SMART Mobility Overview, Key Metrics and Insights Sneak Peek Webinar – Text Version

Here is the text version of the webinar "SMART Mobility Overview, Key Metrics and Insights Sneak Peek," presented by the U.S. Department of Energy's Vehicle Technologies Office in 2023.

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Kevin Vita:
Presentation cover slide:
Hello, everyone. We'll go ahead and get started. Welcome to the first of the SMART Mobility webinar series brought to you by the national laboratories and the U.S. Department of Energy. My name is Kevin Veda with ITS America and I'll be helping facilitate today's webinar. Before we get started, I'd like to cover a few logistics for today's webinar. We are recording this webinar, and the recording along with the presentation slides will be available at a later date. All the attendees are muted by default, but we'd like you to stay engaged by using the Q&A pod for comments and questions. We plan to have a Q&A session at the end of the webinar so if you have any questions during today's presentations, we encourage you to enter them as they come to your mind at any time. We have several presentations today from across the U.S. Department of Energy. The first speaker will be Jake Ward, the acting program manager at the U.S. Department of Energy, followed by Aymeric Rousseau, director of the Vehicle and Mobility Systems Department at the Argonne National Laboratory. Following is Anna Spurlock, the deputy department head of the Sustainable Energy and Environmental System Department at the Lawrence Berkeley National Laboratory. And then we'll have Venu Garikapati, a team leader of transportation, modeling and metrics at the National Renewable Energy Laboratory. So that's all I have, and with that I will hand it over to our first presenter, Jake Ward, to start us off.

Jake Ward:
First slide of presentation [slide 3]:
Thank-you very much, Kevin, and good afternoon and good morning to you all, depending on your time zone. I'll offer a few quick introductory remarks on behalf of the U.S. Department of Energy's Energy Efficient Mobility Systems program before handing it off to our three representatives from our national labs today to talk about the great work they're doing supported by the EEMS program throughout our national lab system. So first I want to acknowledge that our SMART Mobility Consortium expands R&D, research and development, beyond component and vehicle design. It's looking at the intersection and the impact of connectivity, automation, multimodal travel, new modes of travel, and control across a wide range of metrics. You can see depicted on the lower part of your screen a comparison, on the left-hand side of where historical research and development has happened in the U.S. Department of Energy's Vehicle Technologies Office, or VTO. Looking at improving vehicles component by component, better powertrains, more electrification, better control, more lightweighting. The SMART Mobility portfolio expands that, our R&D, by applying a SMART Mobility system lens across components in a single vehicle setting, across small networks of components interacting, looking at smarter vehicles, interacting with smarter roads, controlling speed and powertrain using sensors and connectivity and automated vehicle technologies. Looking at those smart vehicles on smarter roads and how that affects traffic flow. And I'm scaling that up to simulation of vehicles, traffic, and energy impacts for entire urban areas, looking at how smarter travelers come into play as they make mobility choices for themselves and the goods that they have delivered to themselves and shipped to others.

Next slide [slide 4]:
So on our next slide we'll see emerging from that SMART Mobility ecosystem our metrics about convenience and efficiency critical to transportation decarbonization. So looking at factors like land use, combined with affordable, accessible, efficient, and reliable mode choices, are at the center of SMART Mobility. The figure you see here is a graphic extracted from the U.S. National Blueprint for Transportation Decarbonization. This is a joint strategy across four federal agencies and is hot off the presses, released just last month at the National Academy's Transportation Research Board annual meeting. The U.S. Department of Energy worked with the Environmental Protection Agency, the U.S. Department of Transportation, and the Department of Housing and Urban Development to write and release that national blueprint. I encourage any of you have who haven't visited that document yet to do so. But you can see several complementary strategies shown in the figure extracted from that document. This intersection of convenience, efficiency, and clean transportation. So for convenience, by improving community design and land use planning we can increase convenience towards decarbonization. As a complement to that, efficiency, increasing options to travel more efficiently. And clean fuels transitioning to zero emission vehicles and fuels. And you can see highlighted by the green boxes the SMART Mobility Consortium supports research and has produced in sites across all of these, especially in convenience and efficiency, including some overlap with clean energy technologies. So with that I'll pass it to Aymeric Rousseau to start to talk from a lab perspective about the great work in this SMART Mobility context. Aymeric?

Aymeric Rousseau [slide 5]:
Thank-you, Jake. This SMART Mobility Consortium has already a very long history, right. We started almost 10 years ago looking at beyond vehicles as Jake mentioned. Historically the U.S. DOE Vehicle Technologies Office has been focusing on components and vehicles, but with the arrival of connectivity automation, new modes, we quickly realized that we need to go beyond that. So starting in 2015 for about a year all the national labs came together and, you know, put the foundation of the SMART Consortium together. What question should be answered? What should the capabilities be? What are the needs? Where are the gaps? Out of this came the SMART 1.0 in 2016. And what we really did here is develop tools and processes to quantify the impact of new technologies and policies. Out of the SMART 1.0 in 2020 came five Capstone reports, which you can access through the QR code here. And this really became the foundation of what we will be discussing today, the result of SMART 2.0. Over the last two and a half years, what we've done is, you know, focus on faster or better or more scenarios, and doing that by reaching out and engaging with more stakeholders. So today what we are starting on doing is focus on actionable insights that arise from the discussion with stakeholders.

