Road User Cost Analysis for Work Zone Applications Webinar
November 15, 2011

Jennifer Symoun
Good afternoon or good morning to those of you to the West. Welcome to a webinar on Road User Cost Analysis for Work Zone Applications. My name is Jennifer Symoun and I will moderate today's webinar

Before I go any further, I do want to let those of you who are calling into the teleconference for the audio know that you need to mute your computer speakers or else you will be hearing your audio over the computer as well. For those of you calling into the phone line, please note that your phone lines are listen-only.

Today's webinar will last 90 minutes. We will have a presentation given by Jawad Paracha of the Federal Highway Administration Work Zone Mobility and Safety Program and Jag Mallela of ARA, Inc and will be taking questions at various points throughout the presentation. If during the presentation you think of a question, please type it into the chat area. Please make sure you send your question to "Everyone". Presenters will be unable to answer your questions during their presentation, but the questions typed into the chat box will be addressed at the appropriate times. If we run out of time and there are unanswered questions, we will attempt to get written responses from the presenters that will be emailed to all attendees.

The PowerPoint presentation used during the webinar is available for download from the file download box in the lower right corner of your screen.

We're now going to go ahead and get started. As a reminder, if you have questions during the presentations please type them into the chat box and they will be addressed at each appropriate moment within the presentation. With this I will turn it over to Jawad Paracha.

Jawad Paracha
Thanks, Jennifer. I am Jawad Paracha with the Work Zone Safety and Mobility Team in the Office of Transportation Operations at Federal Highway Administration. I would like to thank you all for participating in today's webinar on Road User Cost Analysis for Work Zone Applications.

As you know, road work has been continuously increasing and is expected to increase rather sharply as we try to meet transportation needs, add capacity to existing roadway networks, make changes to the way we manage the highway system, and build facilities to meet growing transportation needs. We also know that this road work can result in significant safety and mobility impacts to road users. It can also have other impacts, such as on businesses, communities and the environment. FHWA's Rule on Work Zone Safety and Mobility requires systematic consideration and management of work zone impacts throughout project development and implementation. Road user cost (RUC) provides an economic basis for quantifying these adverse impacts, which can then be used for effective decision-making to reduce work zone impacts and improve safety and mobility.

This webinar is mainly based on a soon-to-be published report, *Work Zone Road User Costs: Concepts and Applications*. As this report is not yet published, we plan to inform all the registered participants of this webinar as to when the report is available online. We expect it in the next month or so.

Now I will provide some project background and share some of the key areas addressed in the document that I mentioned on the last slide.

An increasing number of agencies are taking road user costs into consideration for decision-making during project development; for example, considering project costs that include road user costs as well as agency or construction costs when analyzing project alternatives. As we were looking at various resources available to practitioners to assist work zone impacts, we found that there is a need to explain the work zone road user costs concept in a document that is easy to understand and useful for practitioners, where we can provide steps using a step-by-step approach supported by example applications, such as MOT alternative analysis; user contracting strategies, such as A+B, Time + Cost, and incentive disincentive; as well as analyzing construction methods such as bridge construction considering work zone impacts or road user costs.

The remaining part of the webinar will be broken into three main parts, and every part will be followed by questions and answers. We will have five minutes for that, and we will try to answer the remaining questions towards the end.

In the first part, we will present work zone road user cost framework, key factors and computation steps. In the second part, we will present one approach to systematically consider work zone impacts, both quantitative and qualitative. In the third part, we will present ways to consider work zone impacts for decisions such as needs for project acceleration, contracting strategies, incentive disincentive calculations, and benefit-cost analysis application considering road user costs.

During the second and third parts of the webinar, we will use example project applications to discuss concepts and computation steps. Note that the projects that we use as case studies have already been completed. We made a number of assumptions to demonstrate application of work zone road user cost, so I just wanted to point out that these projects were already completed, but we used real-life project examples to demonstrate the various concepts.

With this, I am going to request Jag Mallela, principal engineer at Applied Research Associates, to present work zone road user costs concepts and application. Jag, take it over.

Jag Mallela
Thank you. I also want to thank everybody on the webinar for participating and spending your valuable time listening to the webinar. Before I start, I would like to acknowledge the work of my colleague here, who helped me put this body of work together along with Jawad, as well as the volunteer review work of a technical panel drawn from various disciplines related to work zone road user costs on the report on which this webinar is based. As suggested by Jawad in the

outline, I will start today's webinar by going over definitions of road user costs, the components and their computation.

As you can see in this graphic, in the report we define work zone road user cost as the additional cost borne by the motorists and local communities due to work zone activity. The components are shown on the slide here. There are two broad categories of this component: monetized components as well as qualitative or non-monetized components. Traditionally, only the monetized costs and those that impact mobility for the motorists are considered the delay costs and the vehicle operating costs (VOC), but in our framework and the guidance that was developed, we looked at all possible monetized costs; for example, crash or safety-related costs as well as emission costs due to works zones. We also discussed in a less aggressive fashion the non-monetized qualitative impacts like noise, business impacts and community impacts, particularly to local communities in which the work zone is established.

In terms of the application, there are many applications of work zone road user costs—more than we would like to think of. We have some of them on the slide here. In our work and in the presentation today, I'm going to talk about the last four bullets: the applications and contract administration; selecting an appropriate maintenance of traffic (MOT) strategy; benefit-cost analysis of capital investments; and the operational efficiency for work zones. I would like to point out that the use of road user costs in system preservation and improvement-related decision-making—for example, life cycle cost analysis—is well-established and certainly well documented in many different publications. That will be less emphasized, though it is equally important. We have many different application areas for work zone road user costs. Before we get into the computation of the road user costs, I would like to point out that the computation is just one step in the overall road user cost establishment process, as you can imagine.

The slide here is a snapshot of the overall work zone cost computation process. The process begins with the data-gathering phase, which is established when the project is in design stage. It includes traffic data collection or through traffic studies and gathering knowledge of the work zone configuration; the MOT and traffic management plan (TMP) strategies; historical safety information; the influence area of the work zone; and public outreach and understanding of local community impacts.

