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**Managing Transportation
Systems in a Fast-
Changing World**

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TRANSPORTATION RESEARCH CIRCULAR E-C256

Managing Transportation Systems in a Fast-Changing World

Joseph L. Schofer
Editor

Technical Activities Council
Task Force on Data for Decisions and Performance Measures
Transportation Research Board

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Managing Transportation Systems in a Fast-Changing World

INTRODUCTION

Self-driving cars, rising temperatures and sea levels, increasingly strong weather events, changing citizen preferences, and innovations in technologies that are revolutionizing purchasing behavior, social interaction, financial transactions, communications, and travel—the transportation world is changing very rapidly. Planning for the future is becoming increasingly challenging, because we can no longer look at the past and say the past gives us a strong sense of what the future is going to be like. How do we plan and manage transportation systems in a fast-changing world? How do we make choices about long-life investments in infrastructure in an era where we are facing extreme uncertainty?

In this circular we explore these questions from the perspectives of four experts:

- a senior transportation decision maker;
- a transportation modeler;
- a trend spotter in transit and transportation planning; and
- an historian who specializes in the history of technology and the interaction between technology and society.

The results offer ideas for navigating the transportation world ahead.

Leading Under Deep Uncertainty

A Decision-Maker's View

CARLOS BRACERAS

Utah Department of Transportation

Carlos Braceras has been Executive Director of the Utah Department of Transportation since 2013. He is nationally recognized as an innovative leader in the use of technology and strategy for the delivery of transportation systems and services that have strengthened the economy and enhanced the quality of life in Utah. He is currently President of the American Association of State Highway Transportation Officials (AASHTO), Chair of AASHTO's Committee on Design and its Center for Environmental Excellence, and a member of the Transportation Research Board (TRB) Executive Committee. He has bachelor's degrees in geology and civil engineering.

When you think about the topic that we're talking about today, this is so fundamental: What is the purpose of a leader? What does a leader do when you think about it? A leader helps an organization transition through change. A leader anticipates the future to position an organization to be successful in that new future. In 1964, Bob Dylan came out with the song "The Times They Are a Changin,'" and in fact I use that. We have an annual conference in Utah and I get a chance to do my little blurb. I used that as my walk-up music this year because it is so important for people to recognize that things are changing. They have always been changing and it is those that embrace that change, those that anticipate where things are going, that are going to be the most successful.

Now we are pretty close to the New Year. By a show of hands, how many of you made a New Year's resolution? How many of you? That's not very overwhelming. Of those that raised a hand, how many are still successful in your New Year's resolution? A little bit less than two weeks guys! Well, why do we do this? At the beginning of every year, this turn of the calendar gives us an opportunity to think about what did and what we want to do differently. What do we want to change about ourselves, or what's important to us personally or professionally? It gives us motivation to try to do something different, better, faster—whatever it might be. And so I always find it interesting to ask people if they've been successful with a resolution.

There is another way of thinking about it as we are coming up on the milestone in our year when we recognize and remember Dr. Martin Luther King. Do you have a dream? I submit to you that every single individual needs to be thinking about this. What is your dream? What are you dreaming that you want to become? What are you dreaming that you want for the organization where you work? Everyone must have a dream about where they want to go for the future.

That is why I am so excited about this topic being discussed here at TRB. Because at the end of the day, none of us knows exactly what is going to happen tomorrow. But it is those of us that are willing to accept what happens and actually prepare for those things that may or may not happen that is so important. I think about preparing an organization for that future, about telling the people to accept and adapt and be prepared for change. At my staff meeting last week, we went around the table, we didn't talk about pushing snow or project delivery. We went around and we asked everyone what their dreams were for themselves personally and what their dreams were for their portion of our organization.

Where are you going to take us? What are you going to change? What is going to be different? And there was no challenging about if it was good or bad. It was just so important that you have that dream. So, as we look at this topic, if you can't tell, I have hardly ever done a presentation where I actually follow what they told me to do. I want to stop here because this is really fundamental to what we do. If you think about it, there is not a transportation system in the world that was created for anything other than growing an economy or improving somebody's quality of life. I would submit that probably a lot of us, our quality of life, and maybe our personal economy, got impacted by the weather events over the last day trying to arrive in Washington, D.C. When transportation gets talked about, other than by a geek at the Woodstock that we refer to as TRB, is when it is *not* working.

Think about your interactions here over the last day. How many of you had stories to tell or have heard people tell stories about their journeys in getting here? I am not going to tell you my journey to get here. But it is the fact that when transportation does *not* work, it is the story—that is what is hard about this business. Because when transportation works, it is not a story, and it is hard to get people engaged in the discussion about it. So, at the end of the day, it is so important to always remember the “why.” Why do we do what we do and keep going back to that? Keep going back to helping you and all the folks you work with understand that the reason we do transportation is to grow the economy and improve quality of life.

I am here to tell you that we are having these discussions right now in Utah. We are working on establishing a statewide vision for what transportation needs to be for Utah to be successful. These discussions are very interesting because I know I went into it with a preconceived notion. I thought for sure it was going to be economy, economy, economy, economy. In every discussion that we are having with all the stakeholder groups, everything keeps circling back to what you can do to improve quality of life—the things that are important to people. You could define quality of life in many different ways for many different individuals. I would submit that for each person, it would change based on what they are experiencing at that time. It is a very broad category, but quality of life is emerging, at least within Utah. It looks like it is going to be that umbrella issue around which we're going to say: is transportation successful? And we are going to measure it against how we improve the quality of life for the citizens of the state of Utah. That is where it looks like this is coming down to right now.

You know, things change fast. [Figure 1](#) is a reminder of how rapidly things can change. I grew up just outside of downtown Manhattan and spent a lot of time on Fifth Avenue. I am not old enough to say I was there, but if you look at the picture on the left-hand side, you see there is only one motor vehicle (circled in red) in the year 1900. Just 13 years later, look at Fifth Avenue in the picture on the right-hand side, and the question is: “Where is the horse?”



FIGURE 1 Fifth Avenue, New York City, Easter morning 1900 (left) and 1913 (right), (National Archives).

The point of this picture is to help us understand and recognize how fast things change. A lot of times those of us in the business see things from inside, and it feels that things are changing very incrementally. Sometimes, unless you step outside and look back at where we have been and where we have gotten to, it is hard to recognize that pace of change. But I am here to tell you that the pace of change is one of the most fundamental characteristics of our day. The change rate is changing faster than ever before. We just finished reading Thomas Friedman's book, *Thank You for Being Late*¹, the premise of which is that we are living in this age of accelerations right now where the pace of change is accelerating like never before, and we have to anticipate that it is not going to slow down.

I know what it's like for a lot of us when we find ourselves in the midst of something new, some kind of change. What is that? What is the natural reaction? Well, "I'll buckle down now but we're going to get back to normal. We're going to get back to that place where we were comfortable, and where we knew what was expected of us every single day." The premise is that is not going to happen. That comfort place is not going to be what it used to be. We have to become comfortable with the fact that things are going to be changing at a much higher rate than they have ever had before. Again, those people that are successful are going to be those that accept it. Embrace the fact that you're in the middle of these accelerations. Friedman's book is very, very interesting, and it touches on a lot of different areas, but he groups the changes into three different, large areas.

One of those is climate change. Climate change is driving patterns of migration of our societies around the world. That disrupted our typical notion of what nation states are. It is disrupting cultures in a way that we have not thought of before. It's been happening for a period of time, but it is becoming much more noticeable. A lot of problems that our politicians are dealing with right now go back to the impact that climate change has had on different regions of this world and peoples' ability to do such simple things as feed their families. If you are unable to feed your family, there are cascading results of finding ways to do so that create this disruptive force in our world, and it is picking up in pace.

I think the other area that will probably be discussed in this conference, and that is as familiar as any other group, is technological change. You could group a whole lot of stuff into the technology area. The pace of technology is accelerating. The way we use technology is

changing dramatically, and the way we learn is changing. The way we deliver information and assimilate information has to change. If we are going to thrive in this age of accelerations, we are going to have to find a way to be continuous learners in a way that we have never been before as a society. That is going to require the delivery of knowledge in new and different ways, and in formats that are not typical. So, sitting in a classroom is probably not going to be the way a lot of people learn those important skills that are needed for the future.

Then the last change, globalization, is impacting the way we interact with citizens around the world. And the pace of this, again, is changing so quickly, it is difficult to anticipate. So, as you roll these big-picture ideas together, it is important for us to be thinking about how they impact the world in which we live and the world in which we need to thrive in order for our companies, and our government agencies to be successful. I recommend you take a look at that book when you have a chance.

So as we think about our world in transportation, I group things over the last couple of years into these three different paradigms—climate change, technology change, and globalization. Under technology change, I have brought a whole lot of stuff into this bucket of automation. There is a whole different spectrum of what this (vehicle) automation is, everything from the National Highway Traffic Safety Administration's (NHTSA) level five to a driver assist type of vehicle, but that is having profound impacts on how we think about what the future of our transportation systems needs to be. This includes everything, from our designers wondering if they need to have the same width of traffic lanes to a legislator in my office on Friday afternoon who was asking me why we aren't painting our lane dividers six inches wide instead of four inches wide so that her driver assist function can work better. So, there is a whole lot going on in this area.

Next I'll go to electrification. Utah is a state that is in a basin. We have mountains all around and in the winter we get terrible inversions. Air quality is one of our major concerns. We talked about all the wonderful things we have, but air quality is one of our biggest struggles. We are making a concerted effort at trying to find ways to clean our air and we are seeing this movement towards electrification.