Next slide [slide 6]:
Well, Jake mentioned the SMART Mobility Consortium has been focusing on addressing, right, stakeholders' questions. So the six national labs have been engaging with more than 50 stakeholders, as you can see on the left here, including public and private organizations, *[inaudible]* and multinational organizations, planning agencies, startup providers. What we've done is engaged with regular discussions, you know, once a month, every two months, to make sure we understand the questions, and based on these define scenarios and discuss results. But at the same time we've also been actively working with more than 25 R&D partners through subcontract, data sharing agreements. But those are very active engagements. It's a lot of these organizations are universities who've helped us perform R&D, but we've also been working with NPOs, local DOTs and mobility companies. So as you can see the insight we'll be discussing through this series of seven webinars, the first one being today, have been developed with inputs and in close collaboration with a wide range of companies and research organizations.

Next slide [slide 7]:
So how did we answer those questions? Well, we did it in two ways. First by focusing on individual vehicles, but also focusing on transportation systems. But individual vehicle level, we've developed automatic driving vehicle and portrait controls that says enough energy was our primary focus. And because energy savings are highly dependent on individual scenarios, we've run tens of thousands of scenario accumulations. But at the same time, we've also demonstrated and validated our control with experiments, both on dynamometer and on track. Now we all know that full grown experiments with automated vehicles are complex, extensive, and time consuming. So what we've done is we've been running vehicle in the loop test where some of the vehicle and surrounding environment are real while others are virtual. For example, we tested a single vehicle on a track within a mixed reality that includes emulate traffic operating vehicles as well as traffic lights. Now why some of the Excel workflow focus on safety have been deployed by OEMs, right. They're trying to put products on the roads. Our energy focused *[inaudible]* approach is unique in many ways and we will be discussing this. Now at the same time, at the transportation system level we've been relying on agent-based transportation system models, also called ABMs. ABMs model how people run goods, move over 24-hour periods. They use the power of individual representation of decision-making and actions. What it means is that people, train, companies, vehicles, roads, traffic lights, stop signs and so on are all agents. And the models allow us to understand how technologies and policies affect the agent interactions and the up city decisions. For SMART 2.0 we have primarily been focusing on future scenarios and technologies that are just starting to be deployed in *[inaudible]* or that have not been deployed yet, medium and longer term.

Next slide [slide 8]:
Now, there are many technologies and policies affecting the transportation system in many ways. How will people move in the future, and how will this affect *[inaudible]*? How will goods be delivered in the future, and how will this affect where depots are located? Lots of different questions, right. But while energy is important, as Jake mentioned there are many more metrics that need to be simultaneously considered, such as mobility, emission and greenhouse gases, *[inaudible]*, equity, accessibility. But why is that important? Well, some technologies could increase mobility but at the expense of energy and equity. So we need to understand that. How did we consider all those metrics at once? We've been using a multi-fidelity end-to-end modeling workflow, right, initially developing SMART 1.0 but significantly expanded over the last two and a half years, where ABM transportation system model has been linked with other models. Now including land use, the economic consumption, first life cycle, and even electric grid. So while the following webinars will be focused on specific area, for example looking at community model travel with transit, ride hailing, macro mobility, connected automatic vehicle electrification, freight, today we will share with you some of the sneak peek of those insights focusing on some of those metrics.

Next slide [slide 9]:
So the SMART Mobility is funded by the U.S. Department of Energy Vehicle Technologies Office. So let's start with energy and focus on individual vehicles. When we are looking at the impact of any technology, we should first understand the current status. So the question is, are current automatic driving systems saving fuel? And when we are looking at data, more than one million kilometer, 44,000 rates, more than 150 vehicles, the answer appears to be no. Why is that? Well, current technology are focused, rightfully so, first and foremost on safety. And this is to be expected. Technology is new; safety is key. Now what we've demonstrated is that this does not have to be the case, right. When we're focusing on energy improvements, we're focusing on minimizing acceleration/deceleration events, stopping events, and what we've demonstrated – again in simulation and in hardware – is that we can achieve up to 30

percent energy saving through single phase and timing when we know the next traffic lights. Now we can have an additional 10 percent if we know the state of multiple traffic lights. We can also save up to nine percent with vehicle-to-vehicle *[inaudible]*. Now those energy savings highly depend on scenarios, right, which is why we simulate thousands of them. That key is very reproducible, right. Someone is crossing the street, the vehicle needs to stop. But when we're looking at energy, that depends on numerous factors: how many vehicles, what type of vehicles, conventional, EVS, small, big, what type of road, what type of connectivity, what type of automation. So while the energy saving will change, the message here is that significant energy consumption improvements at the vehicle level are possible.