Once data is gathered, there are a variety of tools available to assess impacts. For example you have delay impacts, VOC impacts, safety impacts, emissions, inconvenience to local communities, as well as noise impacts. Once the impacts are assessed, then you combine the impacts with the unit cost for each of those categories to establish the cost associated with each of those categories, like delay cost, VOC cost, trash and emissions, and noise, as well as other qualitative impacts, which are nonmonetary. All of these go into the decision-making process; at least, that's the way we review road user cost components, their computations and their application.

In terms of the tools that are available, there are ready tools available for road user cost computations. The tools themselves fall into two broad categories: the ones that look at traffic impacts and perform traffic impact analysis; and tools that look at the economic impact due to the traffic impacts. The work zone traffic impact analysis tools can be further divided into two broad categories: one is sketch-planning or simplistic spreadsheet or simple computer application-based tools that are based on demand capacity analysis or other simplistic assumptions. These are more applicable at the planning level, at the higher level. There are more detailed tools for traffic analysis that need more data but provide better estimates. For higher impact projects where traffic volumes are higher, the simulation tools are recommended; certainly the mesoscopic and microscopic simulation schools provide better estimates of the impacts.

In terms of economic analysis tools, we have different tools for different purposes. For example, to perform life cycle cost analysis, we have FHWA's RealCost, which also does quantify impacts and monetize those impacts. We have other benefit-cost analysis tools; for example, for improvement decision-making we have the HERS-ST tools, MicroBENCOST, Cal B-C, and BCA.Net as some examples. The report goes into detail on the tool selection process and the advantages and disadvantages and capabilities of some of these tools.

I will briefly go over the computation of work zone road user costs. The first part I will focus on, which will take the majority of the presentation today, is the estimation of monetary components.

All monetary components—all things that can be quantified in terms of dollars and cents—can be computed using three steps. First, you understand the impacts. Then, you derive the unit costs for each impact and make suitable adjustments. The unit costs are typically historical values or indexed values for given year; they aren't computed each year, but are computed for a base year, which may have to be adjusted using economic indices. Once you know the impacts and the unit costs and the quantities of affected vehicles, then you can monetize those impacts. Basically, it's a three-step process.

Under the estimation of work zone impacts, we have mobility impacts, which are delay and VOC impacts; crash rate and crash frequencies, which are safety impacts; and emissions-related impacts to the community, which is not a motorist impact, but is a community impact. In terms of mobility impacts, there are various traffic and economic analysis tools that can be used for that, as I mentioned before. In terms of crash rates, we look at project-specific historical records pre the work zone being set up and compare them to after the work zone has been set up. For emissions, we do the same.

In terms of unit cost, for per unit cost computations for each impact, we use the Bureau of Labor Statistics where possible and economic indices for adjustments: for mobility costs, for example. For crash costs, we have the best available resources on crash costs published by Federal Highway to use for information, as I will discuss later. There's not a huge amount of data, but we use the best available guidance that is provided on that as well.

The first example I'm going to start with is looking at estimating travel delay cost. The slide presents a quick overview of what we call travel delay costs—the typical costs associated with delay. It starts on the left-hand side with an understanding of the average delay time due to the work zone, and then the delay costs themselves are broken down into five different components. The components include delay to personal travel by passenger cars, delay to business travel by passenger cars, and delay to truck travel for trucks. In addition, we have time-related depreciation by vehicle type for all vehicles as a result of work zone delay, and the last one is freight inventory-related delays due to work zones.

I would like to out that of all these costs, typically the personal travel costs are aggregated into one group. They are not usually broken down by passenger cars and personal travel and passenger cars and business travel. They are usually aggregated together. Truck travel is separated, and the last two, the time-related depreciation by vehicle type and the freight inventory costs, are typically not considered and they do form a smaller component of the overall delay cost. In the report that we will be publishing, detailed guidance on estimation of cost for all these costs is provided. Unit cost guidance is provided for all of these cost categories. Once you know the unit cost, you adjust the unit cost for the current year or the forecast year for which you are trying to estimate the impacts, and you know the quantity that is affected in each category. Essentially, you multiply the three left-hand columns and sum them up to get the work zone travel delay cost. As an example, I'm going to dive into this first grouping here, which is estimating delay cost for personal travel passenger cars.

In that sub-grouping, you look estimate the proportion of passenger cars on personal travel. In the guide, we have provided national averages of the proportion of passenger cars on personal travel of all the cars that actually use our roadways. And those national averages are further segregated by local or inter-city travel.

In the next step, you establish the average vehicle occupant. Now that you know all the cars on the roadway, what proportion is on personal travel? Then, among those cars that are on personal travel, you know the average vehicle occupancy. Again, in the report, we provide national averages for the average vehicle occupancy for those cars in the traffic mix that are on personal travel, and certainly those averages are guidance and can and should be adjusted if local data is available, since that would be more accurate. The report recommends the use of those, but for those who are just getting into this or to make it easier to estimate these as a first cut, we have provided national average numbers. Once you have established the average vehicle occupancy, or AVO, you can in parallel or after that establish the unit cost to estimate per person value of people on personal travel. If I'm driving a car and I'm delayed, what is the delay cost to me on a personal basis per hour? In the report, we use the U.S. Census Bureau median annual income for the Office of the Secretary of Transportation guidelines as default values to use for the per person value of personal travel time. Once you know the first three factors—the impact and unit cost—you can compute the per vehicle hour cost value of travel time. By multiplying step two, which is average vehicle occupancy, with the median annual household income, you get per vehicle hour value travel time delay for autos and personal travel. Then you compute the travel delay cost by multiplying step four with the total delay estimated from traffic studies and modeling, which is the average work zone related delay. In that manner, you can compute the travel delay cost for autos and personal travel, and the same process is then repeated for each of the five components.

I would like to point out that we do provide in the report detailed step-by-step procedures on estimating these costs and adjusting these costs for the current year or forecast year in which the cost computations have been made.

The next monetized category is the VOC. VOC comprises typically of these four components, and it's well-known, well-understood and well-documented in many studies. Due to work zones and due to the mobility impacts they have, we have fuel and engine oil consumption cost, tire wear cost, additional repair and maintenance cost, and mileage-related depreciation. All of these are considered in the VOC computation.