Now it is going to take a while for that to make a significant difference in our air quality, but it is also having an impact—not today as much as it will in the future—in our ability to fund the transportation system. Our legislature last session asked us to develop an operational vehicle, a road user charge program that has to be up and running by January of 2020. It will be voluntary for those that are using electric vehicles. That is a big, big lift because when you go down the path of doing something like this, I can guarantee we did not even know the right questions to ask. Every day as we move forward, we are still figuring out new questions and the answers need to follow that. But electrification is having a profound impact on our ability now to think about funding the future transportation system.

Now we are having to start up a brand new program that we never anticipated before, and the tax commission who normally collects our revenues is saying they do not want any part of that. That is a department of transportation (DOT) problem. And so it will change our world as we move forward into this because I am convinced we will start to see more and more states getting into the road user charge programs.

Then there is mobility as a service. I think most of us have used this a lot. I consider this to be a hybrid of the transit system in a way that provides that first and last mile flexibility that we all bought, but it also gives that element that we sometimes don't think about, but we like a lot. We all like to feel in control, don't we? We like to feel like we have that control and when we

put ourselves in public transportation, sometimes we don't have that control. I know last night at 1:30 in the morning, I was sitting in my airplane seat and I could see the gate for an hour and a half. I could see the gate. It was a hundred feet away and I just wanted to open the door and walk out. It was not within my control to do that, because they were deicing another plane at the gate. We like that control, and that is what mobility as a service is giving folks. We don't understand yet how that is going to fit in and function within the entire transportation system.

One of the things we are faced with is that Utah's a fast-growing state with a high birthrate. We are also a fairly dense state. If you're familiar with Utah, we have what's called the Wasatch Front. It's about a hundred miles long, beautiful mountains on all sides, with a couple of big lakes. That is where most of our population sits and that makes us the 9th most urbanized state in the country. Now we have a ton of public land. Sixty-five percent of the state is owned by the federal government. So if you want to have a rural experience, you could come to Utah and you go for a hundred miles and see nobody out there. But we have this urban challenge in that most of our population lives in urban areas. We are going to almost double in population in 35 years and we are feeling the effects of that congestion today.

The question that our legislators are pushing now is: How are we going to meet our mobility needs in the next 35 to 40 years? I respond that we are not going to double the lane miles to meet this doubling of population. There isn't room to put it. Could you imagine what it would look like? We would have roads stacked on top of roads and I am pretty sure that's not the type of community anyone wants to live in. At the end of the day, we want a community that people want to live in. We have started this process where we have now been given authority for transit planning, trends and environmental, and we have been given dollars to implement capital transit projects. For a rural red state, we are now in the transit business and it is a new world for us. We have been changing. We are also doing planning in a way that we have never done before.

We are all familiar with the typical metropolitan planning organizations (MPOs), right? We have four MPOs in the state of Utah. They do their planning process and they do a great job of it. And then we do the planning process in the rural area and we combine all that together and we call it a statewide unified plan. So we have one unified plan and we have one financial set of assumptions that we use to do all the planning. But that is kind of the way we have been doing it for years. And the feeling is that it is not meeting our needs. So we are starting the process of looking at area planning and corridor planning, where we are sitting down with communities ahead of the game, and we are talking with those communities. What do they want their future to be? What is the community of your dreams?

Then we bring multiple communities together within corridors and we start to establish goals and visions for what those communities collectively want to be. Because not every city and town wants to be the center, how can we help facilitate the discussions between all the communities? Then once we have established those visions for each one of these cities and towns, and counties, we sit down and we talk about what are those transportation options that we can do to support the mobility needs and the safety needs of the communities. Then we get to projects. Projects become almost the last thing we talk about. It is a vision-driven, goal-driven discussion with communities. And it takes a long time. It's hard because it is easier to point at a project and look at a line and say, that's my house, and I don't like that. Or you know, I want to park here. That is not the way to go.

That is a lot easier, but we need to get people engaged in a discussion about what is that community of my dreams and what should it look like in the future? In his budget, our governor is promoting standalone money for active transportation, more money for transit, and we are

becoming a more multimodal transportation department to meet this increasing population. So we are trying to anticipate this growth because we are so committed to the fact that without a good transportation system, Utah is not going to be the place that it is today. And we want it to be even better in the future.

How many years ago did we talk about context sensitive solutions? I know it was talked about here at the TRB Annual Meeting probably 20 years ago, in the late nineties. One of the things I am realizing is that this was a ground-changing approach to transportation. We were early adopters and we talked about it early on in the late 1990s and early 2000s, and then the conversation kind of faded away. The presumption was, well, no, this is just the way we do business today. But as I go around and talk to mayors and county commissioners, I ask them after we finish a project, “Would you have us back in your city again?” The answers are not universally positive. And so what we are doing is re-embracing the idea that this is not a mathematical exercise where impacts equals mitigation. Throw that mindset away. Think about a project in a community as the opportunity to make a difference for what's important to every citizen in that community. Think about going to that city and saying, what do you want to be? What is your vision for your community? How can we help you be successful?

Go to the resource agencies with the attitude that when we are done, we don't want to just mitigate impacts, we want to make the environment better than it was before we got here. And I know we always worry about spending road money on other things, but what you are doing is investing in the future of our communities. If you do a project and you anger people and the resource agencies to get that one project done, you are going to have a heck of a hard time coming back and doing the next project. We are in this business for 100 years, for 200 years. You live in the communities. Think about what you want for your families, for your children, and you can do it with transportation. That's what makes our business so remarkable. We could make a difference in every single person's life. You have the resources, the skills, and talent. Just have that conversation, engage people in what the future looks like and then help them get there.

Question: It is a very important and highly motivational statement that you have made. So I want to ask you a question. How do you also comply with benefit-cost analysis requirements with a regional plan requirement that required demand forecasting with the National Environmental Policy Act (NEPA) requirements without losing sight of the vision? How do you see those kinds of institutional requirements? And is it possible actually to change them to create new institutions that are more supportive of the vision and the way you described it?

Braceras: Thank you. I think too many times we take existing processes and we create boundaries within them, yet there is a lot more flexibility in how we utilize the tools that we have been using for years—the NEPA process, the planning process. I believe we give ourselves credit for there being a lot of flexibility. Now what we are doing on this visioning and area planning and corridor planning process is we are getting ahead of NEPA. Too many times we find ourselves within the NEPA process asking the right questions at the wrong time. As soon as you are on a NEPA process, there is a certain time clock that's ticking. There are expectations that have been preconceived in terms of what is going to happen along this path that really limit us in terms of the questions we can ask.

So we try to come out of our area and corridor planning with a really clear idea of what we are doing, what we are trying to accomplish for the community, for transportation, and with the actual mode choice. We are a big part of that now. We are coupling these discussions with something that has typically been off limits to us, especially in a lot of conservative states: local

land use planning. That has been the piece that we do not do—local planning—we just respond to their needs. What is happening now for us is we are engaged in a back-and-forth discussion with those local communities about how they want to plan and what their planning choices are. And quite honestly, we are linking the prioritization of projects to more sustainable local plans.

There is one bill that is moving through the Utah House right now and it is going to be interesting to see how it morphs. This one would say that if we are going to do a project and add capacity, add lanes, every community has to have a system. There has to be an affordable housing plan in place. If one of the communities along the corridor does not have it, then they cannot have an interchange or an updated interchange. That is a little bit of a step. And to think that as a conservative state we'd have that conversation. So what it is creating for us right now could be considered uncomfortable, but we have a seat at the table as a state with local governments on how their plan works. And so, I don't know if that answers the question, but don't allow existing processes to give you ways to say no. There are more ways to say yes than most of us ever believed.

Question: A bit of a similar theme—so it's the tradeoff. How much do you think you can control planning in Utah to accommodate ideas and technologies that are developed elsewhere? How do you play that balance?

Braceras: Everything is a balance. I would counsel that the word “control” is a turnoff. Control is an illusion. And if what we are looking for is control, we are going to lose the game. So what I would suggest is that you think of yourself as a community partner, as a facilitator in the discussion. It is a community dialogue that you need to keep going back to. We sometimes can influence a lot more if we do it in the right way. State DOTs tend to be the *big dogs*. And even if you don't think you act that way, people see you that way. And so you have to be twice as sensitive to the fact that you are not going to come in there and be the know-it-all, pushy state DOT.

Question: It sounds to me like you are trading the ability to forecast the future for a vision and desire to construct a future for. It sounds like you are trying to make that future.

Braceras: I don't know. I think we are forecasting multiple futures. I think scenario planning is the way we have to think about this and it is a risk-based scenario planning. We have to be honest. We think we might know what is happening and we should plan for that, but we should also understand what the risks are, what the deviations are first so that we can anticipate, and be prepared for that as well. I would like to think that we are putting in place scenario plans that will allow us to be better prepared for whatever future comes our way.

An MPO's Approach to an Uncertain Future *Exploratory Choices, Robust Choices, and Preparation for Change*

DAVID VAUTIN

Metropolitan Transportation Commission of the Association of Bay Area Governments

David Vautin is a principal planner and analyst at the Metropolitan Transportation Commission (MTC) of the Association of Bay Area Governments. Prior to joining the Metropolitan Transportation Commission/Association of Bay Area Governments (ABAG) nine years ago, David earned his master's degree in transportation engineering at the University of California at Berkeley and a bachelor's degree at Cornell University, also in transportation engineering.

I am going to talk about how in the Bay Area we are trying to plan for a very uncertain future. I will break my presentation into three components. First, for those who aren't already converted to the idea of planning for uncertainty, I am going to try to convince you that it makes sense to do this. Second, I am going to talk about how we scanned the country for best practices and created a process that is ongoing right now to create a more resilient plan that is able to incorporate uncertainty. And then, third, I will talk about some of the challenges and opportunities if your region or your organization is trying to do something similar.

