Decision Process for Dynamic Operation of Part-Time Shoulder Use
April 23, 2019

Niloo Parvinashtiani (NOCoE): Hello everyone and welcome to today's webinar: Decision Process for Dynamic Operations of Part-Time Shoulder Use. My name is Niloo Parvinashtiani and I will help facilitate today's webinar. So, today's webinar is hosted by the National Operations Center of Excellence, or NOCoE, and if you don't know already, at NOCoE we support the transportation system management and operations by offering resources. So NOCoE's Knowledge Center website is linked on the bottom left side of the screen if you are curious to see that. Through that link you'll be able to see NOCoE case studies, TSMO publications, and previous webinars.

So, with that, let me cover a few logistics for today's webinar. For this webinar, and every webinar, we will be recording the webinar, and the recording, along with the presentation slides will be available through the On-Demand Learning section of our website. All of the attendees' phones are on listen-only mode by default, but we would like you to stay engaged by using the chat pods for any comments or questions throughout the webinar. We have a question and answer session at the end of the webinar, so if you have any questions we encourage you to put that in the chat pod at any time during the webinar as they come to your mind. The questions will be read out loud at the end by the moderators and our presenters will answer each question.

So, with that, I would like to hand it over to David Hale, our moderator for today's webinar, to start us off. David?

David Hale (Leidos): Alright, thank you very much, Niloo, and good afternoon everyone. This is David Hale with Leidos. I'm the project manager for the ongoing FHWA project on dynamic part-time shoulder use. I'll be moderating today's webinar that addresses both static and dynamic shoulder use. Currently on screen we have a slide that summarizes the upcoming agenda; over the next hour we'll have four consecutive technical presentations from our subject matter experts, each one lasting 15 to 20 minutes, with questions deferred until the end of the webinar. Then, in the final 15 to 20 minutes of the webinar, I'll read off as many of your pertinent questions as possible for the speakers to answer.

Our first presenter today will be Greg Jones from FHWA. Greg Jones has been with the Federal Highway Administration since 1984; he's been a member of the FHWA Resource Center since 1999. In 2006, Mr. Jones also accepted a dual appointment as a member of the FHWA Headquarters Office of Operations, and Mr. Jones provides national technical support in areas such as ATDM, managed lanes, freeway management, and hurricane evacuation. Greg is now going to kick off our webinar by providing his overview of part-time shoulder use. In this presentation, he will discuss the advantages, use cases, real-world implementations, and available resources for PTSU.

Greg Jones (FHWA): Alright, thank you David. So, as David mentioned we're going to have an overview of use in the United States.

So, dynamic shoulder use is one of the strategies of active traffic management and active traffic management is used to manage congested roadway conditions utilizing advancements in computing and communication capabilities to monitor real-time conditions and implement performance-based solutions.

So what exactly is part-time shoulder use? Well it goes by various names. We've tried to standardize in Federal Highways the use of part-time shoulder use, but it's also been known as shoulder running, hard shoulder running, which that's the European terminology that you'll commonly hear, temporary shoulder use, and part-time shoulder use, but really all those have the same meaning. It's the use of either left or right shoulders of an existing roadway for travel during certain hours of the day. This is a transportation system management and operation strategy for addressing congestion and reliability issues, and one of the keys to this is, while it utilizes additional capacity at the times it is needed, it preserves the shoulder as a safety refuge for most hours of the day.

So when should you consider part-time shoulder use? Well, if you have capacity issues, one of the first things that you don't normally look at is to widen and add additional capacity, but as we see in the country many times today, there's various constraints to adding additional capacity. Right of way, environment budgets, in all of those combined generally tends to make it very difficult. So using the strategy of increasing freeway capacity by adding the travel lane within the existing roadway footprint, you're able to maybe reduce the width of some of the existing lanes, or allow traffic to utilize the shoulder as a travel lane for a part of the day, so that's, you know, usually can be done within the existing template of the roadway that you have, or maybe just some very minor widening to add width on the shoulders. The additional lane could be utilized by general purpose usage of all vehicles, or you could specify the types of vehicles that would utilize it during those select times of the day when the congestion warrants that.

So why part-time shoulder use? So again, it adds capacity only when needed and it keeps the shoulder intact as a safety refuge for most hours of the day. One of the most common questions we'll get is, well, why wouldn't you just open the shoulder 24/7? And really, when you look into it, it's a safety mix that really makes part-time shoulder use stand out. At the times that you have congestion, by adding additional capacity you can reduce the accident probability of congestion-related incidents by adding that capacity. And those types of incidents are the rear-end types of incidents that happened in stop-and-go traffic. But when you look at that same roadway, and you're outside of those congested conditions, really, you're better off having that safety refuge when your vehicles are traveling at higher speeds, and that's the best safety solution for that type of application. Things like run-off-the-road, striking fixed objects-types of accidents, those that can be in a higher category of fatalities, you're much better off having the safety shoulder in place than you would be having an additional lane when the capacity is not really needed. So, also by utilizing part-time shoulders, you're really moving forward with what we call performance-based practical design, where you look at trade-offs and trying to do what's physically and financially possible within the parameters that you have available to you by using engineering analysis to determine which of those trade-offs makes for a better solution. So, a decision to use part-time shoulders could possibly defer a major or costly widening project for a number of years, and we'll talk about a few of those applications later on as we go through some of the examples.

So, part-time shoulder use falls into three different categories: the first category we refer to is static shoulder use, and static shoulder is open to general passenger vehicles during predetermined hours of operation. That's based upon historic data that indicates when the congested conditions would appear on that facility. The next category is dynamic shoulder use, once again, is open to general-purpose use, but it's based upon real-time conditions and the need for additional capacity. So you may have differing times that it would be open based upon different conditions that would be in that area that would lead to that. And then finally, you have bus-on-shoulders, and bus-on-shoulders is only open to buses and it's usually driven by operational parameters, mostly speed-based, that allows trained bus drivers to utilize the operational parameters to make a decision when they can use the shoulder as kind of a bypass cue for transit buses. Now, shoulder use is typically implemented on freeways, but there are a few limited arterial applications around the country as well.

So, where's it been used? This map shows 17 States that have utilized part-time shoulders and one of the three categories. The original applications were mostly bus-on-shoulders and a few static applications, but in the last 5 years we've seen a number of dynamic applications that have also came online, and that seems to be the trend that we're seeing these days.

So, as you start thinking about whether or not this is a good application for your area, here's some early screening questions. From a preliminary engineering standpoint, you could look at it and say well, is the shoulder with adequate? And if not, is it adequate to have a travel lane? And if not, could it easily be widened? And maybe it's just a small widening that's required, 2-4 feet. Are the vertical clearances over that shoulder adequate to have travel using that shoulder? Is the shoulder pavement structural capacity adequate to have traffic riding upon that shoulder, and is the drainage sufficient, or is that going to have to be modified if you use it for a travel lane? Another safety aspect that we promote with part-time shoulders is to have emergency turn-outs or refuge areas, which are small areas outside of the shoulder that you can actually build and give occasional locations where people can stop outside of the shoulder to be up into a safety refuge area. And from a standpoint of operational efficiency, do you have a long enough segment available to be able to utilize the shoulder, or is there a specific bottleneck that you're trying to relieve, and are you able to accomplish that within the area that you have available to use? From operational concepts, one of the main considerations is should the right or left shoulder be used? The right shoulder has some very different operational characteristics than the left shoulder, in particular, the right shoulder you have a lot more merge and weaving considerations at interchanges, the left shoulder you have to look at how efficient it is to be able to get on to the facility and move over to that shoulder, and then be able to exit from that shoulder as well. You would look at what vehicles is the shoulder going to be open to and how that factors into, again, the riders left usage. Is the shoulder going to be open to more than just busses, and if so, is it going to have a static operation or dynamic operation? The next is to look at the geometric constraints that you may have on the facility and whether or not there's a reason to mitigate that through having lower speed limits either on the shoulder leg or throughout the entire corridor at the time when the shoulder lane is in operation. And finally, are you going to use part-time shoulders in conjunction with other operational strategies? And probably the one operational strategy that's the best fit with part-time shoulders is ramp metering, particularly if you have right-side part-time shoulders, being able to moderate the entrance vehicles from the wraps through that metering tends to work real well.