When VOCs are computed, typically they are broken down into two categories. If the work zone allows traffic to flow through it, then you have the work zone through traffic impacts, because as you approach your work zone, you have speed change and may have stopping and idling conditions, and your impact studies will tell you what those impacts will be. Once you know that, the VOC model can be used to determine the costs and speed change and stopping and idling conditions. There are many different approaches for computing this and the report discusses each of these three. The NCHRP Report 133 has been widely used and also implemented in FHWA's RealCost program. The unit cost computation from there and the methodology is used by many. The Texas Research and Development Foundation's Zaniewski models, which are incorporated for example in the various tools like MicroBENCOST, are also discussed. Lastly, the HERS-ST, which uses modified Zaniewski equations, is also discussed.

We present all three approaches and their slight differences in establishing the unit cost. In addition to the work zone through traffic, if traffic is diverted on the project to detours (either posted, self-detoured, or other detours), and if the amount of diversion is quantified, then you can compute per mile cost for the detour. If you had to take five extra miles by detour, then you can compute the cost for traveling those five miles in addition to the delay related to traveling those extra five miles due to the detours.

One other thing I would like to point out is that work zone through traffic is assumed to be in the force flow conditions whereas the detour traffic is typically soon to be in the no force flow conditions, and the per mile cost that we provide—for example from AAA or the American Transportation Research Institute (ATRI)—assumes no force flow conditions. It is possible to consider force flow even though detours and it is certainly a possibility on congested detours that have limited data routes and high traffic diversion rates, and the impacts then have to be done at the project-level through traffic studies; for example, doing a floating car survey of the detour routes to understand delays and speed changes or idling and stopping on the detour routes.

For the steps for estimating the VOC for the traffic flowing through the work zone, you estimate speed change cycles and idling time using traffic analysis tools; update the unit cost data used in the VOC models, which are the three approaches I suggested for using indices from BLS statistics; estimate cost impact of speech change and idling time using VOC models; and estimate the total VOC. For detour traffic the first thing is to determine additional distance traveled due to detours, and people like to look at signed detours and estimate based off of that, which is sufficient, but if there are other local roads that people are using that cannot be posted as signed detours due to DOT policy, then certainly those can also be taken into account and a more refined calculation can be made. You determine additional distance traveled due to the detour and use the VOC models to consider speed differential for detour conditions. If you wish to do that with a simpler calculation, you can use the AAA or ATRI models. The last step is to estimate the detour-related VOC.

Here are the steps for estimating crash cost, which is the next monetized cost. It is a little nascent in its use, but I have seen its use becoming more and more prevalent these days. There are five steps. The first is to determine the pre-construction crash rate for the influence area. I would like to point out that the influence area is not just the immediate work zone area, but also all other intersecting routes such as underpasses or ramps that may be affected due to the work zone. Then you establish the crash severity. We have two methods recommended in the report: one is the Capco police injury scale. We look at crash severity at three levels: personal injury, property damage, or fatalities. You can use the Capco scale or the AIS scale or a combination of both to sort the crash rate by severity. The second step is to establish this work zone crash rate, so there are the pre-construction crash rates before the work zone is set up, then you establish how the work zone modifies the crash rate. This is the weakest link in the estimation process; to understand the exact impact of the crash rate is a little difficult because not much research has been done in that and in fact we would not have suggested this but for one recent study done by Jerry Ullman from TTI, which provided some insight into typical crash modification factors related to typical work zone setups.

Once you understand your crash modification factor (CMF), it is strongly recommended that the work zone CMF be determined on the local level. Some DOTs like Ohio have looked into this. Once you have the agency-derived work zone CMF or the one suggested in the CMF Clearinghouse website (you have to take the one from the clearinghouse with a pinch of salt because that is based on limited research) and once you have a firm understanding of the CMF, you modify the crash rates due to the increased risk of the work zone and you take the pre-construction crash rate and modify it. Then you estimate the measure of work zone exposure, which is usually measured in terms of million vehicle miles traveled through the work zone area while the work zone is in place. Next, you compute the unit cost of crashes. This is another area where the only report available to quantify the unit cost of crashes is the FHWA that's mentioned here (2005). They have come up with crash cost estimates to use, or you can use agency-derived unit costs. Once you have the unit cost, exposure risk, and CMF, you can compute the aggregated work zone crash rate.

The last monetized cost is the emissions cost, and this is even less commonly used than the safety cost, but it's important nonetheless. Estimating that cost is another three step process: you estimate the emissions rate by emission type. There are different tools for estimating emissions, and the lesson of the problem here is that you have ways to model the amount of emissions due to work zones. In this case, we have two different types of models: static emission factor, which may not be very applicable to work zones, or dynamic instantaneous emission models, which can be used to estimate the quantity of emissions by emission type. Next, you determine the unit costs for emissions. You may have a little bit of a deficiency in this area; this is still an active research area there is no consensus on emissions cost, because we still don't fully understand how to quantify the impact of emissions on cost. The best available guidance today is based on the HERS-ST and Caltrans economic analysis of health impacts caused by emissions. Once you understand emissions rates and unit costs, you can determine emissions costs by multiplying the total volume of traffic by the rate and the unit cost by emission type.

The last slide I have in this section is on understanding the non-monetary or qualitative impacts of work zones. We have a discussion in the report on non-monetary costs. It is well recognized that these costs are as significant sometimes in decision-making as monetized costs. What we're talking about here are the impacts of increased noise levels due to work zones, impacts to local communities due to work zones, and there is guidance on how to quantify those impacts. In terms of noise, the FHWA's study uses noise damage costs, but those estimates are for normal operating conditions, not specific to work zones, so we do have those costs, but did not use them here. Hence, the treatment of those costs in a qualitative manner is recommended in the guide.

In summary, we have a variety of costs. The report provides guidance on estimating these costs and provides some default numbers based on national averages and makes recommendations on how to adjust those numbers for local conditions. It treats the costs and their computation holistically and looks at all possible impacts to provide the best available guidance as we understand it today.

At this point I will pause for the first round of questions and discussion before we move onto the next section.

Jennifer Symoun
Will take about five minutes and try to get to the questions that have been typed in here. Does road user cost analysis assume all road users are in motor vehicles, or are pedestrians, bicyclists and rail passengers also considered?