First, I just want to talk about uncertainty and incorporating into a new plan. Obviously there has been uncertainty in regional planning for decades, but a lot of our planning techniques evolved during the latter half of the 20th century, and those techniques involve looking at linear extrapolations into the future and then trying to optimize outcomes under that linear extrapolation. In a world with increasing uncertainty, sometimes that approach isn't necessarily the right fit. As we look at new topics like climate change and automation, we need to take different approaches. So I am going to dive right into why we think incorporating uncertainty is so important, and why that linear approach is not always the best.

Before we turn to the Bay Area, let's look at Detroit. [Figure 2](#) shows downtown Detroit in the 1920s. Its streetcar lines were well utilized. Its streets were full of people. If you were an urban planner like me doing work in Detroit at the time, you might have been inclined to extrapolate this activity into the future and plan for a region that looks a little different than what actually happened when the city declined in all measures of success in the 1970s and 1980s. It would have been even more difficult to anticipate Detroit's resurgence in the second decade after the millennium. And while the Bay Area did not follow the same path, at one time we had the same sort of clustering of industries like Detroit. We may not always be the primary location for all of the world's major technological innovations. We need to be prepared for uncertainty.



FIGURE 2 Downtown Detroit, 1920s

(Wikipedia: https://en.wikipedia.org/wiki/File:Detroit_Kern_block.jpg).

In the mid-20th century, Phoenix, Arizona experienced perhaps a somewhat unexpected boom, with the automobile and air conditioning making these places that used to be perhaps a little inhospitable into vibrant places for significant growth. And today Phoenix is bigger than the Detroit Metro area. Now let's jump out to California where I live and work.

Figure 3 shows San Francisco in 1906, after the earthquake on the San Andreas Fault. Natural disasters can fundamentally change a regional trajectory, impacting infrastructure and communities, in this case forcing the city to start over, but with new ideas and technologies.



FIGURE 3 San Francisco after 1906 earthquake
(National Institute of Standards and Technology photo).

Land use is critical for our transportation outcomes as well. As we are doing our latest long-range planning cycle, we see this work as a comprehensive regional planning effort. There are no silos because they are all interconnected. I want to talk a little about land use and transportation. Figure 4 shows the contemporary San Francisco skyline, more than a century after the big earthquake, and nearly four decades after the construction of the Bay Area Rapid Transit (BART) system. The post-BART development explosion led to an unexpected backlash against growth that fixed the skyline for about 20 more years, and directions changed yet again in the latest technological boom that brought new, taller buildings to the city center. The changes in all these different factors are nonlinear, meaning that shifts occur in spurts and then they slow. As planners, we need to be prepared and have a process that doesn't just assume that things occur on a single trajectory. Take, for example, the South Bay. San Jose, which was once an urban center in primarily agricultural Santa Clara County, now has some of the most valuable real estate in the world and some of the most valuable companies in the world. If you had been a planner in the Bay Area, would you have foreseen that those orange groves would suddenly turn into these technological campuses? Maybe not.



FIGURE 4 San Francisco contemporary downtown (NIST photo).

I will pivot now to transportation and explain why that linear approach doesn't always work so well. For several decades planners in the Bay Area focused on connecting our two largest airports, San Francisco and Oakland, to our rail system, and invested billions of dollars to get people to our airports. When those studies were done, the ridership forecasts that were

produced were much higher than what we have actually seen. One of the reasons why we have not hit those forecasts is the emergence of low-cost transportation network companies (TNCs), providing lower-cost taxi services that did not exist when those projects were planned. And although it might have not been possible for the planners who had worked on those products to imagine the emergence of Uber, they could have looked at varying the cost of taxis to try to understand how that would affect the ridership on those systems.

When we are planning for these projects, we need to be looking at all these exogenous factors, and thinking of them not as fixed but variable. This is why we need to plan for uncertainty. If you are not sufficiently convinced, I will throw one more thing at you. How many people in this room predicted the presidential election of 2016? Probably a small number of you. All the odds said it was 85%–90% certain Clinton would win the election, right? But that did not come to pass. Sometimes it is important to plan for a variety of different outcomes, because you do not always know which one's going to happen. Just like the election, we don't know whether autonomous vehicles are going to be wildly successful or whether they are significantly overhyped. We need to plan for both outcomes. We need to have resilient strategies.

Let's pivot now. In the Bay Area as of 2016–2017, we were wrapping up our previous plan, Plan Bay Area 2040, and we had been using scenario planning for quite some time, but we were using it in the same way over and over. We held all those variables constant, the amount of growth, the cost of transportation. We didn't assume any autonomous vehicles. We've assumed sea level rise impacts were minimal. We were taking all these factors and saying let's just hold those constant. Let's just study two variables as shown in Figure 5. Let's look at how we make land use decisions, between more focused or more dispersed growth, and what sort of transit transportation investments to build—more transit versus more roads. We built a couple of scenarios. Coincidentally, the transit option with focused growth, aligned with our regional goal.

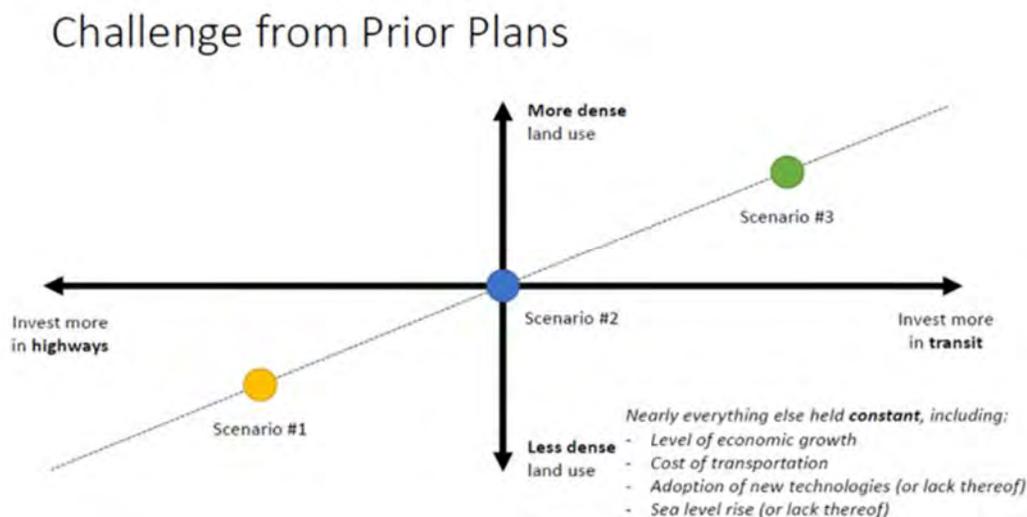


FIGURE 5 Traditional approach to scenario planning.

We were optimizing under a set of fixed conditions. And while that can be very helpful if you're trying to have a conversation about why focused growth with transit investment is critical for our region, it is not very helpful in answering a lot of the questions our policy makers were

asking. We have got autonomous vehicles running down the street. They go by my house all the time in San Francisco. They would ask, “What are we doing about that? How should we plan differently?” And we weren't answering questions about climate change, about a lot of other uncertainties. We realized we need to use scenario planning in a different way, to account for deep uncertainty with factors such as automation, climate change, and many more. Now the approach that we settled on was using a kind of new form of exploratory scenario planning in the transportation sector.

But it is certainly not new in other sectors. Some say it originated in the defense sector with RAND back in the 1950s. Scenario planning has been used for quite some time, but we have taken a very different approach, an approach of looking at different “what if” scenarios as opposed to looking at these trade off-type discussions. This approach had been applied in a few other places before we started doing it here in the Bay Area. The first to really use this approach to uncertainty in their long-range planning was the Delaware Valley Regional Planning Commission in Philadelphia. This was pretty interesting work where they looked at four different futures for their particular region. The Chicago Metropolitan Agency for Planning in Chicago also looked at topic areas of uncertainty and then explored strategies related to them. The Atlanta Regional Commission has also been doing some work on this.

Perhaps the closest parallel to what we ultimately decided to do in the Bay Area was the Prospects for Regional Sustainability Tomorrow (PRESTO) effort done by a nonprofit here in the Baltimore-Washington area, which used quantitative models to simulate different futures and produce a very data driven type futures analysis. Lastly, I do need to mention the city of San Francisco, which didn't do an exploratory scenario analysis. They have done what is called normative scenario planning to establish a vision for the city, and come up with a kind of an ideal transportation vision. I mention it not because it is a similar type of effort, but because the engagement process they did with stakeholders served as an inspiration for what we ultimately did. So after scanning the country and doing some introspection for six months after our last plan, we unveiled this effort, known as Horizon, about one year ago.

In January and February of 2018, the objective of the Horizon process was to prepare for this uncertain future by identifying what we call resilient strategies and investments. And I don't mean that in the narrow climate-resilience perspective. I mean that in a much more holistic perspective where we are trying to find strategies and investments that perform well under wide-ranging, very different circumstances. Horizon is designed to serve as a bridge between our last long-range plan, Plan Bay Area 2040, and our new one, Plan Bay Area 2050, that I will be leading starting in August. We will choose those strategies that perform well and advance them into the next phase of planning process. To do that, we broke our Horizon effort into four core components, starting with public outreach, obviously very critical for stakeholders and the public. We are doing a series of white papers, known as perspective papers, where we ideate and we come up with different strategy ideas to deal with these uncertainties. Our project evaluation, which used to look at a single future, looks across multiple futures. These are what-if scenarios that are very, very different from what we've done in the past.