So here are some examples from around the country. This is a bus-on-shoulder operation in the Minneapolis-St. Paul area. It's on the right side, and these are metropolitan busses in the Minneapolis-St. Paul area. Sometimes they don't travel that long of a distance so being on the right side makes it easier for them to get on and get off.

There is also, in the Minneapolis-St. Paul area, there's about 300 miles of bus-on-shoulders. It is by far the most prevalent application around the country and they have kind of become a leader in developing standards and operational practices for bus-on-shoulders. This particular picture here is a left shoulder bus-on-shoulder operation in the suburban Chicago area, and the vehicles that are using this are mostly express bus service coming from the outer suburbs of the Chicago area, and they're making much longer trips so the left shoulder actually works very well for them because they get into that shoulder lane and utilize it for long distance travel.

This is a static shoulder use on US-2 in the State of Washington, just north of Seattle, and this particular facility, if you can see the sign on the right, says that it's open Monday through Friday, 3:00 to 7:00. And again, that's based upon historic conditions of when they have traffic congestion on this facility. Since it's been open, that's shown a tremendous improvement in the in the congested conditions on US-2 and the adjacent freeway on I-5.

This is a static use shoulder operation on I-66 in northern Virginia. This picture dates back to probably about 8 years ago when it was operating in a static mode. In this particular instance, the lane was being used from 5:30 to 11:00 a.m. in the morning, Monday through Friday, but also they had developed a bit of a hybrid application and which they were using overhead lane control signals to indicate when the shoulder lane was open or closed, and in certain special conditions, they would actually operate it longer than the hours that are shown on the static signs.

In 2015, they moved to dynamic operation, and with that they put gantries over the roadways, they had light control signals, the red X and the green arrow were showing when the part-time shoulder lane was in use, and so while they still maintain using it during the core hours that they had established, they had a lot more frequent usage of the lane outside of those hours. In particular on the weekends, they found that there was times on the weekends where utilizing this lane was very important to them as well. Now, as I had mentioned, you know, sometimes the use of a part-time shoulder lanes can offset the widening or at least delay it for a number of years. That happens to be the case here on I-66 in northern Virginia. They finally have gotten to the point where they now have the ability to add the additional lane that they need, so this particular part-time shoulder use is being taken out of service and there's actually a construction project to add to the ultimate design to add additional widening to that particular project.

This is a unique project on I-70 in Colorado. It's a tolled shoulder lane, and we're actually going to have a presentation later in in this webinar on that, so I won't go into any of the details, I'll let Mr. Harelson from Colorado speak to that, but he'll get into the background and solution.

Another dynamic shoulder use is on I-35 W in Minneapolis. They actually widened I-35 W, but the last 3 miles into downtown Minneapolis, there were some environmental and right-of-way constraints on that last 3 miles, and they weren't able to build the additional lane for that last 3 miles, so their solution was to use the shoulder in a part-time basis for the continuation of this high-occupancy toll lane for that last 3 miles.

So in 2016, a couple years ago, Federal Highways produced a guidance document: *The Use of Freeway Shoulders for Travel.* Again, it's a guidance document, it wasn't a standard directive or policy. But this document is consistent with a number of initiatives within Federal Highways; performance-based practical design, transportation systems management and operations, and active traffic management.

And so the objectives of this guide are to provide guidance on planning, designing, implementing, and operating part-time shoulder use, and it provides guidance on factors that need to be considered in deciding through a performance-based practical design process, if part-time shoulder use is a viable alternative determining the impacts and feasibility of implementing the part-time shoulder use, and then designing and operating part-time shoulder use to optimize both safety and traffic flow and lane utilization.

What this guidance does not address - it does not address part-time use of shoulders in work zones during construction, it doesn't look at full-time permanent conversion of a shoulder into travel lane, and it didn't get into bicycle and pedestrian applications because it was focused on freeway applications. About 98 percent of the document looks at freeways, there are a couple areas where it does have very limited arterial-specific information provided.

So the target audience was State DOTs, tolling agencies, and Metropolitan Planning Organizations and regional operating agencies that would be looking at operating these types of facilities.

So again, you can see the URL at the bottom of the page where you can find this, or you can just Google *Use of Freeway Shoulders for Travel*. As we mentioned we'll have questions at the end so I'll be certainly happy to answer any questions, and you have my contact information there too if something comes to mind afterwards. So thank you.

David Hale (Leidos): Alright, thanks a lot Greg, appreciate that. Just as a reminder to everyone, we're going to do our Q&A session towards the end of the webinar, scheduled for 3:10 to 3:30 so please hold on to those questions, but also if you've got them, please go ahead and type them into the chat pod, which in this platform appears to be called a question / discussion pod. So go ahead and put your questions in there and we'll go ahead and collect them and be ready to discuss them towards the end.

Ok, now we're going to introduce our second technical speaker who, is a Pete Jenior from Kittelson & Associates. Pete Junior is a senior engineer with Kittelson & Associates Incorporated in Baltimore. Pete is the principal investigator for FHWA’s project on decision parameters for dynamic part-time shoulder use, and was the lead author for FHWA’s 2016 Part-Time Shoulder Used Guide. Pete will be presenting on FHWA’s newest part-time shoulder use research; this research investigated decision parameters to help agencies decide when to open and close the shoulder on freeways with dynamic part-time shoulder use.

Pete Jenior (Kittelson & Associates): Alright, thank you, David.

So the objectives of the current research that FHWA is in the process of wrapping up on decision processes for dynamic part-time shoulder use, really two objectives to that project, one is, you know, just spreading information on dynamic part-time shoulder use, and I think more importantly preparing this decision parameters document with factors for what agencies should consider before they open and close the shoulder, how optimal times for opening and closing a shoulder can be determined, and really how the how the dynamic aspect of dynamic part-time shoulder use works. You'll be able to read that later this year, but today we'll give you a sneak preview of some of the things we're going to cover in that report.

And a big picture: we want to keep traffic on the freeway moving. That's the intent behind part-time shoulder use. This is a speed flow curve; when you're up where the green circle is that represents a free-flow condition, when you're down where the red circle is, that's when you've had breakdown in traffic flow: you're in a congested condition, and really before we transition from green to red, that's ideally when a part-time shoulder would be opened into traffic.

What are some of the considerations that go into opening and closing a shoulder? Either on a day-in day-out basis, or on a one-time basis, in other words, when an agency decides whether they're going to do this or not on a given freeway. There are, of course, engineering considerations, what's going to be the traffic performance now and in the future, what type of speeds what we see at different hours of the day, what types of volume, etc. There are environmental considerations; would this trigger the need for a noise wall, some kind of air quality mitigation or not. Facility characteristics; are you simply transferring a bottleneck a few miles down a freeway when you open a shoulder or are you bridging a bottleneck and effectively taking it off of the system carrying traffic through to a place where it drops off the freeway or more lanes add to the freeway or something to that effect. What are typical daily traffic patterns? Are we looking at congestion most of the day, a few hours of the day, multiple times in the day? And there's a, well we can't quantify safety yet, there's nothing in the *Highway Safety Manual* for part-time shoulder use, there are no very robust crash modification factors. We have some understanding that if you're in a low-volume scenario and there's no congestion when your shoulder is closed, it would probably be less safe to have that shoulder open, receive no benefit from it, but have traffic closer to the edge of pavement or barrier or whatever may be beside your road. So there's an inherent, at some point there's, you know, we can assume there's a safety benefit, and limited data shows us there's a safety benefit, to closing a shoulder when it's not providing an operational advantage. Just as important as the engineering considerations are the policy considerations the public needs to, and stakeholders need to, accept. Part-time shoulder use facilities have a need for maintenance, incidents, emergency response, law enforcement needs a way to conduct enforcement and also understand what the status of the shoulder is. All these things contribute to, you know, decisions as to whether or not to open and close the shoulder.