Jag Mallela
In this case, we are looking at mobility impacts on motorists. In terms of the impacts on pedestrians and bicyclists, these are certainly discussed on the qualitative or non-monetary side of things. For example, if there is a work zone impact on rail transit, that comes through public information meetings and gatherings and should be considered in decision-making. So, we do cover that, but not in as much rigor as costs to autos, trucks and freight.

Jennifer Symoun
The next question is: how do you quantify cost per hour value. Is this subjective?

Jag Mallela
The cost per hour value is not subjective; it is based on the OSC guidance. There's quite a bit of guidance on how to establish the cost, and that can be repeated at the local level and also at the project level if it's a very high impact project. I've seen that done.

Jennifer Symoun
Why are business impacts considered non-monetized in work zone road user cost definitions? There is a direct correlation between roadway construction and business income. Some agencies offer low or no interest loans to business owners affected by construction.

Jag Mallela
I do agree with the comment that business impacts can be monetized, but because of the difficulties involved and because of the specific nature of the impacts that are related to the project circumstances, there is no general guidance available for that computation; there is no national default, for example, of how they understand business impacts. At a local level, certainly through surveys and through the indirect economic loss calculation methodology, business impacts can be monetized also. It is a hard thing to do. On the agency side, there is a local impact on business both during construction and post-construction. The benefit should also be understood. It is a little difficult at the project level. Agencies should be careful going into that realm, as most of them are, because it is a very hard cost to compute and monetize. Certainly it can be monetized theoretically, but from a factual standpoint, it is hard to monetize.

Jennifer Symoun
Given the number of assumptions that are necessary for work zone road user cost calculation, is the additional detail provided by meso- or micro- simulation models worthwhile?

Jag Mallela
There is actually guidance in FHWA traffic analysis toolbox that meso- and microscopic simulation has a place for high complex volume. It's available on the website. Meso- and microscopic simulation, as I mentioned, is more data-intensive and does cost more money, but the payoff has to be judged at the complexity level of the project: if it is high-impact with high-impact on the users, then certainly the costs are justified. The other thing you need to look at when considering those is the application: are you using them for just understanding the impacts or are you using them to devise mitigation strategies or are you using them to come up with alternatives that will offset the cost of simulation, and things of that sort. There is actually a very nice graphic and guidance on how and when to consider them. I think the traffic analysis toolbox provide guidance for both top-level managers as well as decision-makers at lower levels on when and how to use these.

To summarize, I personally believe that meso- and microscopic simulation is certainly well-suited for high-impact projects to understand the details of the impacts and to use them in setting contracts options.

Jennifer Symoun
We have several more questions. Do you want to continue or move on at this point?

Jag Mallela
I think we better move on. We will try to record the questions. I see a bunch of them popping up here in the window, and we will try to answer those questions when we send out our e-mail announcement about the publications report. We will try to provide answers to all the questions posted. In the interest of time, we need to move on.

With that, I will step into the second part of the presentation, which is first application area that we're going to discuss today. We have a total of three different application areas we will discuss where work zone RUC can be used. The first one is application of work zone RUC in maintenance of traffic (MOT) alternate analysis. As you all know, maintenance of traffic is a set of coordinated strategies to meet the traffic mobility and safety needs within a work zone. The MOT is part of a TMP; certainly in addition the TMP consists of transpiration operations strategies as well as public information strategies. RUCs have a place in looking at alternate MOTs.

To begin, this is a quick overview of the MOT alternative analysis as we present it here. We will discuss the what: what is the process for identifying the best MOT strategy? The when: when is alternate analysis or MOT needed? The Federal Highway guidance requires MOT alternate analysis for all projects with impacts or a high level of disruption to the traveling public and communities that are greater than what is considered tolerable under the respective agency's policy and engineering judgment. Lastly, how: how to do the analysis, which is the main focus of this presentation. How to do the MOT alternative analysis, through a competitive evaluation of the potential benefits and the costs and the constraints involved. To do that comparative evaluation requires consideration of both the quantitative and qualitative aspects or impacts of the MOT and also the use of our decision analysis tool.

The rest of the discussion will focus on the decision analysis tool, but we will mix the "how" part into this as well. The decision tool that we chose to use in the MOT alternate analysis is the Kepner-Tregoe Decision Analysis framework. Although generally speaking any decision analysis tool can be used, we chose the KT method because it provides a structured systematic framework for gathering, organizing and evaluating information to make informed choices. The KT method, as some of you may know, originated from organization behavioral studies of how decisions are made within an organization. As you can imagine, by moving it over to transportation, specifically to MOT alternate analysis, the framework is very general and broad to accommodate different types of decision processes and analyses. It is a multi-criteria decision-making approach in the sense that it takes multiple criteria into account. It facilitates incorporating both quantitative and qualitative factors. It is not a black box; that is the other good thing about it. It allows flexibility for organizations to find their own criteria, evaluate against them, and select the choicest option based on engineering judgment. It does leave room for tailoring to a situation as well as defining engineering judgment.

The next a few slides illustrate the 10-step process. I will go through all 10 steps here. To make it interesting, as I go through a step I will also illustrate the step with a real-world example. When I say real-world, it really is in quote because the example we are using here is the reconstruction of the Eastern Avenue Bridge over Kenilworth Avenue in the Washington DC area, which is a FHWA Highways for Life pilot program demonstration project, but we did have to make changes. We used as much information as we could from that project, but for the sake of the illustration we made some assumptions. It should not be considered a representation of the actual project that happened there, but it is a close indication of that. It is based on real factors.

The first step in the KT Decision Analysis is to prepare a decision statement. The decision statement should clearly state the purpose of the analysis, provide focus for other steps that follow, and set limits on the range of alternatives considered in the analysis. In the case of the Kenilworth Avenue project, the decision statement was to identify the most effective MOT strategy on mainline Kenilworth Avenue during the reconstruction of the bridge piers of the Eastern Avenue, Bridge. If you look on the bottom right of the screen, you have a picture of the Kenilworth Avenue completed roadway and then we have the bridge going over it, the Eastern Avenue Bridge. It's the most effective strategy that minimizes the disruption to one of the main arteries in the DC area.