Before we get to any of the evaluations, we first asked ourselves, “What are our guiding principles?” To help define our vision for the future of the Bay Area, we talked to more than 10,000 people across the region and came up with the five principles shown in [Figure 6](#). We want a region is that is more affordable, connected, diverse, healthy, and vibrant. As we move forward, no matter what the world throws at the Bay Area, we want to meet to these goals.

Although there are a lot of things that are outside of our control, we can at least strive to achieve these goals through the actions that we take as a region.



FIGURE 6 Guiding principles.

Once we had those principles, our next step was to identify those external forces, things that we used to hold constant but we actually know are variable, to look at what the potential extremes are on each of those different variables and construct a set of futures that hold together. We can't study every potential combination of those futures, because we have a limited amount of staff. We would love to study thousands of them. Instead we collaboratively came up with some narratives that hold together so we can stress test all of our strategies and investments against a wide range of futures—not to try to guess the future, but to imagine different futures. Once we had the forces, we then constructed the futures and we're doing this first analysis where we ask, “What if we keep doing the same things we've always been doing, investing in these projects, and having the same policies as today? What would happen to the Bay Area under those conditions?” We will then apply strategies to those futures and see how that changes the trajectory of the region. For example, if we put in rent control or if we build a set of transportation projects to alleviate crowding, what will that do? Will that affect the outcomes? And that's why we will run the futures a second time to answer that question.

First of all, we identified 24 external forces, key variables outside of the region's control that we had never evaluated in our planning process before. We looked at political forces like the geopolitical status of the United States and the type of government system that we have. We looked at environmental forces, natural disasters and sea level rise, which are dependent on the actions of countries around the world in terms of impacts on the bay shoreline, in our own region, in terms of economic forces.

We looked at issues like productivity and how that might change from increasing automation. There are actually cafes now in San Francisco where the robots serve you coffee—it's much more efficient per person. In terms of land use, we looked at potentially changing preferences for firm and household location, which we had previously held constant, and based them on historical factors. And finally, in terms of transportation, we looked at things like the

level of autonomous vehicle penetration, the cost of transportation and different growth scenarios. We wanted scenarios where we looked at external forces booming and being widespread as well as scenarios where perhaps they've been overhyped. To do all of this, we couldn't study thousands of different futures. We needed to come up with a short list of ones that were representative.

We brought together experts from all four sectors of our planning—transportation, land use, economic development, and resilience. We set up a peer exchange with our federal partners, brought them all to San Francisco, and we had them do an activity that we designed called “Create a Future” where participants assemble all of the 24 forces into a logically coherent narrative. They then pitched their idea of what might happen in the future, not a visioning exercise of what they wanted, but an imagination exercise where they thought about what could happen. At this peer exchange, they weighed the forces, again, not predicting, but thinking, how can we create a cohesive narrative between all 24 forces? At the end of the day they presented all of these different futures. We had wide-ranging futures from one where there was an authoritative plutocratic government leading the United States, all the way to one where there were extreme automation and technological shifts, and another one in which there was an implementation of a nationwide carbon tax.

At the end of the day we had these different futures, and we worked with stakeholders to shrink the list from the 11 that were originally generated by the teams to three that we felt were a representative range and that really would pose a stress test to all of our ideas. [Figure 7](#) shows these three futures that we are studying through the Horizon process. The first is “Clean and Green.” In this future, we are exploring what if there are lots of new technologies and a national carbon tax, which enables greater telecommuting and distributed job centers, thanks to virtual reality and other technologies. Second, “Rising Tides, Falling Fortunes,” is a future where the federal government cuts spending and reduces regulations and leaves more policy decisions to states and regions. And finally, “Back to the Future,” which is a future where the nation's economy goes into overdrive and we have a national economic boom, new transportation options, and a 1950s era-esque wave new of development.

Three Futures for the World and the U.S.



FIGURE 7 Three futures.

Under these three futures, there are the 24 forces. The summary table in [Figure 8](#) clusters them together. You can see we are looking at wide-ranging and very different outcomes. In the first future we had this high tax, high regulation structure, which results in environmental benefits, but also some adverse impacts on some of our disadvantaged communities. In the second future we explore nationalism and high tariffs as well as strict immigration policies. What sort of challenges those might pose for a global megaregion like the Bay Area? And in the third, Back to the Future, we're looking at that rapid economic expansion and the dispersion of housing into the megaregion, and what sort of transportation challenges that might pose. Our economic forecasters have worked their magic with each of the different futures and we are looking at a wide range in terms of growth between now and 2050. The Bay Area has just under eight million people today. In the slowest growth future that would be roughly 8.6 million people. We're looking all the way up to the future with just under 14 million people in the emergence of a northern California megaregion.

Again, these futures are not predictions. We are trying to imagine how the region would respond to these wide-ranging conditions. Now that the futures have been created, we have embarked on the challenge of trying to model all of these complex forces. One of the biggest challenges with this type of work is that modeling is often based on historical data from the past. We want to try to understand how these future forces, especially with all these unknown factors, might shake things up.

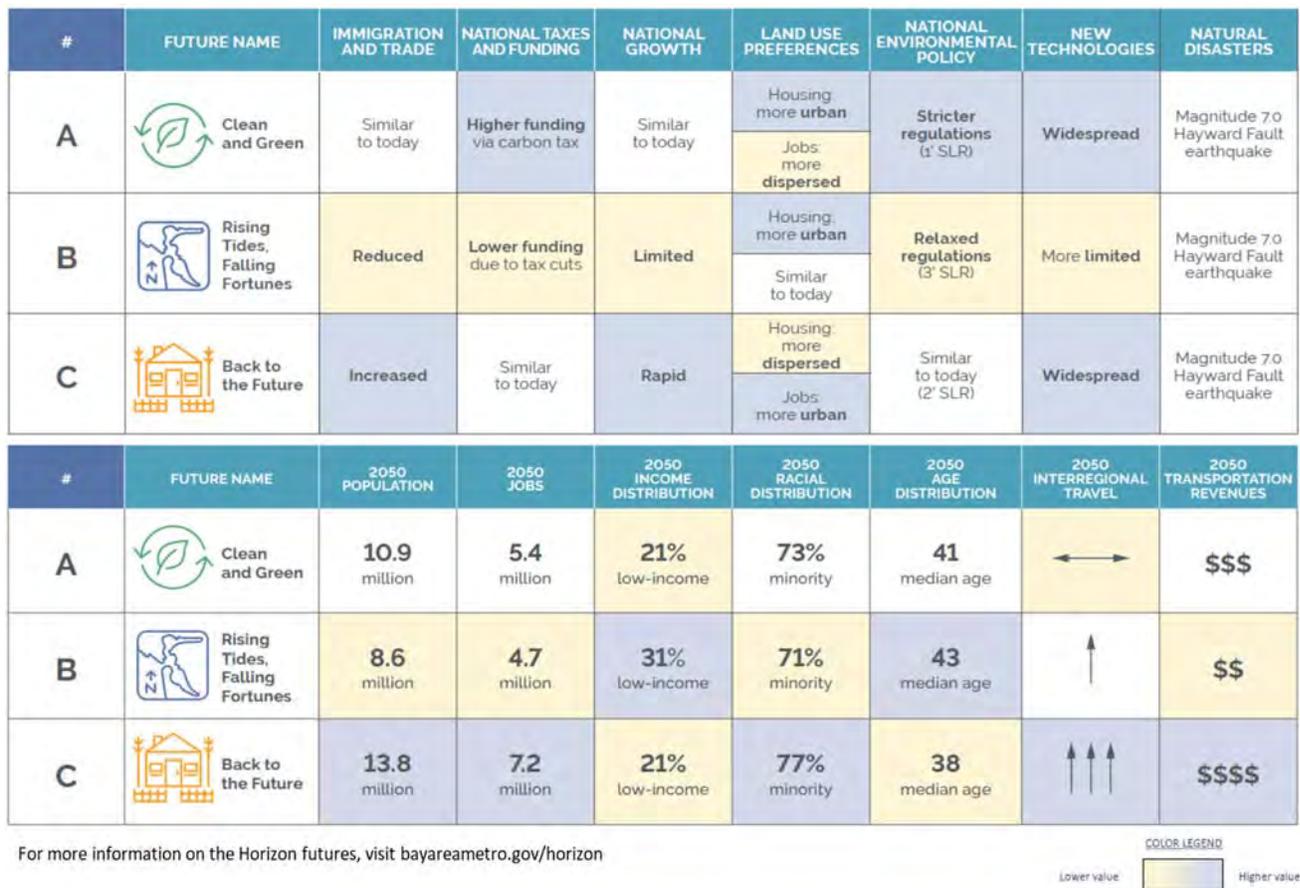
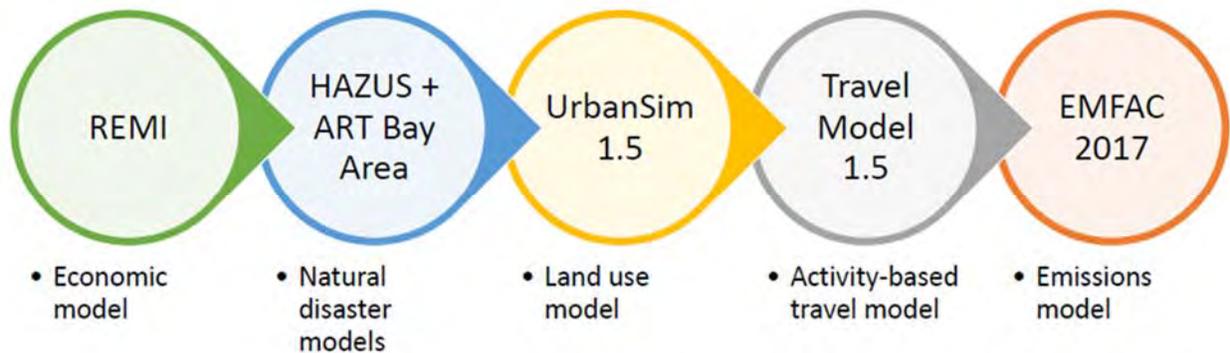


FIGURE 8 Twenty-four forces affecting the three futures.