Thinking about the operational side of things, this would generally be the process that would go through opening a shoulder. Over on the left side, we have really a reactive process where breakdown and traffic flow congestion is observed, the shoulder is opened and then it dissipates that congestion. And that usually is possible, the amount of capacity added from opening the shoulder, it's not incremental and this is not like a ramp meter where you're maybe adding, you know, a few percentage points of capacity to your freeway. You're adding nearly, you know, potentially up to an entire lane’s worth of capacity, so it is possible to dissipate congestion. However, it's always desirable to be predictive and prevent congestion from occurring in the first place. That's really what we see on the right side here, where we can have some real-time information coming in and some historical knowledge of typical daily traffic profile at a facility. Open the shoulder proactively and prevent congestion from occurring in the first place. And of course, this assumes that it's physically possible to open the shoulder and you don't have maintenance taking place or a disabled vehicle or anything like that.

The degree to which shoulder use is dynamic is captured here by this idea of levels of part-time shoulder use. This is something that was developed in the current FHWA research. Level 0 would be no shoulder use, Level 0-Level 1 would be static part-time shoulder use that opens at 6 hours of the day, and Levels 2, 3, and 4 are varying levels of dynamic-ism. Level 2, for example, would maintain core hours. Let's say you open the shoulder every day on an inbound facility between 7 a.m. and 9 a.m., but there are sometimes scheduled deviations of that in advance, so you may open on Sunday at 11 a.m. as you know there's a football game that afternoon and there's going to be heavy traffic going to the stadium, but that's something you would know well in advance. You could communicate that to all stakeholders. There wouldn't be any real-time decision-making, you would know on this particular day, I'm going to open outside of my normal hours. If an agency is new to shoulder use that may be a good way to, or new to at least dynamic shoulder use, that may be a good way to ease in and get everyone comfortable with the dynamic aspect of the facility. Level 3 would represent unscheduled variation traffic. It looks like for whatever reason traffic is building earlier than normal today at 6:30 in the morning, we're going to open the shoulder now instead of waiting until 7:00 a.m. Everybody seems to be on the road early today, we want to avoid that congestion based on the real-time data coming in. At Level 4 would be fully dynamic where there are no core hours and shoulders open purely in response to observed traffic conditions.

These types of decisions are typically captured in the Concept of Operations document. That lays out sort of how shoulder use works, what all the stakeholders need to do, what happens in the TMC, what signs get displayed, what sign indications are displayed out on the road, what happens with other active traffic management treatments, if there are variable speed limits or ramp meters or queue warnings, how they relate or don't relate to shoulder use, and then what everything looks like from a signing perspective. These decisions are typically captured in the Concept of Operations document.

When we talk about opening and closing the shoulder from an engineering perspective, really it boils down to volume and speed, and most agencies that have dynamic shoulder use use a mix of volume thresholds and speed thresholds to understand what traffic conditions are currently, what they're going to be in the future, and we, you know, that certainly is the most effective approach to use both. In general, speed volume thresholds, or you know, perhaps volume of focused thresholds, if you're using both, are more predictive. If volume per lane, let's just say, increases from 1,000 vehicles per lane to 1,100 vehicles per lane, the speed may not give you any indication of that volume has increased, that's still a free flow condition, but if you're monitoring volume from a sensor you can start to see it creeping up, start to understand, you know, in this amount of time in the future, I may be nearing capacity, I may want to start opening my shoulder now. It's a little more complex to use, but it's more beneficial from a predictive standpoint. Speed thresholds are more reactive. Generally you start to observe the onset of congestion and then open the shoulder. Whether or not you have enough time to do that before breakdown occurs really gets into, you know, the specifics of traffic flow on your facility: how fast the volume is increasing, how long it takes you to open the shoulder, what, you know, and what activities like that may need to take place. If you have a volume threshold, you kind of always want to look at speed as a backup. It, you know, perhaps for whatever reason you have drivers that are, you know, it's a holiday and you have drivers that aren't familiar with the facility are driving less efficiently, more cautiously. You may have a higher percentage of heavy vehicles, you may have sun glare, you may have anything that affects roadway capacity and your volume threshold just didn't work for you on that given day, you're observing congestion and a decrease in speed related to that reason. Well, in that case, you know, it certainly makes sense to be observing that speed and open the shoulder.

Here's an example of what these thresholds may play out as. And I'm going to put a pointer on the screen here if I have one. If we look here, this is a volume profile on a given day, and the volume is increasing, and suddenly the volume reaches a threshold for opening. This is volume per lane. So, an opening process begins, that's referred to as the sweep time that may be an agency inspecting their shoulder with cameras, it could also be a physical sweep where a vehicle drives the shoulder to verify it's clear of traffic that happens. The shoulder opens, the volume per lane decreases because there's now one more lane effectively, the peak passes without hitting the capacity up here, the shoulder closes, volume per lane jumps, and continues on. We also see speed here, there could have, you know, there was also an opportunity for a speed threshold to be reached, in this case, volume was reached first. But this this is the type of decision-making that would occur.

There are, the report on this decision process for part-time shoulders is going to offer five techniques for developing thresholds, and I'll walk through each one of these techniques individually.

Thresholds can be used for planning projects prior to, you know, their implementation, or they can be used on a real-time basis when you have shoulder use in place to decide when to open and close the shoulder at given times day to day.

A lot of this information relates to real, observing data from an existing facility as opposed to modeling, simulation, that type of thing. And so sensors, having sensors located in the correct areas and getting data from them is really critical. There's been a lot of movement in recent years towards increased use of vehicle probe data, we'll look at some applications of that later, what we're looking at here is, and in the ground, is an in-roadway sensor, or it could be on a pole, but it's something that's in the field, the agency maintains it. You can see here are three different volume profiles from three different sensors. These two, the sensors were placed beyond the place in a location where a bottleneck metered demand. Here is a sensor that's placed where it's picking up the full demand as opposed to just the volume that's able to pass through, it's not metered, so that the placement of sensors is a key factor for an agency to consider when they're using their field based data.

This is what you, this is the type of thing that can be done with sensor data. This is a freeway in California, it's not a freeway with part-time shoulder use, it's just an example of a congested urban freeway. These points represent observations over an entire year, 15 minute bins of time, and the black points here represent a time period that occurred 15 minutes before the breakdown of traffic flow on the freeway. And this graph here, this is using a statistical technique called the product limit method. This looks at the probability that 15 minutes after one of these points occurs, there is going to be breakdown on the freeway, and you would want to begin an opening process for a shoulder. The point here is with good field data, with good sensors, and a little bit of statistical work you can predict what volume would have at 5 percent, at 10 percent, at 20 percent, or 1 percent increase, you know, probability for example that your traffic flow is going to break down and you can make decisions based on that appropriately, and start to understand what hours of the day would I want to set as my core hours for a dynamic part-time shoulder use facility, or, what, you know, do I need to have a dynamic part-time shoulder use facility? Is that worth the cost or should I stick with 6 hours of operation with a static facility if my congestion is predictable and sort of always occurring at the same time?