Step two in the KT processes to define the objective. You need to define the required and desired attributes; just like we all have when we go to buy a product and we have a must-list and their want-list. We need to define those. What the musts does is decide which of the alternatives gets to play, and the wants decide who wins. In terms of the must objectives, we have to specify the attributes as must objectives and go or no-go options. If an alternative or strategy does not meet the must objectivities, it's kicked out and no longer considered in the analysis. Once we have a shortlist, we evaluate them on the want objectives by using numerical weights to indicate the relative importance to each objective and screen for interdependence. I will go over that.

For the Kenilworth Avenue project, the must objectives were: does the MOT option satisfy constructability requirements? A key constraint on the project was limited work zone space on mainline Kenilworth Avenue, so any strategy that was chosen had to satisfy that constraint. The second must objective was: are there alternate routes available to accommodate full diversion? If we had a 100-person lane closure, then we needed to have an alternate route to accommodate the diversion.

In terms of want objectives, there were a number of them; we made these up here. This is where we step away from reality. We have minimizing the mobility costs due to travel delays, VOC, and work zone exposure; minimizing spillback congestion on nearby routes; reducing the crash costs; reducing inconvenience to local residents, because that particular roadway was a vital connection for pedestrians to cross over, bus transit access, and parking along service roads; providing access to emergency responders and school transportation; providing pedestrian access; reducing construction duration; and reducing traffic control costs as much as possible.

This slide shows that in defining the objectives, the focus in on work zone RUC. All the objectives stem from impact analysis and monetizing of impact analysis. Work zone RUCs play a huge role in setting the must and want objectives of a project.

One thing to avoid is having high correlation among objectives. For example, you don't want to set an objective that minimizes queue length or minimizes the work zone travel speed as well as the average delay time or delay costs, because then you're double-counting something. You want to minimize the interdependency of the variables as much as possible.

In Step Three we assigned weights to the want objectives on an arbitrary scale of 1 to 10. Weighting should reflect agency policies and project needs. Common weighting mistakes to avoid are to not use too many high weights or too many low weights, because that will result in a biased weighting scheme. For the Kenilworth Avenue project, minimizing mobility impacts and spillback congestion were important, so they were assigned high weights. Inconvenience to local residents came next, and then we had emergency response after that. Those were relatively low. Construction duration was big; the MOT should allow for quicker construction because we wanted the project to be completed quickly so the other inconveniences could be minimized, so that was assigned a relatively high rate. Traffic control cost was assigned at a rate of six. That is how the rates were assigned for this illustration.

Here are the five options that were considered in terms of the MOT scheme. The first was to close one of the three lanes in each direction on mainline Kenilworth. The second was to close one of the three lanes in each direction on mainline Kenilworth and supplement with two-lane service roads in each direction. The third option was to close two of the three lanes in each direction and supplement with a two-lane service road in each direction. The fourth one was full closure of Kenilworth and 100% diversion of traffic through a detour. The fifth one was to close one of the three lanes in each direction during nighttime only.

Those were the five options considered, and let's see how they rank. Once you have the options, you summarize the findings of the work zone impacts assessment. For each option, you do an impacts assessment and you summarize the findings in terms of constructability, detour alternatives, service roads, pedestrian access, and so on.

In Step Six you evaluate the potential alternatives against each must objective, which are the go and no-go. In this case, the must objectives are does the MOT option satisfy constructability requirements and are there alternate detours to accommodate a full diversion. If you notice, option 5, for example, failed because it did not satisfy the constructability requirements, and that was the option where we were looking at closing one of the three lanes in each direction during nighttime. That did not satisfy the constructability requirements. Option four failed to satisfy the second must objective, so the only three that are viable are options one, two and three.

Then you move to the next step, which is evaluating the want objectives against the weight that you have established. For example, here we have the listing of want objectives for the Kenilworth project. We assign a score on a scale of 1 to 10. Alternate one on a scale of 1 to 10 it only got a score of 2 because it was not conducive for mobility; mobility costs were very high from the work zone RUC analysis and computation. It only got a score of two. Option two got a score of 10, and option three got a score of 4; option four and five were not considered because they did not meet the must objectives. In assigning this score, you can actually use quantified numbers, and the point that I'm trying to make here is that some of them, like mobility and crash costs, are quantitative and those can be considered directly. Traffic control cost is another one. In addition, you can consider the qualitative factors like inconvenience to local residents, emergency response and school transportation, and pedestrian access. They can also be scored on a scale of 1 to 10.

That is how you evaluate the want objectives. In the next step, you calculate the weighted score. You know the weight for each of those from Step Two. You know the score from Step Seven. You multiply the score with the weight and you get a weighted score. When you look through, you sum them at the bottom and you get a total score. You pick an alternative that has the highest score as a tentative choice. The reason for calling it tentative is because there is an additional step involved in the process in which an alternative—even if it has a higher score—

needs to be evaluated for adverse consequences, separately for each alternative. Basically, you need to evaluate the risk associated with an alternative. You need to identify the potential risk; determine the probability of that risk occurring; determine the severity of the impacts, which is a combination of the risk and the probability of occurrence; evaluate the adverse consequences and impacts of selecting an alternative; and identify a low- and high-risk choice. The idea here is that you evaluate the consequences not comparatively, but individually. Each alternative is scored on its own in terms of risk; so for example, there are two ways of doing this. You can take option two further and evaluate the risk, and if you identify no risk or low risk or medium risk, then you carry on with that. You put risk mitigation in place and move forward. Of course, that will be a cost that you have to account for, but if it is a high risk you can still move forward after adjusting it to a mitigation measure. So in this case, option two has either a high-medium risk or low-medium; there is no high risk option to identify. Emergency evacuation was the only threat that was associated with this particular project. The probability of that happening was low-medium, and if it did happen, the severity would've been high-medium. A combination of those two did not result in a high risk all around because the probability of occurrence was small. There are risk assessment strategies through other guidance documents that can be used to score these different types of risks. In this case, option two did not qualify as a high risk option and hence it can be selected as a preferred MOT strategy.