Next slide [slide 10]:
The *[inaudible]* savings holds at the transportation system and really it depends. Let's consider a level 4 automatic driving deployment across Atlanta and look this time at the greenhouse gas matrix. So what do we see? We see that level 4 could increase greenhouse gases by two percent, even with cooperative driving, right, and we all know that this is the best case scenario because adaptive cruise control most likely would be worse. So why does that happen? Well, by making travel easier, the driver can press the button and the car drives itself in the highway, so some people will then travel longer distances. So besides having better energy consumption for each vehicle on a per distance basis, the increased vehicle mass travel leads to increased greenhouse gases overall especially along highway in that particular use case.

Next slide [slide 11]:
Now, if we know this might happen, can we do something about it, right? And the answer is yes, again looking at greenhouse gases here. Well-designed policies can counteract negative impacts of technologies. So in the figure what we are looking is that in addition to higher events *[inaudible]* travels level 4 automatic driving leads to increased population density in the suburbs. That's the dark green. And decreased population density downtown. That's in the red here. What happens? We make it easier for people to drive; they move away from their workplace into the suburbs, increasing VMT. So what can we do to mitigate that? So in this particular example, we applied increased cost of carbon emissions. That means conventional vehicle operating cost increase. And we combine that with electric vehicle subsidies. So that specific policy reduces greenhouse gases by up to 25 percent when we consider the land use change. Again, it is important here to understand the potential of each technology at the vehicle level but also at the system level, and when necessary consider appropriate policies to mitigate unintended consequences. In this case here we can get best of both worlds.

Next slide [slide 12]:
Now we look at greenhouse gases, but equity is also a very critical and important metric. The U.S. government through Justice40 initiatives has sent a clear signal that disadvantaged communities that are marginalized, underserved, and overburdened by pollution be the focus of new technology deployments. Let's look at an example of equity metric. What would be the impact of road pricing across the Chicago metro area? So in that case, yeah, right, different road pricing policy, we look at the delay based road pricing, and our simulations show that we can increase network speeds by 11 percent. That is significant, right. But this will be done at the expense of a significant cost increase *[inaudible]* of communities. As you can see in the figure, you know, the figure here shows the changing costs based on the daily income, where the total daily cost includes the actual cost of vehicle travel plus the cost of travel time, plus congestion pricing. On the west side and south side here of Chicago, right, road pricing increases up to 7.5 percent of people’s daily income. On the north side, which is an Asian community, very little to no increase. So how do we keep the benefits of some of these policies but make sure we

address equity at the same time? Well, one option is to reinvest revenues and reduce travel cost burden.

Next slide [slide 13]:
This is the example related to our cost metric. So one way to address the equity issue we just saw, right, would be to reinvest in transit. Again, looking at the Chicago metropolitan area, we consider different options to increase transit ridership, from increased frequencies to the rapid transit lane and the associated resulting costs. So the idea here is that, how can we maximize ridership with minimum change in operational cost? So our results show that it would be more beneficial to increase frequency in the suburbs. This will be *[inaudible]* base. but adding new routes and *[inaudible]* downtown in Chicago will be most beneficial. So why is that? Well, downtown *[inaudible]* frequency is already quite high, but you know, because of the have been spoke current system, new routes would have more impacts. Now, in the suburbs, and it has lower frequency, so increasing those without the highest impact. And again here, right, with all these scenarios have been designed very in close collaboration with our stakeholder. So for example here all the *[inaudible]* designs came from CTA.

Next slide [slide 14]:
Another way to increase transit ridership is by making it easier for people to access transits. So this is our example of the mobility metric. Subsidized first mile, last mile can increase transit by 12 percent. And this happens by increasing catchment area up to 1.8 marks. Now, the primary impact here is on people going from the suburbs to the Chicago business district downtown. And the overall impact is significant, right. This policy has a potential to remove about a hundred thousand auto-based commuter trains. These are cars coming from the suburbs to downtown where a lot of the congestion is here. So primary and secondary impacts are significant. So far we've been discussing metrics related to energy, mobility, emission and greenhouse gases, cost equity. Venu will now present the first of the two accessibility metrics that have been developed and used in the SMART Mobility consumption.