Moving on to one of the other methods these were some experiments that we did using a tool called FREEVAL. FREEVAL implements the *Highway Capacity Manual* freeway facilities method and it looks at different components of a freeway in relation to each other and in time series. For example, if you analyze a basic segment and there's an on-ramp downstream, and there's cue spill back from that ramp freeway junction, FREEVAL is smart enough to understand that these facilities are next to each other, to apply the effects of that queue going back, and to even do it over time series looking at different 5-minute bins of time, you know, hour after hour in analysis. And with FREEVAL we modeled an on-ramp that was creating a bottleneck on a freeway and looked at different volume and geometric scenarios, over 4,000 of them to be exact. One of the key findings of this experiment was that the rate of volume increase is really critical in making decisions on opening or closing the shoulder. If it takes time to open a shoulder, this is not something that's done instantaneous, it usually takes about 15 or 20 minutes from what most agencies have shared with us, and in order, and so that means that if you want to open the shoulder in advance of congestion you need to understand how soon you'll get there, and the rate of volume increase is really key. If your volume is rapidly increased, if your volume increases slowly, you have quite a bit of time. If your volume increases rapidly, you may only have a few minutes before you get from a starting volume to a volume over capacity, and understanding how your volume will increase in the future is a function of both what you've observed on that day and what you know is a typical profile on a facility. So, this ability to look in, to understand what's going to happen in the future and look there is really critical for knowing when to open a shoulder, and this speaks to some of those findings.

The reason that there's a certain need to be conservative, to not open the shoulder every single time, you think your volume may be increasing as rapidly as it could be, because you'll get a lot of false positives, then you might open, you know, an hour before you need to open, or perhaps this is a weekend scenario, you might open on a Saturday when you really didn't need to open on that Saturday at all, the volume never increased that high. So to avoid false positives there's a lot of value to understanding volume increases.

Overall findings from both the FREEVAL experiments and some microsimulation experiments, as noted earlier, speed focused thresholds are easier to implement, but they don't provide as much advanced warning and they don't really help you look at how volume is incrementally approaching capacity. Somewhere in the range of 45 miles per hour, you nearly always get breakdown, you nearly always get on the other side of that speed flow curve where you're in a congested condition, you know, that could be a little lower, that could be a little higher, but, you know, at that point that's about what you'd always want to start to think about, opening the shoulder. Volume focused thresholds are a little more challenging to implement and they do have more variability site-to-site, but they also help get ahead of congestion, so to speak.

So what's best for a given facility? It's best to start looking at a full year or more of data, at the probability-type graph we had earlier, what are the odds there's a given volume, you're going to exceed capacity 15 minutes into the future in a certain time of day. There's value in both speed-focused and volume-focused thresholds, it is best to have both and really, all this analysis can really help you understand what level of shoulder use is right for your facility. There's no need to go dynamic, particularly not right away, if your congestion is predictable. If you're focused on, you know, the opposite extreme would be a recreational-type facility where your peaks are maybe going to be on weekends or different seasons, and there's going to be a great deal of variation. There'd be limited benefit to static shoulder use in those scenarios.

We'll take a look at one case study of dynamic part-time shoulder use. And this is from I-66 in Virginia, eastbound, this is heading into Washington, D.C., so the a.m. is the peak here. What's interesting about this facility, as Greg described earlier, is that it was converted from 6 hours of operation to variable hours of operation.

And, we can see here, this was when our facility had fixed hours of operation, and the shoulder was never opened in the afternoon. It was opened in the morning, and that wasn't really enough to prevent congestion, that's why the facility is now being widened as Greg mentioned, but in the afternoon shoulder was never opened. Dynamic shoulder use was implemented, there's now an option to open the shoulder in the afternoon if needed, and most of our afternoon off-peak congestion has gone away. Weekends are also included in here, so part of this red that you see here was Saturday or Sunday congestion when the shoulder was never opened, and now that has gone away as well. So here's one example of the benefits of not just having shoulder use but having dynamic shoulder use that can respond the traffic conditions.

We'll cover all these items in our project reports, and with that, I'll turn it back to David.

David Hale (Leidos): Alright, thanks a lot, Pete. Again, just as a reminder, we're going to be doing Q & A towards the end of the webinar, so please type your questions into the chat pod. Appreciate that.

Our next speaker is Stephanie Palmer from Michigan DOT. Stephanie Palmer is currently the region traffic safety and operations engineer for the Michigan Department of Transportation University Region. Over the past 20 years, Stephanie has worked in both the private and public sector, specializing in traffic engineering and operations. Recently, she served as ITS project manager for Michigan's first active traffic management system. This system includes a dynamic lane and shoulder use, a queue warning system, and a variable speed advisory system. Stephanie will be presenting on the dynamic shoulder operation for the US-23 flex route in Ann Arbor, Michigan, focusing on the operational procedures and thresholds for the activation of the dynamic shoulder. She will also discuss some of the early performance measures since the system has been operational.

Stephanie Palmer (Michigan DOT): Thank you, good afternoon. Today I'm going to talk about the US-23 flex route, which is Michigan’s first active traffic management system, which has been operational about a year and a half now, and I'm really going to try to focus on when we open it, how we open it, and the different reasons that we open it.

So just to give you a real brief background on US-23, it's located in southeast Michigan but just north of Ann Arbor, so really close to the University of Michigan, and we have really high reoccurring directional peak hour congestion there. So southbound in the morning and northbound in the afternoon. So very directional peak hour. We also have non-reoccurring congestion that is associated with incidents in the corridor because we don't have a good alternate route, and also on special events, primarily related to the University of Michigan. In the corridor we also had some interchange and mainline operational issues, just really because we had pretty dated infrastructure, and we were already going out to do road and bridge improvements in the area and that's really what brought this improvement about. We were looking for operational improvements that we could make that were feasible that didn't require, you know, adding a permanent third lane in each direction.

So the alternative that we came up with was active traffic management. So this is a general overview of what our system looks like. It is eight and a half miles long in each direction. We're using the median shoulder for dynamic shoulder use. We have our infrastructure, it's mounted on a truss, typical sign truss-type gantry, and we have lane control signs that are five by five and a half feet mounted over the shoulder, and the two general purpose lanes, as well as nine small dynamic message signs strategically placed throughout, and then we have full camera coverage and detection. The active traffic management strategies we use include the dynamic shoulder use, which I'm going to focus on today, but we also do dynamic lane use, variable speed advisories, and we have a cue warning system.

So our dynamic shoulder use, it sounds like it would be considered a level three based on what Pete had just discussed about the levels. So we have a, those core hours, and our core hours are southbound in the morning from 6:00 to 9:30, and then northbound from 3:00 to 7:00 p.m. But we also have a congestion alert that, when thresholds are met, where we open it on for congestion, and then also we do schedule it for special event traffic.

So one of the things we did for our congestion thresholds is we went back and looked at our feeds and our volumes on US-23, and we looked at, we knew when the system was breaking down, we had all the data, and we knew when it was breaking, down so we went back, we took the actual data to determine when it broke down. And then we wanted to catch it before that, so that, like Pete said, we're trying to catch it before we get on that drop in capacity.

So we looked at our speeds, and then we also looked at our volume. So we compared those for US-23, we know we know how the traffic was behaving, and then we developed our thresholds. We use a volume of 1,400 vehicles per lane and along with the speed of 60 miles per hour, so speed reduction in order to trigger that threshold that says the shoulder, we may consider opening the shoulder due to congestion.

So, regardless of the reason that the shoulder is open, whether it is a scheduled shoulder open because of the peak traffic, or it's because of a congestion alert, our operators verify that that shoulder is clear of obstructions before opening. So there's two means for us to do that. Our primary means is our freeway courtesy patrol, which is our freeway service patrol. So that that's the primary mean. They are driving the shoulder prior to that opening and making sure that it's clear of obstructions or debris, while at the same time, our operator in our Statewide transportation operation center is also using our cameras, where we have full coverage to pan the opposite way. So the freeway courtesy patrol drivers driving with traffic as the operator takes those cameras and they are panning through the entire corridor with the cameras. And once that's done, then we can open the shoulder to traffic. In order to streamline some of this, we actually developed standard operating procedures for that, and one of the things we developed were some quick-reference guides for our operators. There's a graphic shown on the slide here, but, so for each one of the critical tasks they, do such as opening the shoulder, we have a step-by-step, very quick, two to three page guide that assists them on exactly the steps that need to be taken.