We have spent a good chunk of 2018 upgrading all of our models to try to prep them for this work. Our modeling process is shown in Figure 9. It involves five different models strung together and iterating with each other from the Regional Economic Models, Inc. (REMI) model, which does our economic forecasting; Hazus for natural disasters; the UrbanSim model to estimate local land use impacts; the activity-based travel model, which looks at the transportation implications; and finally our emissions model, which tells us about some of the environmental impacts. This work is incredibly complex and many of these things are hard to forecast into the future, but we feel like if we don't try to incorporate them in our model then we have a huge blind spot, so it is worth these challenges. Ultimately by upgrading these models, this year we are going to be able to test the efficacy of those strategies and projects to see how they might influence these widely divergent futures for the region.

Now before we can do that, we of course need a bucket of strategies to test out, to solve these challenges. So we created a parallel process called perspective papers where we generate strategy ideas for some core topic areas that we hadn't really looked at in the past (e.g., shared mobility, autonomous vehicles). These papers are posted on our website and they are actually applicable for metros across the country, as they are not entirely unique to the Bay Area. For

Futures Modeling – Currently in Progress



The modeling of the wide array of external forces – from earthquakes and sea level rise to immigration policy and autonomous vehicle adoption – is **complex**. But ultimately we believe it will provide valuable information about the **efficacy of strategies and projects**.

FIGURE 9 Horizon modeling process.

example, in the first paper that came out in June, we identified a bucket of different strategies that we want to test out to deal with some autonomous vehicles, which are widespread in two of the three futures we're studying. These range from new pricing strategies to a reinvention of our region's transit system, and some strategies to address the equity and economic impacts of automation. For the sake of time, I am not going to go into all the perspective papers, but there is a lot more material on our Horizon website (mtc.ca.gov/horizon).

In a parallel effort, we engaged the public and stakeholders to brainstorm new transportation projects to align with these different futures. Often in our region and many others, we just see projects marching their way through over the decades as a pipeline of ideas. We don't get a lot of new ideas to evaluate when we are doing our process. So we shifted that around this time by allowing the public to submit their ideas directly to the metropolitan planning organization and awarded cash prizes based on the best ideas. Thanks to the media outlets in the Bay Area, we were able to get a lot of pretty hefty submissions from people, which has given us plenty to work with in terms of aligning some new transportation projects to this wide range of scenarios. The most important step of the process yet to come is the stress testing of those projects.

One of the great things about being able to share this work with all of you is that it is still underway, so I don't have all the answers today, but we have learned so much during this first year of the process. The stress testing work that we are going to be doing in the coming months will actually load in those strategies into our models and see how they impact the outcomes. For the region, using these futures is a way to take an idea like rent control or construction of a second Transbay Tube and see how they influence the regional outcomes. With all these simulation models ready to go at this point, we are going to be able to do much of that work in the spring of 2019.

One other major aspect of our long-range planning process is individually evaluating our major transportation projects. We have been doing it for several cycles now. We calculate a benefit-cost ratio and a qualitative score for all our major projects. This is something that is very valuable for us to be able to strategically place projects in the fiscally constrained plan that perform well.

In that process, too, we see an opportunity for evolution to incorporate uncertainty. Instead of scoring projects against a single end use pattern in a single forecast, we are loading the project into each of the three futures. This will allow us to assess individually how a project will perform in a high-AV future versus a low-AV future, and a future with 14 million people versus one with just 8 million. This will help us understand how the performance outcomes of a project, like a new bus line, a new transit line, or a highway widening, might differ under these different circumstances.

There is plenty of work left for us to do as we are roughly halfway through the process. Our goal by this fall is to release a final report that identifies those strategies for transportation, land use, economic development, and resilience that shortlists the best ideas—the ones that perform well under a wide variety of circumstances. Instead of optimizing to a single future, we will have the strategies that performed well across multiple scenarios going into our long-range transportation plan.

I will wrap up with some conclusions on challenges and opportunities if you are in a community or region or state thinking about doing a different type of planning process that incorporates uncertainty. First of all, changing the status quo for how we do long-range planning is never easy. It is a challenge transitioning from kind of a linear approach, where it is so much simpler to just optimize against a set of fixed conditions and say those things are outside of the transportation realm and we're just going to leave them fixed.

It is a lot easier to do that than trying to look at all these forces interplaying and the challenges there. It can also be a bit jarring to folks who are used to the traditional approach, and developing the tools necessary to do this is quite hard, and staff- and time-intensive. Lastly, like any long-range planning effort, some members of the public might perceive it as a somewhat intellectual exercise when they are trying to figure out how to deal with today's significant traffic congestion or housing affordability issues.

We think the opportunities for using this sort of approach make a lot of sense. First of all, it gives us an opportunity to consider some of our longstanding investments on the transportation side and strategies on the other fronts and make sure that we are still confident that they are going to get us where we need to go.

We don't want to be building white elephant projects that don't perform well in 10 or 20 or 30 years when the conditions are different. Many of these projects are supposed to last 50 years, 100 years, or more. The type of planning we are doing is also helping to address the questions we are getting from policy makers. They want to know how we can plan for autonomous vehicles. They want climate resilience baked into the plan and not dealt with in some parallel process on the side. By doing this work outside of the traditional federal and state requirements of the Regional Transportation Plan/Sustainable Communities Strategy process, we are able to answer those questions and create a better plan. In a region like the Bay Area, with Silicon Valley's rapid change and innovation, we believe this sort of stress test approach will create a much firmer foundation for our next long-range plan. So we are very excited to see where the Horizon effort takes us and how we can really create a more robust regional plan for the San Francisco Bay area. Thanks for your time today.

Question: I really liked your presentation and really interesting thought experiment. Maybe I am being a little too analytical about it, but in this process and in future processes, I had a question about how you weight the performance in different scenarios. In this case when you were taking three scenarios it might not be quite as important, but in potential future processes, if you consider more and more scenarios, weighting the performance of projects based on how they

do across these scenarios equally might not be most logical thing to do if one particular future may be less likely to occur than others. Has there been any thought about how potential weighting of different scenarios might be incorporated into this process or in future processes?

Vautin: What I would say is it is difficult to figure out the odds of a particular future happening in the first place. We are all influenced by present day conditions. So I think that is a challenging exercise in the first place. We have talked a little bit about when we're prioritizing projects in the fall and really prioritizing the strategies, there might be some opportunity for policy makers to weight the futures in some form, but we haven't gotten to that point in the process just yet.

Question: I am just wondering who was driving, from a personnel or political perspective, the effort at San Francisco Metropolitan Transportation Commission. It sounds fantastic. I am a modeler. I am always trying to push people to run more scenarios, do more with the model, look at all these features, but it's hard for people to find the time and money and effort, because especially in the United States where we are driven by this continuous conformity analysis cycle, there never seems to be enough time to explore the options. I am surprised that you found the time and money to do it. There must have been somebody driving it. Was it you, maybe who was responsible?

Vautin: It was multiple people of course, as this is a major effort that involves 20 to 30 staff who are at our agency. What I can say is that when I was offered the opportunity to lead this next generation plan, one of the first things we did was a strategic planning exercise. We went through everything we did with previous planning cycles and figured out what we thought worked and what we thought didn't, eliminating the stuff that we thought was not helping and reassigning all those resources to make this sort of effort happen. I think we had the policymakers' support because they were asking these questions and we weren't answering them as planners. We had the support of executives who were saying we need to change our process. We shouldn't do the same thing for the third time.

Planning Strategies for Addressing Massive Uncertainty

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When I first started thinking about the planning process, it was in Joe Schofer's classes and in his living room when we coauthored a paper about how that planning process works. Some 40 years later we are still thinking about how that process works as we move ahead. I know when I left Northwestern, everybody said what an exciting time it was to be joining the profession. We were right around the corner from change. I decided a couple of years ago that we got to that corner, but we still don't know quite what's around that corner. But clearly, while there were some dynamic times at the turn of the century between the 1800s and 1900s, and perhaps post World War II, as it relates to the lifetime of most of the professionals in this industry, we are truly at the point of maximum change, in many, many respects.

Some of those we have talked about, and some others are more subtle, but I think are equally relevant. I am going to talk a little bit about characterizing the change and I am focusing on public transportation because in some ways public transportation is really at the nexus of a lot of these changes—it's on the bubble. It is perhaps most at risk or most impacted by a number of these changes and it is an interesting place to look when we think about preparing for the future and change. I am going to talk about some specific examples of the tactics and strategies we might use to cope with change. This is by no means an exhaustive discussion. It's kind of a sampler, teaser approach, and then I am going to make some observations about what's going on in transit.

