planners to tell a story of how the future can unfold. EMAT+Tandem gives planners the ability to reframe the discussion to account for uncertainty and design a solution that can withstand all potential futures with the data to support it.

**You can customize the tool for your region's unique needs.** EMAT+Tandem is a fully customizable tool carefully designed for a specific analysis. EMAT+Tandem provides a system and methodology for scoping out the objective of the analysis and the combination of uncertainties, policies, and performance metrics that will help an agency determine if the objectives are met.

**You can redefine the planning process.** EMAT+Tandem produces a rich set of data allowing for a rigorous, data-driven approach to policy evaluation. The exploratory modeling features take advantage of this data to inform decision making by:

» Utilizing visualizations to assess how the interactions between the policy-levers and uncertainty factors affect performance.

» Employing algorithms and optimization features to evaluate which individual and combination of policy-levers are most successful in reaching the overall objectives under various conditions.

## INTERESTED IN LEARNING MORE ABOUT EMAT+TANDEM?

**Try it yourself!**

https://tandem.camsys.xyz

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## WHY CAMBRIDGE SYSTEMATICS

Cambridge Systematics, Inc. specializes in transportation and is dedicated to ensuring that transportation investments deliver the best possible results. By providing innovative solutions in planning, modeling, operations and software applications, we help our clients make decisions to meet future transportation needs while enhancing the performance of existing infrastructure. We foster strong relationships with our clients and share with them a commitment to improving transportation for future generations.

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