Venu Garikapati:
Next slide [slide 15]:
Thanks, Aymeric. As Aymeric just mentioned I'm going to introduce an accessibility metric that works both with vehicle-level inputs but primarily quantifies the efficiency of a transportation system to connect people to goods, services, and opportunities. Before I dive into the details on the metric, let's do a small thought exercise to estimate the quality of mobility you are experiencing and the location you're currently in. If you can bear with me for just a couple of seconds, close your eyes and think about how easily you can get to the closest grocery store from the location that you are in by car. Can you get there in 10 minutes? How about 20? Now in the same context think about the ease of accessing the same grocery store by walking or biking. Can you even get there by transit? That feeling of connectedness that you're getting is what the MEP metric tries to quantify while taking the externalities of any given mode, primarily the time, energy, and cost externalities into account and reframe this as the quality of mobility. If we can quantify the quality of mobility of a location such information can help assess if a region is progressing towards providing sustainable and affordable mobility to all of its citizens. Such information can also be utilized to quantify the impact of competing infrastructural Investments such as adding a freeway lane mile versus putting the same amount of money into trans-data structure. To compute the efficiency, quality of mobility for any location, we start with building an isochron, what you're seeing on the screen to the right here. The orange-colored boundary is basically showing how far you can get in 40 minutes from the blue location than by biking. This isochron measure quantifies the ease of traversing a network. Once we have the isochron, we overlay it on top of a land use layer to quantify what you can get to. We quantify these isochrons for four modes, namely walk,

bike, transit, and car. And when intersecting with the language layer, we quantify access to six different types of activities, namely jobs, restaurants, grocery stores, recreational facilities, schools and hospitals. The resulting opportunities measure we get is then weighted by the time, energy, and cost efficiency of each of the modes you see on the screen there. For example, drive is a time-efficient mode, so it gets upgraded in that dimension, but it is not the most energy or the cost-efficient mode so it gets dumped down with inverse dimensions. Next slide.

Next slide [slide 16]:
When all of the calculation happens, the resulting score is displayed to the end user as a single number. Let's take the example of the highlighted pixel here, having a score of 79. Of that 79, 5, 11, 15, and 48 units are contributed by walk, transit, bike, and car modes. This means that the majority of the quality of mobility in that specific location is being availed by car, followed by bike, and so on. Even for the quantification of car, 16 of the units per the car measurement are coming from access to jobs, 12 from access to restaurants, etc. For any given location, the one number that the user sees comes from a combination of four modes and six activity types, namely 24 different layers that are weighted by the time, energy, and cost-efficiency measures. These layers can be filled open to identify things such as food deserts or healthcare deserts or transit deserts, information that the decision-makers can use to remedy any access and efficiencies in and around the city. Next slide.

Next slide [slide 17]:
Now let's see how we are using the metric to quantify the quality of mobility in various contexts. This particular slide is showing how we are using the metric in the SMART Mobility research to quantify how low- versus high-income cohorts have different qualities of mobility in the Chicago metro region. The same exercise is also conducted for vehicle ownership by taking no vehicle cohorts and contrasting them across the vehicle-replete cohorts, meaning households who have as many or more vehicles as there are drivers in the household. There are two, three takeaways from this slide. One is that the low-income cohorts have a quality of mobility that staff need, 1.5 times lower than that of the high-income cohort. But when we look at vehicle ownership, that has an outsized impact on the overall time, energy, and cost-efficient accessibility that these denominated cohort in a way, almost 10 times lower than the vehicle-replete cohort. Another dimension here is the bi-directional plot is showing on the X-axis what is the score of a given location. So if you see a darker blue-colored shade, it means that the MEP score, the quality of mobility, is greater than that location. In the Y-axis direction, what we are showing is what proportion of people live in that location. Ideally you want the MEP scores for any cohort to be high in the locations where they are residing. When you look at the top MEPs, the lower is the high-income cohorts, you see much sparser JCS parser MEP for low-income cohorts, meaning that the quality of mobility for these cohorts is not as high in the locations they reside in. The same when you look at the no-vehicle cohort. You almost see a swath of land towards the top left corner where there is pretty decent quality of mobility, but the no-vehicle cohort actually does not live there. The story is completely different from living through the big cohort to enjoy a good quality of mobility across various parts of the city. Next slide.

Next slide [slide 18]:
In research conducted outside the SMART Mobility Consortium, we've used this metric to compare e-bikes against the drive mode. We all know that e-bikes are slower than the drive mode, but e-bikes have greater time – or sorry, greater energy and cost efficiencies, when compared to drive mode. So we took some representative data from a mini-pilot conducted by the Colorado Energy Office, where e-bikes were given to low-income essential workers in the Denver metro region. And we're derived speed measures for e-bikes and computed energy and cost measures and then developed the quality of

mobility scores separately for drive and e-bike, and then for each location, each square kilometer pixel in the Denver metro region, completed the ratio of e-bike score to drive score. The resulting map to the extreme right side here will show how e-bikes are faring in comparison to the drive mode in various locations within the Denver metro region. We found that about nine percent of Denver's population lives in places where e-bikes can provide at least half of the access that driving can provide. Furthermore, there are some locations in the central part of the city where e-bikes provide a tough competition to the drive mode. Information like this can both be utilized to encourage e-bike adoption at a more wider scale but can also be a decision-making tool for the cities to show that e-bikes can provide time, energy, and cost-efficient mobility. Next slide.