If we think back even in a short history of what's going on with public transportation, not that many years ago we were probably talking about reaching a 50 to 60 year high in terms of transit ridership. As we see in [Figure 10](#), there were a lot of people talking about having reached peak vehicle miles traveled (VMT). There was strong developer and land use planner interest in public transportation as a tool. The millennials were different, central business districts were doing well and they were gaining residential development. Referenda were passing and folks were implementing public transportation, and we were feeling pretty good about it. Not that many years later, things changed relatively dramatically. We are now actually past the end of the fourth year of pretty pronounced, declining public transportation ridership almost ubiquitously across the country. Some of those perceptions that we had about millennials and behavior are starting to morph as millennials are maturing.

We are realizing that some of their uniqueness washes away and diminishes with time and hence their behaviors may not be as profoundly different. We realized that, with the economic recovery, VMT started ramping back up again, and transit agencies were struggling as they have always struggled with a host of financial issues exacerbated by things like health care costs. We continue to find new ways to be surprised with cost overruns and project delays. We

realized that transportation network companies that we originally had decided were a great first-mile, last-mile complement to public transportation could indeed complement public transportation, but they could also compete and cannibalize public transportation. The credibility and awareness and thinking about automated and connected vehicles became more pronounced in discussions about what we are going to do. What does that mean for transit's future? How competitive will we be? This started to become very pervasive and we are seeing the consequence of that with a fair amount of concern in the industry for the future of public transportation. Everything from bus drivers worrying about job security for fear of automated vehicles to other folks more profoundly concerned about investment priorities.



FIGURE 10 Change is happening.

The map in Figure 11 shows ridership changes and percent changes across the country for the period from 2014 through 2017. You will notice that with few exceptions, big cities, small cities, east coast cities, west coast cities, northern, southern, with rail, without rail, etc., 36 of the 40 largest metro areas had declining ridership in that time period. Collectively, at the end of 2018 we're seeing about a 10% decline in ridership nationwide over that four-year period. Miami, for example, is one of the leaders of the decline, a more than 20% decline. These declines are not restricted to declining metropolitan areas. They are not restricted to low-density areas without the good transit. They are relatively broad-based. We are recognizing that there is uncertainty not just in our own business, but in others, as well.

We are starting to recognize that the uncertainty about just how close we are to automation is getting more real. I was intrigued a number of years ago at one of the early automated vehicle conferences that we had very credentialed experts on both sides of that issue. Some were predicting automation was a few years away, others were predicting that it was a few decades away. Again, these were equally credentialed, highly experienced folks. That still tends to exist to a certain extent, but with the passage of time, I think there's certainly at least some credibility to the folks that this wasn't quite as simple as we thought. In another example, Waymo, the purported leader in terms of technology deployment, is also not quite on pace with where they had hoped to be.

that into our political and technical processes as well. We are seeing some core value and priority changes, and we are seeing the diversity of those across geography. For example, I have sat in a number of meetings and conferences in California and Florida, and I can tell you that the priorities, concerns, and interests of the folks in the room are really different in those two geographic environments. The world is not at all uniform anymore.

Obviously the technology trends David Vautin discussed challenge our efforts to build public transportation infrastructure that we spend five years to plan and five to 10 years to implement for an amortization and useful life that's somewhere in the range of 25 to 50 years or more. Obviously when we've got that kind of time frame of investment thinking, it makes sense to be able to, or at least try to, predict the future of travel behavior and customer utilization.

And finally, we are challenged with the pace of change overriding the speed at which we can collect and analyze data. For example, the national household travel survey, one of our core data sources, has an eight-year cycle, and about a two- or three-year development and procurement cycle. We've got people wanting to know scooter and transportation network companies (TNC) penetration in a one- and a two-year cycle, perhaps more frequent than that. So we do have some challenges.

The traditional planning process is shown on the left side of [Figure 12](#). While everybody's got his or her own set and terminology for these, it is a basic problem solving sequence of activities, starting with goals and proceeding through implementation and monitoring. We can argue about the steps a little bit, but when we think about changes in planning, on the right side of [Figure 12](#), the zero-based budgeting approach might make sense.

Generic Planning Process	Types of Changes
<ul style="list-style-type: none"> ▪ Establish goals – Define problem ▪ Engage stakeholders ▪ Gather Information ▪ Generate alternatives ▪ Analyze/evaluate ▪ Decide ▪ Implement ▪ Monitor 	<ul style="list-style-type: none"> ▪ More goals, more political Safe, cheap, fast --> socially inclusive, equity, economic stimulus, etc. ▪ Substantial new stakeholders ▪ New modes, new measures, rapid changes ▪ New modes and business models, staging/phasing options, policy and pricing versus infrastructure and service ▪ Modeling behaviors and impacts? Measuring flexibility, resiliency, etc.? ▪ Who decides? Complex decision making process ▪ Different procurement strategies

FIGURE 12 Traditional planning and how it has been changing.

Perhaps a much more radical, pervasive review of planning might be appropriate, where we pay attention to each of these steps. The goal establishment step has gotten far more broad-based than the old days, when cheap, fast, and safe were the universal criteria. Today we worry about social inclusiveness, equity and economic impacts, health and related things. Obviously this makes the transportation planning process more complicated. We have got a lot of new stakeholders in this business.

We used to go to meetings and we would have urban planners and civil engineers in the room and we talked about planning. Now you can go to conferences and you will see lots of logistics people and computer people. You will see the new technology folks, and even finance people in the room, in pursuit of opportunities for private sector participation, not only in P3s but in mobility as a service and automated vehicles. This dramatically changes the set of

stakeholders, and I don't think we have thought that through in terms of how that plugs into our traditional planning processes and citizen participation activities. New modes, new measures and rapid changes are upon us. We have been fighting about definitions. Is a TNC ride-sourcing? Is it ride hailing? Is it e-hailing? What do we call it? What constitutes these services, and what are their components? So not only do we and consumers not know the terminology, but we certainly don't have good current data and information. And if we do, it is often out of date by the time we get it and we are no longer in a position to use it. If you look at the TNC business models and pricing structure, they have changed so dramatically that the ability to extrapolate the implications of some data that was collected in San Francisco four years ago to the Midwest today is virtually irrelevant because so much has changed over time.

Generating alternatives is similarly a challenging opportunity, because it includes more than just technologies. It's new modes. It's new business models. There are some pretty dramatic changes that are taking place.

Modeling behaviors and impacts are part of the challenge, as are things like measuring flexibility and resiliency and adaptability. I think the decision-making process also needs some reflection. We tend to think of some discrete process, but the reality is we have got such inclusive planning, and a multitude of partners, such that we have, in effect, got a multitude of decision makers, almost any of whom can veto a project. This makes it extremely difficult to wade through, communicate, educate, interface with and plan for all stakeholders.

Finally, on procurement, we are looking at pretty dramatically different potential procurement strategies for deploying and procuring solutions. These comments certainly all apply to public transit, but by no means just public transportation. A lot of these concerns are generic. While we certainly have not solved how to do this, with this top-to-bottom review of the planning process, I hope to at least tease you with some of the issues.

Figure 13 is a little deeper dive into the issue of travel behavior and the kind of foundational forecasting. If you look on the far left, you will see all of the technology changes that have been occurring and their features. If you look on the right, you will see the factors that we know influence travel behavior. Historically, almost all of our energies have been focused on the time and money costs.

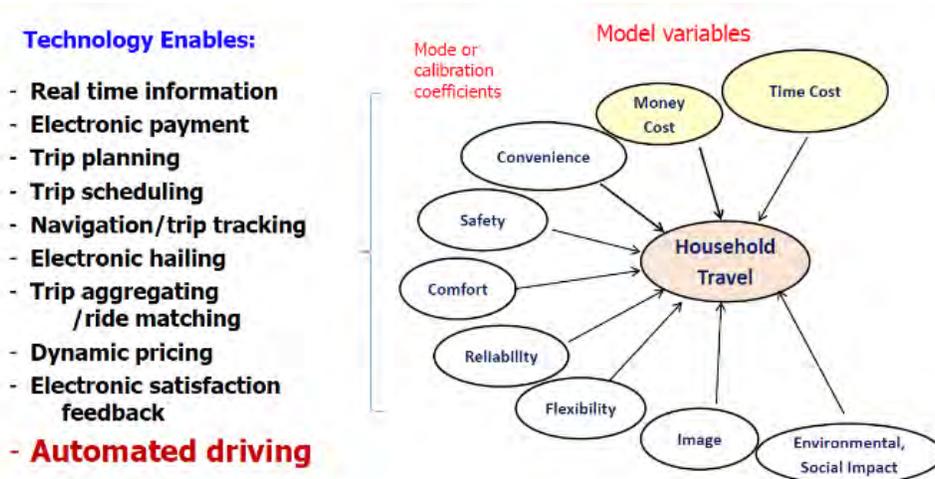


FIGURE 13 Travel behavior forecasting.

Those are the input variables that we tend to change in our forecasting. Almost everything else is captured in the mode specific constants. We don't necessarily measure and forecast those characteristics going forward for each of the modes and technologies. And yet a lot of the technology features that are changing are influencing those things like flexibility, reliability, and convenience. Those are the things that are being altered, across all of the modes, including public transportation, through the influence of technology. When you think of this behavior spilling into a traditional planning process, the right part of Figure 14 shows the old four-step process and the blue text indicates the changes that have been caused by emerging technologies. Without going into all the details, you can see that virtually every aspect of that set of decisions or implied sequential decisions has been influenced quite dramatically.