To recap, we have the various options here, the total weighted scores for each option, the adverse consequence score, and the rank. This rank is more or less subjective because there is no numerical value associated with the total adverse consequence score, and you rank each alternative based on these two: the total weighted score and the total adverse consequence risk. Since it had the highest weighted score and the lowest adverse consequence risk, option two ranked high on an engineering judgment basis. Option two was the winner and was built into the project.

That ends this part of my presentation. I will take some questions, Jennifer.

Jennifer Symoun
We had a question specific to this part so we'll start with that and maybe go to others we missed. In Step Three of KT decision analysis, weights are identified for various impacts, but some impacts are monetized and some are not. Are weights intended to prioritize the monetized impacts relative to each other and to non-monetized impacts?

Jag Mallela
The weight actually reflects the importance of the objective to the project. The definition is not based on whether you can monetize them or not. If you don't monetize something but it is very important to the project, it will be given a higher rate. For example, if there is a project with very high public interest or opposition to a certain scheme, the weight of that in the decision-making should rate higher than the other monetized options, which may or may not be as impactful. So the weights are project specific and specific to the impact analysis that is done at the project level. They are not based on whether you can monetize them or not.

If we can press forward we can take more questions at the end.

The final part of my presentation is another application area. Actually, it's not the final part; it's the one before the final. The second application area I would like to talk about is the application of work zone RUC in contracting and project delivery.

This section has three parts. In the first, we will outline relationship between work zone RUC and completion time of highway projects—completion time being in sharp focus due to the long delays on certain major projects these days.

We provide an overview of how work zone RUC can be used in administering contracts to achieve the desired acceleration goals on a highway project. Considering that schedule acceleration to minimize work zone RUCs are most beneficial when applied appropriately to the right project, in the next part of the same section here, we will outline a questionnaire-based process that we developed in the report to identify the need to accelerate potential project schedules, because not all projects need to be accelerated. Only those that need to be accelerated should be accelerated. The questionnaire helps us answer the question of whether a project needs to be accelerated. In the final part of this section, we will demonstrate the use of work zone RUC in setting time-related contract provisions, such as incentive disincentive.

This graphic provides the relationship between work zone RUCs versus project completion time. Highway agencies are increasingly interested in shortening project delivery and managing the overall impact of construction delays and associated road user costs. This graphic tells the story in the sense that if you have delays or overruns of the project completion times, you incur additional cost. What is shown here is that work zone road user cost increases, but in reality other costs, such as agency costs, also increase dramatically in some cases. The oversight cost and construction engineering cost for agencies increases, but if you complete the project early, then you have associated benefits.

The role of work zone RUC in quantifying the costs has traditionally used liquidated damages. Liquidated damages are used in traditional contracting to recover the additional agency oversight cost incurred due to construction delay. As many reports have pointed out, the use of liquidated damages has resulted in moderate success. By themselves, they did not incentivize the contractors to complete ahead of schedule or on schedule.

Secondly, there is a significant limelight on one legal case classically known in our industry as Milton vs. State of Alabama, which is also described in a very excellent compendium put out by Federal Highway on contract administration as part of their core curriculum on contract administration. In that case, there was a sharp focus on the use of work zone RUC and delayed them to daily costs for users in setting the contract provisions based on rational analysis. The underlying purpose of mentioning this case is that the Alabama Supreme Court ruled against the State of Alabama, citing that the State did not adequately demonstrate how the contract time was established or how daily incentive/disincentive rates were related to daily work zone RUCs, and therefore they voided the contract amount. The point we're making here is not that this is a legal precedent for the ID provisions, but that RUCs should be considered and they play an important role in establishing the incentive or penalty.

Considering the importance of RUCs in contract administration, it can be applied first to identify the need for schedule acceleration and subsequently to select an appropriate strategy to achieve early, completion, which is the desired goal of many agencies. Secondly, once the strategy has been selected, work zone RUCs can be applied in establishing the time-related contract provisions for computing the incentive/disincentive fee.

So, the first part is justifying the need for schedule acceleration and selecting the appropriate project delivery strategies. Accelerating the project delivery schedule has three steps. First, you establish the need for schedule acceleration. You want to expedite projects, but recognize that expediting the project will cost money. It is not required for every project. You identify the need based project conditions and work zone road user impacts. Once you establish the need for accelerating, then you select a project delivery method. You may wonder why you select this. Selecting the delivery method defines all the roles of the agency; it defines things like the contractual roles and responsibilities of all parties involved. An agency may identify project acceleration as a viable need, but they may not have in-house capacity to achieve this goal, so they may need to go outside to find the ability with a project delivery vehicle like design build or CMGC to accomplish that goal. Once that is done, the third step is to select a schedule-focused contracting method,

Here is a question-based format for identifying the need for schedule acceleration. It is a combination of FHWA guidance and what people do at the project initiation level in understanding the need for acceleration. Here is a list of questions, and if you answer yes to the majority of these questions or some of the key questions on this list, then need is established. For example, if it is heavy traffic volume area, road user impacts are heavy if the project is delayed by traditional delivery. By accelerating the schedule, you have savings in many forms, both to the agency and to the user. We want to accelerate the schedule to minimize the impacts of various types of projects, including: urban area projects; commuter routes; routes with network level impacts; a gap in infrastructure you're trying to fill; time sensitive projects; projects with significant local community interest or political interest; projects with safety issues, both to motorists and construction workers.

The form, questions and discussion are provided in the report on setting up these questions appropriately for various projects and answering them. Once that is done, then you look at the available strategies for acceleration. You have project delivery strategies, such as traditional design-build or the CMGC method or others. These are not the only ones by any means. You also have good construction techniques. We bring in construction as well in this application because that also plays a significant role in accelerating schedules and reducing work zone related mobility and safety impacts. Even if you are using traditional project delivery, but you use a construction technique that accelerates construction, that can still be considered in analysis, as presented here. You have accelerated techniques versus cast in-place techniques. Then you have contracting methods. Some of them are listed here: liquidated damages; incentive/disincentive for early completion; A+B and Time + Cost bidding; with or without ID lane rental; no excuse incentives; interim completion; and liquidated savings. Some of these are considered experimental by FHWA, and some of these are not, like A+B. The same thing applies on the project delivery side; design-build is not considered experimental anymore.