Next slide [slide 19]:
The metric is also being leveraged outside of the DOE research consortium. For example, on this slide I am showing some excerpts from an article published by the American Council for Energy Efficient economy, who have analyzed MEP scores for about 100 U.S. cities and computed what they've termed as an efficient mode membration. This is the score for the quality of mobility available using walk, bike, and transit modes divided by the total MEP score for a location. What they found in their analysis is that the cities that score high in their transportation chapter, meaning that the cities that have sustainable Transportation policies in place, also have high efficient movement ratios. So this goes to show if a city invests in sustainable transportation policies, that comes back as good quality of mobility in non-driving modes. Next slide.

Next slide [slide 20]:
I will conclude this section with a summary slide that shows how this metric is being utilized both within and outside the DOE research consortium to quantify the quality of mobility and help in decision making for transportation planning and sustainable transportation future forecasts. I will now hand it over to Anna to conclude with *[inaudible].*

Anna Spurlock:
Next slide [slide 21]:
Great; thanks so much, Venu. So I'm going to talk about a different accessibility metric that we're working with in the SMART Mobility work, particularly in the context of this beam core model, which is one of the agent-based – integrated agent-based transportation system models that you'll hear about in future webinars more. What in contrast to the MEP, which is a location-based metric, the INEXUS suite of metrics are person-trip-level accessibility metrics. So it's sort of a complementary lens that lets you kind of explore the concept of accessibility from a couple different angles. So what the INEXUS suite of metrics consist of is three different metrics. One is referred to as the potential INEXUS, which captures the kind of aggregated full utility of the modal options available to the individual for the trip that they're taking. And then the realized INEXUS is then the utility associated with the mode actually chosen for the trip taken. And the social INEXUS adds the social cost of carbon associated with the trip taken to the realized INEXUS. So it sort of adds the social externality cost associated with the environmental externality. All of these metrics are derived from the mode choice model used in the simulation models. So it's a weighted metric capturing the kind of weights associated with the mode characteristics for the agents. So time, wait time, travel time, etc., cost, and other modal attributes. And we're going to give a little example of some of the ways that this metric can be used and thought about using just a little case study where we took the ride hail, the price of ride hail, and varied it in a sensitivity from zero to eight hundred percent of the baseline. And the reason we're using this particular case as an example is just because ride hail is sort of a flexible option that's sort of on demand; if it's made more or less affordable

or accessible it's a way of sort of painting the picture of how metrics like this can say some something about both environmental factors as well as equity. Next slide.

Next slide [slide 22]:
So firstly, just looking at a slide looking at the potential INEXUS, this just shows how a metric like this can say something about the degree of inequity in the baseline transportation system. So we all know that there are a lot of kind of systemic inequities associated with a lot of things in our society, transportation being one of them. And this wraps up a number of factors including, you know, residence location where people tend to live, the availability of modes in those locations, budget constraints of the households, vehicle ownership of the households, and things like that. So this just shows, for example, that the potential INEXUS in this case, in the baseline for the highest 10 percent of income households, is 16 percent higher than for the lowest 10 percent of households. And this is from our San Francisco Bay Area simulation. Next slide.

Next slide [slide 23]:
Another thing that these metrics can look at is then the degree of impact across different facets of the agents or kind of subpopulations in the in the simulated population, with respect to scenarios that are analyzed. So what you're seeing in this figure is an income ranking of the households in the simulated population on the bottom, and on the top it's the change in the potential INEXUS relative to the baseline for the different levels of pricing that we looked at. So for the – when ride hail is free is that top orange line. And so what you see is that the, you know, having ride hail become free is something that benefited everybody but it disproportionately benefited the lowest income subsection of the population. And so it improved their potential INEXUS for the lowest 10 percent of the income ranking by 44 percent compared to 13 percent for the highest income for example. Next slide.

Next slide [slide 24]:
So another thing that's interesting about these metrics is it lets you understand different types of benefits for different types of interventions or scenarios that you might be looking at. So this is just an example here, when we think about two types of benefits. So the – in this case what you're looking at is a series of graphs that show the change in both the realized and the potential INEXUS for agents that did not change their behavior as a result of changing the pricing of ride hail. So the people in this top group up here are people that took ride hail both in the baseline and in whatever the pricing scenario that we're looking at. So these are people who as ride hail becomes cheaper don't change their behavior. They're still taking ride hail, and they just get to pay less for it. So they get what we can refer to as sort of like a free ride or direct benefit of the improved affordability of the mode. But then what you also see with the potential INEXUS is you see that for people, for example, who took transit, both in the baseline and in the scenario that as ride hail becomes more affordable they actually have an increase in their potential INEXUS because the backup mode does become more kind of appealing or affordable to them. And so that is a bit of a way of thinking about the indirect benefit associated with one of one's options becoming more accessible, even if you don't take advantage of it in a particular situation. And it's a way of thinking about resilience at a household level to disruptions or unexpected events. Next slide.