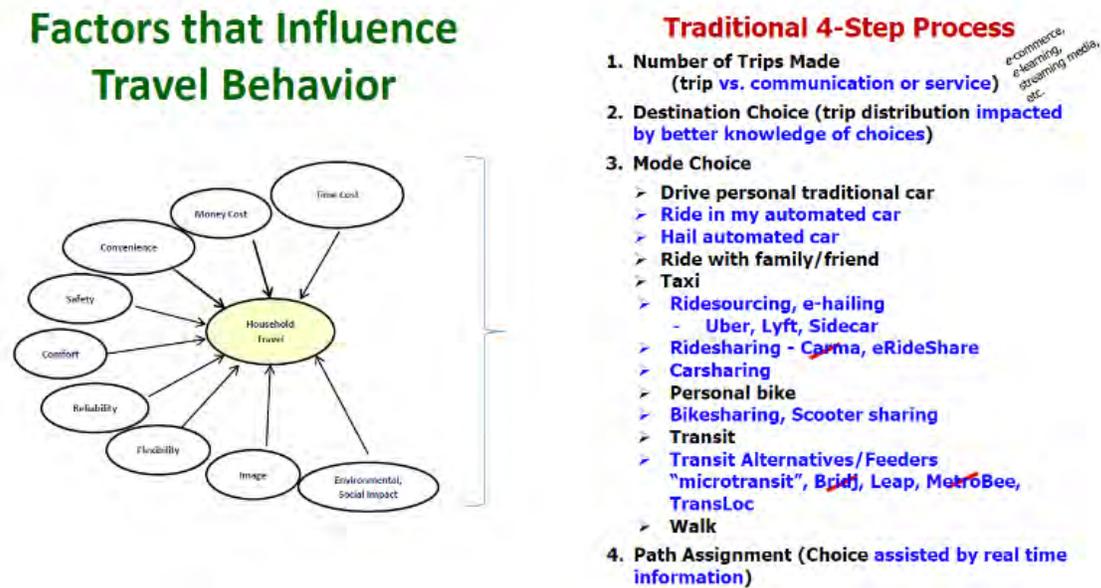


FIGURE 14 Technological influences on travel behavior and forecasting.

The range of choices is dramatically different than it was. One that I believe is fundamentally underestimated is the substitution of communication for travel. I don't think that we have a good handle on this is one. But throughout, there is obviously a big set of new options for mode choice and that is continuing to evolve and emerge. When you think of the fundamental roles in society, and components that influence transportation, historically individuals, with their ability to secure and own and operate a vehicle, have been the dominant decision makers and providers of transportation, but not independently, because of the role of government, employers, and community. Over time, that may well change if we move to a mobility-as-a-service world. All of a sudden, government and/or the private sector become centrally important. I don't think we know who, or which, or if both will play a more significant role, and the individual traveler may be relinquished to more of a consumer of services.

Figure 15 illustrates uncertainty and risks in decision making about transportation investments. We sometimes forget that really the high-risk decisions are the decisions that are associated with a high expenditure and things that are not reversible, things that have long-term impacts, or perhaps are original and rare situations where we don't have a data and knowledge base to extract. A lot of other things are relatively lower-risk decisions. They are low cost. They are reversible. And the impacts might be near term. When we think about the planning that we

do, to the extent that we're doing things that are low risk, it has implications in terms of planning and decision making. We can do experimentation. We can try something like pricing, and if it doesn't work, we can change it.

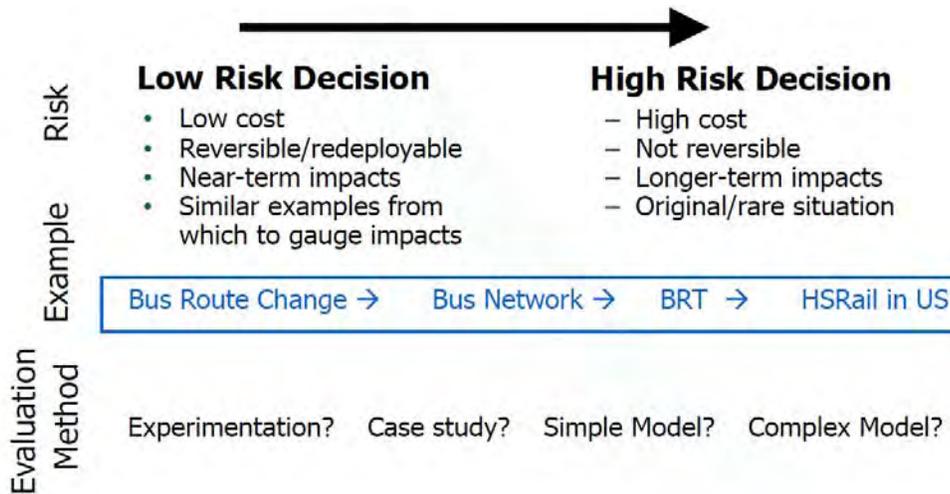


FIGURE 15 Risks and uncertainty in transportation investment decisions.

There is risk, of course, for public transportation. If we are building a capital project that will cost a couple of hundred million dollars a mile, it would be nice if we had a good handle on whether or not people would be there to use it towards the end of its useful life, which might be 40 years into the future. Those are the high-risk decisions. Those are the ones that historically we have built the planning and modeling business around, but perhaps as we move forward, the magnitude or the relative significance of those kinds of actions may be diminished in the context of the full set of things that we do to provide mobility. I was intrigued with David Vautin’s description of chaining together five very complex models. What do you get as a result?

Adaptability can help us cope with massive uncertainty about the future. Most of us live in homes and work in buildings where the fiber optic connections might be five, 10, 15, 20, or 30 years old, and they are still powering our cable sets and computer modems. But we have leveraged that technology dramatically differently in the past 15 and 20 years. We push a lot more stuff through that tube a lot faster, and we do a lot more with it on both ends in terms of processing it and using it, but the cable's the cable. I think to a certain extent transportation will evolve in a similar way. We are going to have traveled ways. This suggests by analogy that we might have dumb infrastructure and very smart operations and management.

The vehicles might be very smart. We might have a different products and commodities in them at different speeds and at different times of the day and the week. So we may end up with an infrastructure that is highly flexible and highly adaptable over time. Those travel corridors are going to be the critical asset in keeping and preserving the ability to operate across them.

There are some tactics in terms of how public transportation can respond as shown in Figure 16. The goal is not to preserve the institutions or the technologies that we know as public transportation today. The goal should be to ensure that the public purposes of public transportation continue to be met in the future. Now that might not sound good for folks getting paychecks and worried about the future of their agencies. It is sometimes hard to swallow that, but I think that it's an important thing to think about as we plan for the future.

1. **The goal is not to preserve the institutions or technologies that we know as public transportation today.**

The goal is to ensure that the public purposes public transportation serves continue to be met in the future.

2. **Leverage the emerging modes/services to complement transit**
3. **Leverage the emerging technologies within transit operations**
4. **Be at the table in preparing for and adapting to new technologies**
5. **Advocate for transit's goals/strengths**
6. **Acknowledge the uncertainty and adapt long-range planning to mitigate risk**

FIGURE 16 How should transit respond?

There are some other tactics and strategies the industry is thinking about and using as we move ahead. There are also varying degrees of progress and these are summarized in Figure 17. The industry is embracing innovation. Certainly, internal to public transportation, they are deploying technologies to improve customer convenience, safety, fare collection, vehicle information, trip planning, and service integration. Almost everybody is toying with some type of autonomous vehicle and interface with the first-mile, last-mile systems. We are learning from some of those experiences. More folks are looking at adaptability of projects. There is greater attention to the temporal patterns of project outcomes, the ability to capture benefits in the near term on projects, and perhaps fewer major greenfield capital projects for 50 years kind of planning than there might have been in the past. So I think there has been some progress there. We are looking quite comfortably at the concept of mobility manager. Nobody quite knows what that means yet, but certain transit agencies are anxious and willing to embrace a different role for them as service providers.

- Embracing innovation
- More consideration of options that can adapt
- Greater attention to existing and near term markets
- Embracing role of mobility services manager
- Limited evidence of updated predictive capabilities
- No sign of reconstituting governance structure
- Some shift of emphasis from moving people to place building

FIGURE 17 How is transit doing today?

We are not doing a particularly good job yet of updating our predictive capabilities. I don't think we have even captured the recent changes in ridership in terms of what that means for our forecasting ability. There is not much going on in terms of breaking down silos and

restructuring governance. There has also been some shift in emphasis from the concept of moving people to building places and offering choices. In some cases, that is a defensive strategy. We are struggling on ridership, so we are not just about ridership. In other cases, that reflects the fact that transit is more than just moving people. This was in the news recently when the driverless car killed the robot in the Consumer Electronics Show. So there is uncertainty. The driverless car didn't work, and the robot didn't know how to get off the road.

We've Been Here Before

Historical Perspectives on Addressing Rapid Change

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I am going to focus on the one rapid technological change that I know the most about, the history of the automobile. Most of my remarks today will be drawn from two books: my own, *Moving Violations: Automobiles, Experts, and Regulations in the United States*², and Peter Norton's *Fighting Traffic: The Dawn of the Motor Age in the American City*³. To keep things simple I am going to boil down my thoughts to three main points. At the end, I will give some consideration to what these three points have to offer thinking about present and future technological change.

Point 1. When we think about large-scale technological transformations, we often focus on the core technology itself, but just as important, and often more important, are the manifold interests that come together to reshape society around that technology and the interests of its promoters and advocates. In general, this might be a way of re-stating a truism in technology studies, which seeks to move away from ideas of technological determinism towards the social construction of technology. But in this case, I want to highlight that when we examine rapid change, what we actually see are people restructuring sociotechnical orders around new systems.

When thinking about the automobile, it is important to remember that the first cars were prohibitively expensive, objects that only the rich could afford, akin to today's Lamborghinis and Maseratis.



FIGURE 18 Depictions of “auto fiends” at the beginning of automobiles (postcard, circa 1905).