Of these strategies, there is guidance on how to select a project delivery method focusing solely on shortening completion times. The actual selection of a project delivery mechanism obviously considers many other factors and is not just focused on shortening completion times, but in this case we're focusing narrowly on selecting a project delivery method only focused on shortening the completion time. We know that by shortening the completion time we save road user costs and other costs. Here is a table that I suggest you use. If you go through this table from left to right, in the last column you have suggested strategies for completing this work. As an example, we have a project in mind. Its size is large. Is it a routine or innovative project? It is innovative; we're trying something new here. It could be a construction technique, like accelerated bridge construction, or using a different traffic control mechanism or strategy. Is the agency certain of the design scope of the project? We know the design scope of the project well. Is the design to be performed in-house? The answer to that question is yes. Is the agency sure of the constructability? This is no; the agency is not very certain of the constructability. Is the agency confident of its early cost estimates? The answer is yes in this example. Because of the constructability answer being no, I think the assumption here is that agencies can be somewhat cautiously confident of their cost estimates, although there may be some questions in there about constructability. The suggestion strategy, if you go through this, is a design-bid-build with hiring a consultant or local contractor or trade association to provide input on the constructability of the project. If you walk through this, it gives you a first order approximation on a selected project delivery method, and note that we don't exclude the traditional method at all.

The next step is selecting a contract method. Once you have the delivery vehicle, it's selecting the contracting method within the delivery vehicle. Again, we have a metrics. You start on the left side and answer the questions. If you look to the right, you have a suggested strategy that you can use. In the early stages, when you're thinking about looking at options for project delivery strategies, this can be a good first-order approximation on what to consider.

For the baseline project duration estimate, there are two choices: short or long. In this case, it was long. Anything over maybe a construction season or even less than half a construction season can be considered long. We don't have definite guidance on what short and long is, but that is a subjective assessment. Then you get into time sensitivity. Is it a time sensitive project or do we need to open it by a certain day? In this case, no, but do we need to complete early? The answer is yes, so there is a focus on early completion. Intermediate phases: are they critical? For example, if it's a large project on intersections, you might want to consider completing those early so the impacts are mitigated. In this case, they are not critical. Are detours impractical or long? In this case, detours were impractical or long—more than 30 or 50 miles—and hence full closure was required. The owner's confidence on estimate duration to complete the project was very high. The owner is certain that it will take long in the baseline traditional scenario to complete if it is a low-cost, low-bid selection process. If you go through the matrix, the suggested strategy in this case is A+B, which focuses on completing early. It is also suggested that they use a no excuse incentive, again focusing on the early completion and the detours being impractical. We don't want to inconvenience both. Incentive/disincentive is also suggested in this case. Finally, accelerated construction techniques, as appropriate, can also be considered. This gives you a feel for what the guidance looks at.

Once the strategy is selected, how do you establish time-related contract provisions? The three contract provisions we typically focus on are incentive/disincentive, A+B bidding, and lane rental, in all three of which work zone RUCs play a significant role.

Applying work zone RUC incentive/disincentive computation: the project acceleration requires additional labor materials and equipment, and therefore costs more money. To provide real incentive to the contractor, the incentives that we select should be adequate enough to cover the contractor costs of accelerating a construction. If the incentive exceeds the work zone RUC savings, then there is no justification for acceleration. On the one side, you balance the costs that the contractor has to incur to increase productivity and complete early; you incentivize them in the truest fashion. On the other side, you look at agency savings; the incentive should not be so large that it negates the savings from lower RUCs. There is a balance there. Therefore, FHWA and most industry believe that incentive/disincentive fees should be balanced. Typically, incentives are based on work zone RUCs, as suggested in the equation at the bottom of the screen. The cost of acceleration should be less than or equal to the incentive/disincentive amount, which is less than or equal to the work zone RUC. The incentive/disincentive amount itself is calculated as a function of the RUCs by applying discount factor, by multiplying the work zone RUCs savings with the discount factor. The accuracy of the estimate of the RUC was certainly critical in doing the right incentive/disincentive.

The discount factors are essentially a portion of the RUC savings shared by the agency with the contractor for completing a project early or recovered from the contractor by the agency if the project runs over. The rationale behind the selection of the discount factor is used by many agencies (for example, New Jersey). They apply a discount factor typically from .2 to .5. The actual rationale for selecting a discount factor is the agency's decision and is largely non-documented. It could be a function of many factors, like market conditions, confidence in the accuracy of the RUC estimates, and work zone factors and other time sensitivities involved with a work zone. It can be seen as a way to match the value of the work zone RUC with the agency cost, especially if the work zone RUC estimates are very high, as is the case for high impact projects.

It is a federal requirement that total project incentive/disincentive amount should be capped at 5% of the total contract amount. That also goes into the selection of the factor.

Is there a way to determine the discount factor that is adequate enough to stimulate schedule acceleration? We attempted to answer to that question in the report; it discusses the sensitivity of the discount factor. This slide demonstrates the effectiveness of the discount factor. So what we did here was we took a hypothetical project scenario and we utilized a model for estimating the project acceleration cost that was published in the TRB publication. The authors of that paper used data obtained from 15 Florida DOT projects. Then we assumed a baseline completion of 60 days and calculated the profits and losses for various combinations of early and late completions scenarios and discount factors. In the table that you see here, we have numbers, and those numbers are actually profits and losses; a negative number means it's a loss and a positive means it's a profit in thousands of dollars.

Here are some of the key observations for this example. If you use a discount factor of 1, the agency takes no savings or losses; this is not a scenario anybody uses. At a discount factor of .1, on the other extreme, the agency recovers only a small portion of the additional cost as disincentives for late completion. It's losing out on the penalty side because it doesn't use the right discount factor. At a discount factor of .1, in a similar fashion, the agency shares only a portion of savings with the contractor as incentives for early completion. Again, this is a small portion that is shared.

The incentives to complete early go up with increasing discount factors. By using something like this, you can play with the sensitivity of the discount factor for the project and come up with a scheme that works best for your agency, and some of this is detailed in the report.