Next slide [slide 25]:
Finally, when we think about the environmental factor that's captured in the social INEXUS, what I'm showing here is mainly focused on just the component of that, that's the social cost of carbon, to kind of drill down and make a point here. But basically as we saw from the preceding slides, we know that when ride hail became cheaper, it disproportionately benefited lower-income people. And in particular what we see in this is that a lot of that is driven by more of those subsections of the population using ride hail

more than they were before. So for the highest-income people, you see that the rate at which ride hail is being used, which you see on the left graph, the vertical axis doesn't change that much for the highest-income group. But for the lowest-income group you have a significant increase in the rate of using ride hail, which is associated with this 44 percent Improvement in their potential INEXUS as well, which we saw before. However, there's a little bit of a trade-off that comes with that. So what we see is that, you know, when ride hail is relatively more expensive all the way up until the baseline, which is shown where the bracket is on the second figure, basically the higher-income people basically produce more of the social cost of carbon for the kind of travel that they do, relative to lower-income people. But when as ride hail becomes more affordable, you see this increase in the rate of using ride hail for lower-income people, and so their carbon emissions share becomes more and more like it resembles more and more the higher-income group, for example. And so what you see from this is that – and this is true in a lot of different kind of policy domains – that improving both equity and environmental outcomes simultaneously can be difficult. Sometimes there are trade-offs. But having metrics like this that let you drill down into both mechanisms for the different impacts on these different dimensions, and being able to explore potential pathways to either simultaneously improve both and have win-win outcomes or at least understand the nature of the trade-offs, can be really useful when thinking about policy and design.

Next slide [slide 26]:
So that is what I have to say on the INEXUS metrics, just to kind of give a little bit of a sense of ways that we can think about equity and other outcomes in this way. Before we get into the Q&A, and we do know, you know, there's a number of questions that have come in and we will get to those, I just want to highlight the rest of the webinars that are coming in this series. This one that you have been enjoying, I hope, today is our first webinar in the SMART Mobility series, where we're giving this kind of overview of the concept of the program, the approaches used, and the metrics that we are kind of focusing on here. But we have a lot more to come including in March and April some content on multimodal travel topics, where we're going to be, for example, talking more about our work using these integrated agent-based modeling systems and other projects, talking about ride hail transit and micro mobility. In May and June, we'll have a couple of webinars on connected and automated vehicles from a couple different perspectives, both at sort of more of a vehicle and powertrain and control context, but also system-level impacts. And then in July, we'll have one focused on freight, and in August one on electrification. So we hope that you can come and join us on all of those.

So with that, I think we can turn to answering some of the questions that have popped up. And given that I am talking, I'm going to take the liberty of answering the first question, which came at the beginning, which was: How does Justice40 fit into these metrics? So I'm just going to chime in and say the, you know, the kind of context for Justice40 is one that all of the federal agencies are grappling with, that have kind of covered programs under that umbrella. And the specific metrics that those agencies identify for compliance with that program is going to kind of vary by program, vary by agency. But I would say that, you know, all of the ways that we measure outcomes with our methodologies are things that play in that space, and that potentially align with some of the types of metrics that might formally be used for Justice40. And while a lot of our work tends to be a little bit more like regionally focused, or kind of smaller in scale rather than like a national coverage kind of type of modeling program, there are ways that one can gain insights pertaining to Justice40 from our kinds of metrics. So for example, just taking the MEP or the INEXUS, you know, there's nothing that limits us from being able to aggregate that to looking at differences between Justice40 disadvantaged communities and not, for example, and sort of painting the picture of outcomes with that frame. So I will then turn it to … let's see, what do we have next? I think the next couple are you, Aymeric.

Aymeric Rousseau:
Yeah, so thanks, Anna, and Kevin, please feel free to guide us on the questions. So if we're going in order the next question is, how can emission increase *[inaudible]* when automated vehicle will be electric? Well, so a lot of the automated vehicles right now, the vehicle we do have of some level of automation are not pure electric vehicles. So that is, I'd say, a big assumption. And what we want to look at is understand the impacts of technology is under some uncertain conditions. One of the scenarios is that a lot of the automation and connectivity will be deployed in electric vehicle, but again this vehicle will take time to penetrate the markets and be in the stock. Right now, a lot of these functionalities are in conventional vehicles, in hybrids, in plug-in hybrids. So again, that is one of the scenarios that we can think about but definitely not the only one that that is feasible in the future. … And like, yeah, Kevin, I don't know if you want to go back and forth between questions, or we go in order.

Kevin Vita:
Sure. How about we just go to the next one? Wouldn't EV subsidies counteract the land use effects of carbon pricing? With an EV cheap to drive regardless of any carbon price, could that just enable more sprawl?