On another procedure, a quick reference guide that we needed to develop was, okay, so we know we're opening the shoulder, and we do find an obstruction, so now what do we do? So we went through and determined all the types of blockages that we have seen in the past with our freeway courtesy patrol, and we went through each one to figure out how would we deal with those in order to clear that so that we can open the shoulder. Most of the types of debris or things that we would encounter on the shoulder, we were able to follow our normal procedures for. However, for a disabled vehicle, that actually required us to do more coordination, and we came up with an agreement with our State police that we would treat the shoulder as if it's a lane in this corridor because, because that shoulder is dynamic it can become an active lane at any point, they recognize that as a lane for us, which was very important, because if it's recognized as a shoulder, that means our current law says that a person has 48 hours to remove that disabled vehicle, whereas if it's in an active lane it needs to be removed immediately. So that was a critical decision-making-in-process that we came up with that has helped us to keep that lane clear of disabled vehicles.

So here is a, is kind of a software capture of our dynamic shoulder operation. The upper left corner is showing our normal cameras, they're 90 foot poles, so we have continuous coverage of our whole corridor looking at the entire corridor through that, then the camera on the lower left is actually our low-light cameras. For this corridor, most of it is dark, we do not have freeway lighting, so we need to be able to see in dark conditions, especially during our morning peak that occurs in the dark when we have to open it. So that that one in the bottom left shows you what it looks like from, that's a low-light camera, so those are actually mounted right on those gantries, so a really close-up view, and those are the ones we're doing our sweeping of the lane width. In the center, you'll see a graphic, that is actually showing southbound in the morning. So the way that we display it, we have a green arrow over the shoulder, and then our speeds, we also have variable speeds, but they will automatically go to 60 miles per hour and that's really because of the design speed; when we have the shoulder open, the design speed for the road actually decreases and we post 60 miles per hour as an advisory speed. Then our small dynamic message signs will say left shoulder open to traffic. So that is how it looks in the morning, southbound, when it's open. So on the right side that graphic, that's showing northbound during the morning. So we call that our resting state. So northbound we do not need the shoulder open in the morning, so we put a red X with the word closed over that left shoulder, and then the other two lane control signs are actually blank, and then the small message sign says left shoulder closed to traffic. So that would be our typical operation when we're opening the entire shoulder, whether it is for a peak-hour operation, or it could have been for a special event, but that's what it looks like.

We also use our shoulder for incident management. Right here you're seeing on the left, there's an incident, it's in the right, it's in the right lane but it's also, you can see the emergency responders are sticking out a little bit into the center lane. And then on the right you'll see what it looks like in our software. The software automatically, when the operator enters that the incident has occurred, the software will prompt the messages for those signs which will basically merge people over around the incident and close that lane. And you can see the drivers actually have been very compliant, they move over and use the shoulder, and so that's another way that we're using our shoulder for incident management.

Another really benefit that we hadn't really thought of prior to operating the system was that this is a very heavy, heavily traveled corridor. In the past we've only been able to go out there and do a maintenance and construction at night, because the volumes during the peaks were pretty heavy. And then even in the opposite direction of the peak they were too heavy to close a lane. However, with the system, we are able to use that dynamic shoulder to maintain traffic so that we can do the maintenance for the system. In this picture you can see on the upper right you'll see we are doing a moving lane closure we're able to close the right lane and shift everyone over to the general purpose, left general purpose and the left shoulder to get around so we can actually go out there with a very short lane closure and maintain traffic during daytime instead of having to do our work at night. So that was kind of a hidden benefit that we didn't originally anticipate.

One of the things I really would like to point out about the system is that we had pretty high reliability goals for the system. It was set at 97.5 percent, and that really is so that the commuters only are experiencing any sort of failure one time during the month. So if this is a heavy commuter route, so they're driving during the peak, we, our success measures said if it's down more than once then they're going to say the system isn't reliable. So that's where we got the 97.5 percent, and then we designed around that. Some of the things that probably made the biggest difference were the ITS maintenance efficiencies we designed, which were to remove all the major components are in the cabinet, and so there's less maintenance to do that is overhead in the signs, and then also we have the ability to remotely diagnose the issues and remotely access the system so that we don't have to go out there every time that there is an issue. So that was very important in getting that reliability. And then finally I wanted to hit on the winter weather. We treat that left shoulder as if it's a third lane, as far as our plowing procedures. And so we plan to open it just like it's a third lane. The biggest issue we've had is during snow events that occur, especially if occur in the middle of the night, it is very difficult to find the time to, when we actually treat that left lane so that once we treat it we can actually get traffic in it so that we can active the salt, because if we do it too early there's no traffic that will actually get in the lane, even if we open it, so there is a fine line and that has been a challenge for us, but most of the time we have been able to deal with the winter snow event and get that lane open.

And then finally I just want to touch on some of the performance. What you're seeing here, this is the peak speed performance before. The blue lines are our project limits. On the left you'll see southbound we had traffic that was stop and go within the project limits, and then basically pretty, you know, stop traffic southbound. And then northbound, very similar. We had traffic throughout the project limits that really routinely it was just stop and go traffic. This is a scan for after the implementation of the flex route. Southbound we are seeing really, really good conditions: free flow within the project limits, and we're seeing a little bit of a slowdown downstream.

Northbound we are seeing a good improvement in the traffic flow, but we are seeing a slowdown northbound at the end of the project limit, and this is primarily because for northbound, the shoulder actually drops where as in southbound it drops into, and it basically opens up into another lane.

But overall, we've seen some pretty good improvements, especially, like I mentioned, for southbound because that does open up into additional lanes. We have seen an improvement in planning time of over 50 percent. So what took 22 minutes to prepare for for a drive that's 8.5 miles, you used to have to assume 22 minutes if you needed to get there on time. You can now do that in 10 minutes. We've also seen average travel time savings of about 5 minutes, and then speed increases from 43 miles per hour to 62 miles per hour. And we are showing, also, improvements in the northbound, and it has alleviated a lot of the congestion, but we're just not seeing quite the improvements that we're seeing southbound. We will be doing a research project within the next 2 years, it just started, and we are going to be looking at the, even in more detail, on the operational benefits of this project and the safety benefits. And so I hope to be able to share those probably within a year and a half or so we’ll have some really good information on that.

And with that, that is the end of my presentation and I think we're going to wait until the end for questions.

David Hale (Leidos): That's right, thanks a lot Stephanie, appreciate that. Again, we'll be doing the Q&A right after Stephen’s presentation, so we're taking down the questions that are coming up into the chat pod and we'll go over some of those in just a few moments.

So as I was just alluding to, our fourth and final technical presentation is from Stephen Harelson from Colorado Department of Transportation. Stephen is a program engineer for the Colorado Department of Transportation responsible for Interstate 70 design and construction in Clear Creek County, west of the

Denver metro area. He led the team that built the eastbound peak period shoulder lane in 2015, and is currently working on a similar project for the westbound direction. Aside from the peak-period shoulder lanes, other significant projects completed or underway include the Veterans Memorial Tunnel expansion, the Eisenhower-Johnson Tunnel fixed-fire suppression system, and the Floyd Hill expansion project. Stephen has been with CDOT since 2002, and prior to that worked in the engineering consulting industry for 16 years. The presentation now is going to discuss the operational need for the peak-period shoulder lane on I-70, as well as a physical and political constraint. Also discussed are the evolution of tolling protocols, performance of both tolled and general purpose lanes, and lessons learned on construction and operation.

Stephen Harelson (Colorado DOT): Thank you. Can everybody hear me? Yes. So as we discussed, we're going to talk about the eastbound peak-period shoulder lane. We've since branded it to call it the Mountain Express Lane. All of Colorado's toll lanes are called express lanes so I'll refer to both names as we go through, but it's the same facility.