Localities in the United States began passing traffic and speed laws in about 1900, nearly a decade after the first automobiles were built in the country. These first laws often focused on wealthy young men known as auto fiends. Auto fiends, as depicted in Figure 18, used cars for speeding and other thrill-seeking behaviors.

But the thoroughgoing reconstruction of American society in the automobile's image began only later, in the 1910s and especially in the 1920s. This reconstruction was enabled by the mass automobility that accompanied Henry Ford's Model T, shown in Figure 19.



FIGURE 19 Model T Ford
 (Image File:1910Ford-T.jpg available
 on Wikimedia Commons,
 in Public Domain,
https://www.allaboutlean.com/firstlecture_hom_3/ford-model-t-1908/).

In Hoover's autobiography⁴ he wrote: "We sent an automobile from New York to San Francisco and another from San Francisco to New York. [Each driver was told] to follow the laws of his own state and municipality. One of them was arrested eighteen times, the other twenty-two times, for violation of laws which differed from their own. The two together met with sixteen actual accidents and avoided scores of potential ones only because of their driving skill."

Similarly, the use of electric traffic signals spread around the United States throughout the late 1910s and 1920s. Figure 21 is an image of one of the famed New York City traffic towers along Fifth Avenue in the early 1920s. Yet at that time there was no standard meaning for traffic lights. Different municipalities assigned different meanings and rules to each color.

The number of cars on the road grew quickly, often exponentially, throughout this period. And with that increased presence of cars, injuries and deaths mounted. The first American was killed in an auto accident in 1899. By 1920, more than 12,000 people were dying each year. By 1930, that number was more than 30,000. See Figure 20.

In 1924, Herbert Hoover, who was then the Secretary of Commerce, held the National Conference on Street and Highway Safety, the first national gathering to consider the issue of automobile safety. Hoover's conference tackled many different topics, but a central concern was the lack of standardization around the country. This lack of standardization was true for many things that we now take for granted. For instance, as localities around the nation created traffic laws, they often created inconsistent and conflicting rules such that drivers could not sort out right from wrong behaviors.

Year	Registered Vehicles	Deaths
1899	<8,000	1 st US Auto Death
1905	78,800	252
1915	2,490,000	6,600
1920	9,239,200	12,500
1925	20,068,500	21,900
1930	26,749,900	32,900

FIGURE 20 Early trend in U.S. motor vehicle deaths.

John Harris⁵, one of the men responsible for erecting traffic signals in New York City, said, “The signals flashed from the towers indicate the following: *Yellow*: Traffic moves on Fifth Avenue and all cross traffic from side streets stops . . . *Red*: All traffic on Fifth Avenue as well as the side streets stops . . . *Green*: Traffic from side streets proceeds.” Drivers could not assume what traffic lights meant when they drove into a different town.

Hoover was a believer in a form of governance that scholars later called Associationalism, which recognized the crucial role that interest groups played in organizing society. Associationalism focused on bringing those interests together, to work out differences, to form a plan, and often to create standards. In the 1924 National Conference on Street and Highway Safety, Hoover brought together an enormous variety of types of individuals and interests, including insurance executives, educators, railroad executives, mayors, psychologists, engineers, taxi company owners, police officers, lawyers, auto club presidents, the heads of the Bureau of Census and the Bureau of Railway Economics, self-declared safety experts, the president of the National Congress of Parents and Teachers, and on and on. We can debate how effective these efforts were, but the simple reality is that these people standardized many things that we now take for granted, including traffic rules, street signs that we still use today, and the colors of traffic signals. It took this huge variety of interests to remake society in the image of the automobile.

In *Fighting Traffic*, Peter Norton found that chambers of commerce played central roles in restructuring cities around automobiles by, for instance, creating permissive speed laws, widening roads, and creating places to park. One reason why the automobile won politically is that all kinds of businesses—not just auto manufacturers and dealers—saw hope in cars. We will come back to this in a moment.

Point 2. What you think about technological transformations has to do with who you are and where you sit in the world. There are always losers during such changes (including workers, competing industries, consumers, and local environments), and sometimes their interests are just pushed to the side. A major group of interests that lost out to automobiles were companies focused on horse transportation, including carriage makers and liveries, though some of these companies transitioned into the automobile business rather than dying off. What’s more, as Ann Greene⁶, Joel Tarr, Clay McShane⁷, and others have shown, horses were used in cities well into the 20th century. This raises the question, what is rapid change?



FIGURE 21 First traffic signal on New York's Fifth Avenue (1922), <http://stuffnobodycaresabout.com/2012/06/27/old-new-york-in-photos-19/>.

But the group that most clearly lost out to automobiles was pedestrians. As Norton describes in *Fighting Traffic*, streets were originally social spaces that included an intermixing of modes of transportation, most definitely including walkers. People met, socialized, and played in streets. Figure 22 is a picture of a New York City street in 1903. There are no cars visible, just walkers and horse drawn vehicles. Pedestrians lost out to cars most of all by becoming their victims. Most of the people killed in automobile accidents from 1900 through the 1920s were pedestrians.

But as Norton shows, in the 1920s, auto clubs, chambers of commerce, safety councils and other groups came together around the notion of jaywalking—that is, they redefined the street as a thoroughfare first and foremost for the passage of automobiles. The street was no longer a space in which pedestrians were free to move about as they chose.

Point 3. Technological transformations often involve the creation of new risks or the exacerbation of old ones, and it often takes quite a long time and much political wrangling to finally address them. In the United States, it took 30 years between the time the first automobile was constructed and Hoover held the first real safety conference. It was another 40 years—in 1966—when American legislators passed the first national automotive safety standards. It wasn't until 1970—or about 80 years after the first car was built in the United States—that the country passed meaningful automotive air pollution rules.

We can tell lots of other stories like this around transportation technologies, for instance, positive train control. The simple reality is that new technological systems introduce new risks, that some people shoulder more of those risks than others, and that it often takes a long time to find the political will to deal with risks in a meaningful way. Sometimes we never do.

To summarize:

1. When we think about large-scale technological transformations, we often focus on the core technology itself, but just as important—and often more important—are the manifold interests that come together to reshape society around the technology in ways that fit the preferences of its promoters and advocates.
2. What you think about technological transformations has to do with who you are and where you sit in the world. There are always losers during such changes, and sometimes their interests are just pushed to the side.
3. Technological transformations often involve the creation of new risks or the exacerbation of old ones, and it often takes quite a long time and political wrangling to finally address them.
4. I think these points are broadly applicable to lots of technological systems, including transportation systems. I think we see the same things, for instance, in Steven Usselman's



FIGURE 22 Fifth Avenue and 42nd Street, about 1903
(<http://stuffnobodycaresabout.com/2017/07/22/old-new-york-in-photos-78-fifth-avenue-42nd-street-1903/>).

great book, *Regulating Railroad Innovation: Business, Technology, and Politics in America, 1840–1920*⁸.

So, what can we do with this today? Well, the best news I think is that we have existing organizational infrastructure to deal with transformations and risks. For instance, we could tell the story of TRB or the Society of Automotive Engineers and how they fit into the narrative I laid out. We have existing professional groups that know how to address problems and create standards. That was not as true in 1910. Some people believe that we need to be more proactive and actively anticipate risks with new systems. In general, I am for that. However, I have a piece coming out on the so-called Fourth Industrial Revolution that emphasizes just how bad human beings are at predicting technological change.

That means we also have to be humble. It is very possible for us to focus on the wrong thing or create bad rules that cause more harm than good. And most of all, I believe that we need not focus solely on whatever technology is currently drawing our attention but rather to examine the bigger picture in these three points because it is through the social groups that surround a technology that we find the most promising solutions to the problems that concern us.

Closure

In this collection of four presentations we learned that it is important, though not necessarily easy, for individuals as well as organizations to be prepared for change. A key resource for addressing rapid change is leadership that is willing to recognize and address an uncertain future for transportation systems and service.

While traditional transportation planning and decision making have relied heavily on forecasts of future conditions and needs, in a world of rapid change, confidence in forecasts, particularly long-range forecasts that support capital planning, is waning. A more proactive approach is to collaborate with stakeholders to develop of a vision of what the future should be, and then to build toward that future.

A different strategy is to recognize the critical sources of uncertainty and to use these to map multiple scenarios that span the range of future possibilities. Rather than planning for a single future, the task becomes defining a trajectory for transportation that functions well under the range of possible futures. Preferred policies either stand up well to multiple futures—they are robust—or they are sufficiently flexible to adapt to the futures that actually occur. Forecasting models then become test beds for assessing how well proposed actions and policies perform across different futures, rather than as tools for predicting performance in a single future.

The evidence is strong and growing that rapid changes in technologies, service modalities, behaviors, and values are forcing changes in traditional services and outpacing our data and planning tools. These changes call for refocusing our efforts toward core values (e.g., mobility, accessibility, environment, equity) rather than on preserving established roles and organizations. Fast change warrants adaptation of planning and decision processes themselves to select for flexibility and adaptability, rather than predictability. This may lead us to pursue core infrastructure that may be used in multiple ways in the years ahead, placing less emphasis on new facilities, more on mobility as the essential service, and place-making as perhaps even more important than mobility.

From a historical perspective, we have experienced many major technological and social changes, and we can learn about preparation and adaptation from those examples. History shows that there will always be winners and losers, but society has a strong and consistent ability to respond, individually and institutionally, to change. To some degree we can anticipate and prepare for externally-driven changes, but in the end we should recognize that rapid change may be even more common, and perhaps less predictable, in the future, and nimbleness and adaptability may be the real keys to success.

Notes

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