Aymeric Rousseau:
Yeah, so that that is actually a very good question, right. We have been looking, again, different scenarios. Are we looking at 20 percent of details, 30 percent, 50 percent. And you know, obviously the more EVs penetrate the market, the impact of policies such as carbon pricing would be very different, right. But is that an additional incentive that will push people to buy EVs faster? So EVs are cheap to drive under certain conditions, but even now, right, there still needs to be some – there's still some work left on battery cost and battery life, not just for passenger cars but for major media and heavy duty. So again, you know, very similar to the previous question is, in a perfect world where we have a very fast EV penetration, some of the policies such as carbon pricing are the different impacts, and that is one of the things we're looking at. Again, today we really wanted to give you a sneak peek, right. That's the keyword, sneak peek. When looking at the impacts of technologies and policies, how they interact with each other, how they affect different metrics from energy to emission to equity. And a lot more will come in the following webinars, where we will be able to show you how, for example, different EV market penetration will impact the value of different policies.

Kevin Vita:
Excellent. I know Venu has requested answering this next question: Can we fork an instance of the MEP to create new models and functions, for example, to build custom tools for city planners? How do we customize the MEP?

Venu Garikapati:
All right, great question. I want to take this question live because I thought it's beyond like an online response where a mode essentially doesn't mean a bad thing. We are currently in version 2.0 of the MEP metric code, which is being benchmarked with version 1.4. A couple of things we were able to do with version 2 is increase greater amount of flexibility in model combinations you can use to quantify an isochron. For example, if you walk to transit, and then take the transit, and then actually use an *[inaudible]* to reach your end destination, the Web 2.0 calculation process can quantify an isochron for that model combination. So that version is being finalized and will be available for widespread consumption soon. But instead of forking, one way we envision users interfacing with the metric is we are making them a calculation of cloud-based service, so you should be able to configure a run for a city

that you'd like to quantify the metric per, using the modes that you'd like to include in the quantification, and launch a run and get the results in no more than a few minutes. So for the lack of a better answer, immediately there is an opportunity to use existing data that we've computed using the MEP version 1 code through a web visualization tool. If you're interested in that, just send me a note. In the near future, we should be able to provide access to a cloud-based calculation for method you can use to customize city specific round.

Kevin Vita:
So for this next one, how is INEXUS beam different from Polaris? can you elaborate more on when you recommend INEXUS versus other?

Anna Spurlock:
So the work we did with INEXUS was work done integrated into the beam framework, but there's no reason why a similar type of metric can't be developed or implemented in the Polaris framework. It was just that we were doing it specifically within the beam framework. In the context of what we did, like I mentioned, it's derived from the mode choice model used in the simulation. So it would be specific to whatever mode choice model would be used in whichever simulation you might Implement a similar kind of framework in. In terms of the question of whether, like, when you would use INEXUS compared to other options, I mean, I really think it's a matter of what types of questions are relevant to the policy or kind of like decision context. So I feel like one of the things that's a strength of this concept of a person-trip-level metric is it really lets you look at very flexibly sort of distributional differences in outcomes across different kind of slice-and-dice sections of the population relatively flexibly. So that's something that that can be taken into account. In addition, though, it just sort of answers a different question than a location-based metric. For example, where that's sort of saying from a specific location, you know, how does your set of modal options reflect in terms of your ability to access the, you know, surrounding opportunities, whereas the person-trip-level metric sort of abstracts away from the, like, set of opportunities and it says OK, people have a particular plan, a particular trip they're trying to accomplish, and it tells you something about how much easier or less easy it is for them to accomplish that specific trip given the opportunities they have – or given the mode options they have in their immediate surround. So I think it's just a different framework. It's just a different lens to think about a kind of complementary ways of thinking about accessibility. And I would say in most cases, you know, it would be useful to use both.

Kevin Vita:
So Aymeric is requesting to answer carbon pricing and/or road pricing: What might be the best strategy while accounting for the equity implications to reduce greenhouse gas emissions in the long term?

Aymeric Rousseau:
Yeah, so and that's a really good question, and say, like, you know, first of all it will depend on the city, right. So we now have seven operating models, but that's Chicago, Austin, Atlanta, Detroit, Dallas, Greenville, and six more coming up. So what it means is that, you know, when we run the same policies across different cities, different policies and technologies have different impact. Now, you know, carbon pricing is usually bad for these synchronous gases, road pricing, congestion pricing is usually best of reducing congestion. Again, depending on your city, depending on the type of your vehicle fleets, you know, that what that one maybe more influential than the other depending on your targets. So there is not, you know, unfortunately one size fits all ways, say, for any city this is the way to go. You know, if you really want to decrease greenhouse gases and emissions, electrification is obviously key, but you also need to make sure that we're looking at ability and VMT. So combination of those in in some cases.

So we know we're looking at different policy combined with different technologies on different metropolitan areas. You know, coming up soon, we are running 256 individual combinations of technologies and policies across multiple areas. Why? Because one size fits all unfortunately for us is not the way to go.