For those of you not familiar with Colorado, the Front Range is where everyone lives, and, let me get the pointer going, so Denver, Fort Collins, Boulder, Colorado Springs, that's where the vast majority of Colorado's population lives. And these ski areas and the mountain playground is within about 50 to 100 miles to the west, so in this area, so Vail is right here, Breckenridge and Keystone are right here, Winter Park is up in the L of the word Boulder, so every weekend people like to do day trips and weekend trips from the Denver area west to the mountains.

So this is what it looks like on a typical Saturday morning or Sunday afternoon on Interstate 71. Direction is essentially empty and the other direction is bumper-to-bumper for most 50 mile, most of those 50 miles.

The peak traffic at the Eisenhower Tunnel is, on a normal day, between 25 and 30 thousand, and on the weekend it gets anywhere from 45 to 55 thousand. I think our all-time peak is just under 55,000. Immediately east of the tunnel there's a 12-mile bottleneck where there are, the Interstate 70 traffic is met with US-40, which serves the Winter Park and Sol Vista, and to some degree Steamboat Springs traffic, and it feeds into I-70 at Empire Junction. And there's a 12 mile segment which carries all that traffic, and then at the east end of Clear Creek County, the road again forks, US-6 continues down the canyon and Interstate 70 heads up Floyd Hill, and also Interstate 70 gets, turns from two lanes to three lanes. So that 12 mile segment is our bottleneck.

So here's a graphic picture. This is the, let me get my green pointer here, this is the road to Winter Park, US-40. This is Interstate 70, it carries traffic from Vail and Summit County. It's the bulk of the traffic. The US-40 is about 20 percent of the traffic at this area and Interstate 70 is about 80 percent of the traffic. Here's our 12 mile bottleneck, goes through the town of Idaho Springs, once it gets to Idaho Springs the interstate climbs up Floyd Hill right here, and then US-6, which serves the City of Golden in the northern suburbs, splits off. So we have, you know, two eastbound lanes coming down the hill combining with another eastbound lane from US-40, dumping into two eastbound lanes for this 12-mile segment, and then once it gets to this point there are three eastbound lanes on the interstate and one eastbound lane in US-6. So this is our problem area and the project limits.

One of our big constraints in working in Clear Creek County is the geography. Here are a couple of photographs: the one on the left is, this is the US-6 Interstate 70 junction there at the east end of Clear Creek County. This is old US-40, which is now the interstate, and this is US-6. This is back in like the late 50's, I think, when, before the interstate was built. Then right next to it is 1963, when the interstate was completed and this interchange was finished. You can see all the work, you can see this this large rock cut, where previously was just the native canyon wall, and trying to shoehorn another two lanes of the interstate in this area is challenging.

We are working on an EIS, we don't have funding for it, this project is a 500 million dollar project, but you can see in order to get those extra lanes in there we need to do a tunnel rather than another massive rock cut. That's the physical constraint. Politically, we also have a, we did a programmatic environmental impact statement for Clear Creek County about 9 years ago and, it's a 50-year plan for expansion of the interstate and transportation in general in the mountains in Colorado. And one of the concerns with Clear Creek County is they don't want, you know, six or eight lanes of interstate running through their county. So they've got some very sensitive environmental resources and we set up some triggers that would allow us to do expansion, and prior to those, to that expansion being completed, we are asked to look at operational improvements and some other work. So we've got some political constraints as well as the economic and physical constraints of the mountain terrain.

So our operational improvement is very similar to what some of the other speakers have talked about. We use a left lane as our peak-period shoulder lane. We've got the two general purpose lanes on the right, we have a 4-foot right shoulder. In our eastbound construction we did a, the right lane was 12 feet, we narrowed the left lane to 11 feet, we did a peak-period shoulder lane of 11 feet, and the shy distance from the median was 1 foot. Operationally, we've had some challenges with that. The shy distance, I think, is the biggest complaint we get. The 1 foot distance from that white line to the barrier is unnerving for a lot of people and it slows it down. So as we're designing the westbound project, we've widened our section up about 2 feet, you know, one of the reasons we minimized it initially was to, you know, in working with the citizens of Clear Creek County, they really wanted it operational only. They did not want any infrastructure expansion. So that's why we choked it down to that 39 foot section. But I think after 3 or 4 years of use, they've recognized and we've recognized that just a little bit more room is desirable.

To set our tolling and operating protocols, one of the things we had to do was we have a, we got a loan in order to finance the trip, so, or finance the project, so we had to do a traffic and revenue study. And this is an unusual corridor in that it's recreational traffic so it's only 2 days a week and it is, it trips that aren't people going to work, for the most part. Its people going to play, so I think the T & R industry wasn't sure exactly how to model that. Our initial study said that the quarter would support tolls from 4 dollars up to 30 dollars for this 12 mile trip and that the expected average revenue would be 12 dollars per user. We also, we're going to try to invoke dynamic tolling where we would use traffic counts, as has been discussed earlier in this webinar, where we varied the price in order to, I think our, what we were hoping to do was keep the speed differential at less than 10 miles per hour so that the express lane would be going no more fast, no more than 10 miles per hour faster, and, well, I'll get to that in a minute. That didn't work as well as we'd hoped. We also negotiated operating protocols with Federal Highways and Clear Creek County. And Federal Highways, from a safety perspective, wanted us to limit it to 73 days per year, which is 20 percent, and it's, and that's pretty much every busy weekend. Clear Creek County wanted us to similarly limit it to the 20 percent for noise purposes and just traffic impact. So that was what we did the first year. The second year we expanded that to 100 days, and I think that's worked a little better. We've done it, we've done the 100 days for the last 2 years, and it's, we've not run out of time or days to operate it and it's been a little more flexible than the 73. The 73 was just too tight. The other thing that we've done is, in terms of opening it, rather than using the traffic triggers for opening it, we just open it at 9:00 a.m. every Saturday and every Sunday. The primary reason for that is we send a work crew out to sweep up the trash, there's a lot of tire chains used on this corridor so, you know, cars will throw off tire chains, we've got to pick that stuff up. We don't like to send those crews out just as the traffic's about to break down so we do it at 9:00 in the morning, several hours before the traffic picks up primarily for safety reasons for those crews. As soon as it's clear we open it up to traffic, and even if traffic's not backed up there are some people that will jump in and pay that toll, you know, it's, I joke that it's like Thurston Howell III on Gilligan's Island: if these, some people, just, if they can pay a toll they'll pay a toll, so we'll take their money.

We found that trying to do dynamic tolling was difficult because it took 15 or 20 minutes to reset the toll signs at the entrance, and upstream of the of the lane, and by, often times, when we would reset those tolls, the traffic, it would just be a quick wave of traffic, and we would end up, you know, not needing to raise the tolls, and then it would be wasted effort. We also noticed that nobody likes to pay more than 8 dollars. Even though our T & R study said we could expect an average of 12 and up to 30, whenever we raise the tolls above 8 dollars, our use would drop from 600 cars an hour to 200 cars an hour, and it just didn't make any sense. We also found that even though this is a very predictable route, it's people going skiing or people going hiking, there were some unpredictable elements of the traffic numbers.

One thing we noticed is that in the summer time, the peak lasts much longer. The, you know, people will stay fishing or camping or hiking, you know, until sunset rather than until 5:00 when the, in the wintertime, when it gets dark. The wintertime peak is tied to the sunset and when ski areas close at 4:00 p.m., so everyone gets into their car as soon as the lifts close, or an hour before the lifts close, and it's a much more intense peak, but it's much shorter. In the summer peak, we never get the peak hour numbers like we do in the winter, but if, you know, it starts at 2:00 in the afternoon and goes till 8:00 at night. The other thing that's kind of counterintuitive in the wintertime, bad weather in Colorado, we call those powder days, people like to go skiing in the fresh powder. So if we have a snowy day we tend to get more traffic in the mountains, and the opposite is true in the summer, if we get rainy days people either don't go to the mountains or people leave early. We often get afternoon thunderstorms in Colorado so, you know, sometimes people will stay until 11:00 or 12:00 on Sunday and then head home before the thunderstorms hit in the afternoon. So it's kind of made it, you know, we're getting used to it but trying to predict those traffic peaks has been challenging. Unusual events, Bronco games, home or away, competitive or not, that seems to drive traffic down. I think a lot of people either stay in the mountains and watch Bronco games on TVs in bar rooms and such in the mountains, or they rush home to get to watch the Bronco games on TV at home, but that 2:00 to 5:00 p.m. period on Sunday afternoons, particularly if the Broncos are winning, our traffic counts drop way down, so we always open the lane during those times but we don't see a ton of traffic. The other issue, or special events, the X-Games is a kind of an offbeat ski and snowmobile and snowboarding competition in Aspen. Aspen is about 2.5 hours away from this lane, so if people are in Aspen at an event, they will stay there until the event ends and then they will start driving home. That will tend to delay the peak hour on our lane. World Cup ski races in Vail also push the peak later, it's not as far west as Aspen and I don't think it draws the numbers that the X-Games do, but it's the same sort of situation. And then holidays obviously, Christmas week, and how the weather and the Bronco schedule fits in with those drives some of our demand.

So our current process after running the thing for 3.5 years, we open it at 9:00 a.m. on Saturdays with the opening total of 4 dollars. Late morning, usually by noon, we raise it to 5 and then by 1:00 or so we raise it to 6, and then it stays open until 6 p.m. unless, you know, there's one of these funny events. On Sundays we get more traffic generally because some people go to the mountains for the entire weekend so we follow the same opening hour pattern, it's just a dollar more expensive, so it's 5 dollars at the open and it goes up to 7 dollars. In the summertime we extend those open hours to about 8 p.m., and we usually increase, we go up to the 7 dollars a little earlier, like at noon or 1:00, just to try to stay ahead of that traffic. At the Eisenhower Tunnel we have a real-time traffic counter that's about 20 minutes west of the lane entrance, so we can keep an eye on that and if, you know, if we see a big drop-off we can close the lane earlier or we can adjust the tolls. We regard the lane capacity is about 800 cars per hour. I think, you know, a normal lane is considered, normal lane and a flat lane is probably close to twice that. This freeway has a lot tighter curves than a normal freeway. We've got some 45 mile an hour curves in here, and so we count on it, we try to shoot for 800 cars in the toll lane. We very rarely get above 600. It has to be Labor Day weekend to get above 600, typically, and our system capacity for free-flow is about 3,200. So that's what we try to keep moving.

Here's a graph of the performance. This on the right hand side of the chart, this is the first four weekends; well, the two big red columns are the last weekend in November and the first weekend in December, right before the system opened, and then this fourth column is that's the weekend it opened, opening weekend. So, you know, the red is, means heavy congestion. It's pretty much 4 or 5 hours’ worth of heavy congestion. The next weekend it didn't snow as much or it wasn't as big a ski weekend, but then when it was open a week before Christmas we had no congestion. So it was immediately viewed as a huge success.

Here's a graph that shows the seasonal effect so each one of these axis’s going this way, that represents a weekend, and the green means no congestion, the red means great congestion or lots of congestion. So on a Saturday before the lane was constructed we have this big hunk of congestion, and then over here almost none. On Sunday which is the big demand day, every weekend it's congestion all year long, and then after it's built in 2017, much less congestion. We think it's providing about, on average, 29 minutes of traffic relief to the users of the Mountain Express Lane, but even more telling is the general purpose lanes, people who don't pay the tolls, they're getting the 22 minute benefits. So it's helping both the toll payers and the free riders getting home from the mountains.

Surprises that we've seen since we built it, the price sensitivity is very inelastic. It's more of perception, if people perceive that there's congestion they will get in it. The use between 4 dollars and 6 dollars is almost the identical given the same congestion, and then, but once we raise it above 8 bucks, nobody will use it regardless of the perceived congestion. Our revenue has grown and our use has grown about 50 percent since that first year, which was 3 years ago. We've got two peak days per week, just Saturday and Sunday. Saturday is, we don't get, it's only a peak of an hour or two a day. Sunday is a much bigger peak, we're generating about 100,000 per month, you know, the summers we generate more, the heart of the ski season we generate more, but, like, right now, we're opening the lane but very few people use it because it's what we call mud season. The ski areas are all closing, there, it's too snowy and wet to hike or go fishing, so people don't go to the mountains this time of year. We're trying to open the lane even this time of year mainly so people will rely on it and know that it's open rather than trying to outguess us as to when it will be open. We, unlike Minnesota, we don't open it in the heart of a blizzard. Our big worry is safety and we get very intense blizzards in the mountains, so we just, we just don't open it, you know, but it's kind of a judgement call, is what is a blizzard. One person's blizzard is one, and another person's snow squall, but I think we've figured it out pretty well. The last point is something that we had to have some discussions with Federal Highways on. Initially when we built the lane we used a white stripe between the shoulder lane and the left general purpose lane, and people kind of ignored it. So we tried a yellow shoulder stripe and it seems to have cured the problem of people wandering over onto the shoulder to pass people. The yellow stripe, for some reason, really helps our, when the lane is closed it keeps people out of there, so that's something to consider if anyone else is having that problem.

Moving forward we are, we have the westbound lane under advertisement right now the bids are going to open Thursday. The section slightly wider, as I discussed. We've doing 12 foot general purpose lanes and the 2 foot shy distance at the median. We're going to be able to use the eastbound median shoulder for construction, similar to what Minnesota was talking about, that will, its extra space for construction, so it's going to make our westbound construction go smoother. We're still, you know, we've got a whole group of ITS people that are looking at real-time dynamic pricing and some of the ITS technology that's coming out, but we've not been able to predict traffic effectively and do that effectively. So we've just, you know, we're on hold with that, we're going to use this continuous, our fixed schedule.

And I will take questions when we're done.

David Hale (Leidos): Okay, thanks a lot Stephen. That concludes our set of four technical presentations, and so now we can start the Q&A session. Actually, we've got 3 minutes left in the original timeframe but I think most of our speakers are available to stay on an additional 10 minutes to try to defray some of the questions that have come in.

So first question I want to direct to Greg Jones from FHWA and he could possibly also invite Pete to contribute the answer. First question wanted to know about studies about the safety and public acceptance of either fully-automated or largely-automated dynamic shoulder use.

Greg Jones (FHWA): Okay, so as I mentioned, majority of the dynamic operations have been in the last few years. Our initial assessment of the operations has been that they're successful and they're well accepted. I would, you know, say that it's been positive feedback from the public and majority of them are operating with a system that is developed scenarios and they're generally implemented by their operators. So I would not say that they're fully automated, but they do get automated responses that their operators initiate.

David Hale (Leidos): All right, thanks a lot Greg.

Second question I want to direct to Pete Jenior, and I think a couple of our speakers touched on this a little bit, but the second questioner wants to know what is typically done to ensure the shoulder is clear of obstructions such as debris or disabled vehicles before opening to traffic flow?

Pete Jenior (Kittelson & Associates): Yeah, typically the corridor is driven by a freeway service patrol vehicle or some other kind of official vehicle, and they verify themselves. Some agencies supplement that with cameras. In Europe, there are agencies that use cameras entirely and don't drive the corridor, but that's less common here.

David Hale (Leidos): Okay, and I think the second question also for Pete, is there going to be any guidance on where to best locate the sensors, such as either right at the physical gore or a third of a mile upstream of the of a physical gore?

Pete Jenior (Kittelson & Associates): Generally, you want to have them right at a bottleneck, so if the physical gore, I'm assuming that's referring to like an on-ramp, in which case the on-ramp and the traffic from it causes the bottleneck, you'd want to have it right there, kind of right at that physical gore where the traffic streams start to meet. And we'll touch on that in the report.