Venu Garikapati:
Can I chime in real quick, too, Aymeric, excellent answer. So Carlos, a very important question and a very important one for many cities in terms of where things are going. If we benchmark this code, this course, any of the metrics that you've seen, vehicle, miles traveled, overall mobility, or accessibility, to a baseline year and do this for different modes, the city should be able to track using the same framework if the scores are moving in the right direction. If congestion is getting worse without any change in the overall fleet of the city, that should get reflected in the time, energy, and cost-efficient access method that we've shown today. If both of these change together, that is also important for the city to see what the net impact of change in fleet versus Improvement or lack of improvement in both our condition is. So some other answer here is identifying what a city would like to use as a benchmark; you know, using the past couple of years as a benchmark obviously wouldn't be the most ideal case with ever in travel patterns we've seen. But to see if there is a near-term future where the city can say this is an average travel pattern for our city, and use that as a VMT benchmark or an overall line suspension market track tracking cycle.

Kevin Vita:
So we have about five, six minutes left. Let's see if we can get another one here. Anna is requesting to answer: How did you estimate the social cost of carbon estimates for INEXUS?

Anna Spurlock:
Yeah, so basically because it's all integrated into this integrated agent-based modeling framework of beam core, that whole modeling framework includes the ability to estimate the energy expenditure or sort of energy use of all of the vehicles that are operating in the system. And so we can allocate that energy use to the specific agents for the trip that they take based on the vehicle they're taking or mode they're taking, and then translate that to carbon emissions, and then apply the social cost of carbon multiplier on that. So it comes from the fact that we've developed all of the ability to look at all of the energy from this integrated modeling system.

Kevin Vita:
OK. What tool do you use to monitor, evaluate, and report on the progress of the metrics discussed in this webinar? If a metric is not trending in the way we want, where could we find Improvement plans or action plans to make things happen differently?

Aymeric Rousseau:
Yeah, so that's a good question, right. So one, I'd say, if I come back to at the end of SMART 1.0, right. After three years we were able to simulate quality functions. Right now we are simulating hundreds. So with that the great thing is that it allows us to quantify and understand the relationship between technologies and policies a lot better, right. We can actually have introduced one technology at a time or one policy at a time. So that means that, you know, we need new tools and new ways to understand how to monitor and evaluate all these metrics. And by the way, right when we're looking at equity, there's a lot of other metrics that we haven't even discussed and noticed, right. Is actually a big issue for like freight, for example, that the application can address. So the fact that we are running all the different combinations between technologies and policies is actually a way to understand the

relationship between all of them so that when one goes one way, you know, let's say improves mobility but not energy or equity, we can actually see how potential policies could mitigate that, and up to what extent they would do that. So it is – you're very much a work in progress. But you know, to a great extent our processes are fully automated. We can now run the technology and the policies across a very large number of MEP free scenarios, you know, probably about more than a dozen by this summer. And we can combine, you know, do all the combinatory evaluation of all of them, which allows us to understand this relationship. So again a lot more to come in the upcoming webinars. This is going to be one of our primary focus, is show you how each technology and policies individually but also collectively impact the different metrics. So stay tuned.

Kevin Vita:
We have enough time for one more question here, and it'll be: Were you able to break out the data based on gender and age in regards to the use of various mobility options?

Aymeric Rousseau:
This is the whole point of ABN, right. Every agent, every person, is an individual. So we know gender, age, income. We know what type of vehicle, how many vehicles, if you have kids, what type of work. So you know, this is really the foundation of the ABM, where by almost de facto, right, we know what the equity impact is because we model every single individual characteristic within every single household. So and you know, Anna, you want to like – that's the foundation for the INEXUS, right?

Anna Spurlock:
Yeah, I would second that. And I would say, I mean, I do think that there are trade-offs. It's sort of the degree of detail that's in the mode choice model can kind of dictate the degree to which you want to really drill down in interpreting something like gender equity, for example. But when it comes – so you know, for example our mode choice model that we're using right now doesn't include things like, you know, aversion to public transit because of safety concerns or something. But so you know, there are certain things not explicitly kind of captured in there that we know matter on the question of kind of gender preferences. But when it comes to, broadly speaking, certain factors that we do capture, that based on the estimation of the mode choice model do reflect the preference structure of individuals, we can say something about the trade-offs that these different subpopulations face when they're thinking about their options.

Venu Garikapati:
And if there is something called tripling, I'll triple that and say the whole point of this detailed analysis that we're trying to do is to slice and dice the mobility preferences of various types of cohorts, not just in the current day but how would these cohorts react to the introduction of new ones or new technologies in the future. So through the information in the SMART Community Consortium and the matrix that you've seen today, we should be able to quantify switching times.

Anna Spurlock:
And I will say, so we didn't get to all the questions, but speaking for myself if there was something that you had a question about pertaining to what I spoke about, do feel free to email me, and I will be happy to get back to you on that.

Venu Garikapati:
Likewise.

Kevin Vita:
Well, it is three o'clock and I'm sorry to end it, but thank-you, Aymeric, thank-you, Jake, thank-you, Anna, and thank-you, Venu, for your presentations today. And we look forward to everyone joining us next month on March 14 for the next in the SMART webinar series. Thank-you all again, and the recording and the slides will be available very soon, for those that were asking. Thank-you again, and hope everyone enjoys the rest of your day.