David Hale (Leidos): Okay, thanks. And last question for Pete before we move on to Stephanie and Stephen, this one refers to the Primer, the 2016 Primer, FHWA Primer on Use of Narrow Lanes and Narrow Shoulders on Freeways, and they're concerned that some of the experiences reported show a capacity reduction of 2 percent for lane narrowing, 3 percent capacity reduction for shoulder narrowing, and also some crash rates increasing, but between 3 and 10 percent in some real-world implementations. So are these sort of valid outcomes, and should agencies be concerned about reported outcomes like this?

Pete Jenior (Kittelson & Associates): The studies to date have been somewhat limited, they've usually been facility-specific, and there's always changes in volume associated with part-time shoulder use, not necessarily daily volume but hours volume at different hours of the day, so it can be hard to isolate the effects of shoulder use from some of those other things. There is an NCHRP project ongoing at this time that will better answer that question in a couple years, specifically about part-time shoulder use safety.

So I'd say for now it's really been a mixed bag. The Primer that is referred to here, and I just want to clarify the difference that the Primer and what this question is referring to relates specifically to narrow lanes and narrow shoulders permanently, that the Primer has nothing to do with part-time shoulder use. So if you permanently have narrower lanes and narrower shoulders on a freeway, then yes, there is some, then yes, there is a trend there towards, you know, slightly higher crash frequencies, as noted.

David Hale (Leidos): Alright, thanks Pete. Next, a couple of questions are for Stephanie Palmer.

First one is what, if any, hurdles did you need to clear to revise or create new policies with the State Police for handling disabled vehicles?

Stephanie Palmer (Michigan DOT): Okay, so we didn't actually have to revise or create new policy, and that was because we, when we met with the State Police, they recognized the need to declare that shoulder as an active lane. So when they did that, when they said we're going to treat this as an active lane because it can become active at any time, then all we're doing is following our current policy that says if a disabled vehicle is in an active lane, it needs to be removed immediately. So we were very fortunate, and that's what I was trying to get across, is that because they recognized it as a lane, we didn't have to change any policy.

David Hale (Leidos): Okay, second question for Stephanie, have you observed any changes in travel patterns or profiles, for example peak contraction due to improved operations in the peak-period southbound, since you've been operating the shoulder lane?

Stephanie Palmer (Michigan DOT): Okay, so, we have, we have seen changes in travel patterns, especially, like you said, in the southbound direction. So we have seen a slight increase in the daily traffic for the corridor, but we've also seen a pretty significant increase in the peak hour traffic, so what we're seeing is a shift in traffic behavior. More people are driving during the peak than they were before, but overall, there's only a slight change in daily traffic. I think that's what you're getting at.

David Hale (Leidos): Okay, thanks. Last question for you, Stephanie. Has there been a change in the number of incidents on the US-23 corridor since beginning the operation?

Stephanie Palmer (Michigan DOT): So, we have been monitoring that. So at first there was a slight decrease in crashes, and then there was an increase in crashes, so we don't really have enough data yet. So in general, we're overall seeing a slight increase in traffic, or crashes, and that's one of the reasons that we're doing this larger study, research study, that so that we can get more data and actually compare the crashes, because, because the traffic patterns change, we actually, where before we had crashes in a different area that we are now, so we've got to take a step back and look at the entire picture and try to determine exactly what have been the safety impacts of the flex route.

David Hale (Leidos): Okay, thanks a lot. I’ve got now one question for Stephen, followed by possibly up to four questions for anyone on the panel.

So the question for Stephen is, do you change the toll rates when there's a lane blocking crash during operations?

Stephen Harelson (Colorado DOT): Yes we do, and in fact, we've even done it when, on a weekday, when it was not in operation, we will open the peak-period shoulder and charge a zero toll just to, you know, once the crash is cleared, if we've got 3 miles of backed up traffic, we'll open it up to drain it that much quicker.

David Hale (Leidos): Alright, thanks a lot Stephen. So again, the four questions for anyone on the panel: the first one is about, is there a, mayb,e a well-known, successful, real-world implementation for part-time shoulder use on the inside lane?

Pete Jenior (Kittelson & Associates): Our presentations were on inside shoulder use, so certainly those are.

Greg Jones (FHWA): David, I'll just mention the other third facility that operates on the inside shoulders in I-35 W in Minneapolis. So I think the two presentations we had now, and I-35 W are all successful projects that can be looked at. They have unique aspects, but they're all successful.

David Hale (Leidos): Alright, thanks a lot. Second general question was, is there any minimum shoulder width that is recommended for part-time shoulder use?

Stephen Harelson (Colorado DOT): In my mind it's 11 feet if you want 65 mile an hour traffic in it.

Pete Jenior (Kittelson & Associates): I was going to note that, you know, the blurring between the shoulder and the lane here, you know, it's a little unusual the way we've described it in the 2016 Guide, shoulder width is anything outside of the general purpose lanes, so that, you know, your shoulder lane, so to speak, and if there's sometimes a second edge line, a shoulder beyond the shoulder, we'd call all that shoulders. So yeah, somewhere in the range of 10, 11 feet is, you know, about as narrow as you want to go there, including, you know, that's from edge of general purpose lane to edge of pavement.

David Hale (Leidos): Alright, thanks Pete. Second to last question: are stopping sight distances for shoulder use measure the same way as they would be for regular lanes?

Pete Jenior (Kittelson & Associates): I'd say that they are measured the same way in the sense that, you know, you would use the same equations from the Green Book, to compute stopping sight distance. A challenge that often occurs on shoulder lanes is when you're alongside a barrier and you have a curve, there is now decreased visibility around that barrier because you're closer to it. And so oftentimes, you have reduced stopping sight distance on a freeway as a whole because a different portion of the freeway, specifically the shoulder, is now being used for travel. So that has been an issue and has come up on some facilities, and, you know, that's one reason that variable speed limits are sometimes used for part-time shoulder use.

Stephanie Palmer (Michigan DOT): This is Stephanie from Michigan. That is exactly why ours is posted at 60 miles per hour, is because stopping site, we could not get the stopping sight distance for the shoulder when the shoulder was being used as a lane. So that's why we had to drop our advisory speed to 60 miles per hour for stopping sight distance.

David Hale (Leidos): Alright, thanks very much. Last question: FHWA has new guidelines for LCS, which I believe stands for lane change signs, using only a fixed amber X and not using shifting arrows or chevrons, and how will this affect moving traffic to the left or the right in lane changes?

Greg Jones (FHWA): Yeah, I'll jump in on that one. So this is a recent memo that came out and basically the chevrons and the diagonal errors that you may have seen in some of the pictures were all under experimentation when they were utilized on those facilities. And so the memo, this recently came out, says only using the yellow X going forward, that they're not going to approve any more experimentation projects. For part-time shoulders it probably doesn't affect it quite as much because in most cases you only have one choice where to merge from a part-time shoulder lane. I think that the bigger question that we have and we're still exploring and discussing with our MUTCD team, is just the general knowledge of the using public as to what the yellow X means and the understanding that that that means the lane is going to close at a point ahead. But I think for part-time shoulders, it probably is not that big of an issue. It's more of the all lanes in a corridor lane control signal operations that there are some questions on how that's going to be handled moving forward.

David Hale (Leido): Alright, thanks so much Greg. I think that's all the questions we recorded for now, so Niloo, I'm going to toss it back to you.

Niloo Parvinashtiani (NOCoE): Thank you very much. I just want to take a minute to thank everyone for attending the webinar today and also our wonderful panelists and moderator who were able to share some good information here. I hope you found it helpful. So, like I mentioned, all of this webinar was recorded and that, along with the presentation slides, will be shared on the NOCoE website shortly. So on behalf of the National Operations Center of Excellence and our presenters, thank you for joining us today and have a great rest of your day.