Here's an example of a Highways for Life demonstration project where we illustrate the setup of the incentive/disincentive scheme. It's a project in Virginia on I-66. Again, we modified the actual project parameters. It involved three lane closures. There were four lanes in each direction—three lanes and an auxiliary lane. Three lanes were allowed to be closed between 10 PM and 5 AM, and two between 9 PM and 5 AM. We did not consider this in the illustration; we focused on the three lane option. We used FHWA's RealCost for simulation.

The lane rental fee computation: here is a difference in daily work zone RUC for the actual project period minus work zone RUC for the allowable period. A negative difference means that if the daily work zone RUC for the actual closure is less than the allowable closure, then it has no adverse impact and no lane rental fee, and the cost includes construction engineering costs, adjusted using a discount factor.

In the case of this example, we have the allowable closure between 10 PM and 5 AM, and the first three columns here show the lane closure conditions. We have early closure, allowable closure and failure to open. The early closure is ahead of 9 PM and allowable closure is ahead of 10 PM. Failure to open is if you don't open at 5 AM, which is allowable, but you open at 7 – 9 AM.

Here's a daily RUC computation for this closure period: 1.5 million. If you take a lane at 7 PM, it goes down to 264,000, but the actual allowable is 72,000. If you fail to open early, it goes up to 360,000. This column provides the difference in the daily work zone RUC between the actual and allowable closure periods. It is zero if you're within the allowable, but if you are either close early or fail to open on time, then you accrue additional RUC, which can then be used in setting the lane rental fee.

In the slide I fail to mention that we have an estimate of the impact. If you close early, we have 16.7 miles of queues, according to our model, and the maximum delay time is shown. All of these can be actually quantified and used in setting rational criteria.

Using our estimate, then we focus on allowable closure time and additional RUC due to failure to open on time. In this case, if you fail to open by 5 AM and you do it at 6 AM, you have $220 of cost. If it is 10 PM, it's $278,000 per hour. This is with a discount factor of 1.

VDOT actually used these lane rental fees. They used $9,000 for a 6 AM opening and $28,000 going all the way up to $68,000 after that. If you use a discount factor of 1, you have these costs, but if you use variable discount rates, if you take $220 and multiply it by 0.25, you get $55. Multiply it by 0.5 and you get $110. Here's a quick comparison of how the VDOT lane rental fee compares with the lane rental fee using the various discount factors. Again, I want to emphasize that we are not trying to make a one-on-one comparison between RealCost and the VDOT process. The objective here is to show the process to compute lane rental based on work zone RUC.

In this case, if this project was not using lane rental but was using A+B bidding, what would the scenario be? If we assume that the baseline duration is 44 days and we use a discount factor of 0.25, the early completion would attract an incentive for the contractor. If he has to complete in 44 days and he completes in 39, then 5 days are saved and he gets an incentive of $90,000, using a discount factor of 0.25. This table illustrates how to compute incentive/disincentive. On the other side, if he fails to open on time and is 5 days behind, he gets a $90,000 penalty. It is a balance incentive/disincentive scheme based on RUC.

The final application of work zone RUC is in benefit-cost analysis, and the reason we thought it was important to put it in here is because there is increased emphasis today on early completion. People are trying different strategies, either contracting methods or construction methods, in trying to accomplish the goal of early completion. A lot of times the question is asked: does doing something innovative to complete early cost more money to the agency? Does it save money to the user? What is the extent of the savings? All of these questions need to include RUC as integral part of the overall economic analysis. That is well-demonstrated actually in the FHWA Highways for Life pilot program, which looks at various construction innovations to get projects done faster and better and cheaper and safer. In that program, there have been several demonstration projects that use an innovative delivery method, contracting strategy or construction technique, or a combination of all three to accomplish the desired goals of the program.

Benefit-cost analysis plays a huge role in justifying adopting innovation. When you do the benefit-cost analysis, you need to be fair on both sides .You need to look at agency costs: all the costs for design engineering, construction, mobilization, traffic control, law enforcement, and additional incremental costs due to applying innovation. Then, you need to look at delay costs on the other side: what are the savings from implementing the innovation?

Here is an example from a project in Council Bluffs, Iowa, for improvements to the 24th St. Bridge over a major I-29/I-80 interchange. In this case, there was a need to accelerate the construction. The cast-in place option would have taken two construction seasons, or 426 days to complete. Iowa DOT decided to use an accelerated process using A+B bidding as well as pre-fabricated bridge elements systems, or the ABC method, to complete the project in 175 days, or less than one season. They did incur an incremental cost, as you see at the bottom of the blue table. The agency costs were $11.1 million for the cast-in place traditional scenario and $12.5 million for the accelerated construction. They incurred an additional cost of $1.4 million in this case, but when you look at the RUC, which includes both the mobility impacts and safety impacts and the savings associated, there are $2.4 million in savings, with a net savings on the project of $1.01 million saved due to the adoption of the innovation. Another thing to say about innovation is that as people get more comfortable with a certain contracting strategy, project delivery method or construction technique, we have seen the incremental cost of innovation go down.

With that, I think that concludes my slide presentation. We can open up for any questions, and I thank you for your attention. I do apologize for going over.

Jennifer Symoun
We had one new question come in: how would performance-based MOT contract specs fit into this decision process for project acceleration?

Jag Mallela
That is a very classic example; it's a Highway for Life pilot demonstration project. It's documented and available on the Highways for Life website; there's a project summary for the Michigan M-115 project if person asking the questioning interested in referring to that. Basically, performance-based MOT strategies are an excellent way to administer contracts. The whole approach of that particular project was performance-based contracting, and as part of the performance measures they selected, they had mobility measures and safety measures. The desired goals included that they shouldn't have a delay time of more than 10 minutes through the work zone that that their crash rates should not exceed the pre-construction crash rate. These were loaded into their contract documents. The contractors picked up on that and they delivered the project and collected incentives for meeting and exceeding the goals. For example, if they had a baseline travel time and there was delay associated with travel time, then they had a disincentive, but if they beat the travel times or met expectations then they had incentives on that project. In that way, they were able to consider directly the mobility impacts and the costs associated into the contract.

Jennifer Symoun
We have some additional questions. Is there a strategy for incorporating RUC into design-build contracts?

Jag Mallela
Actually, that's in the earlier part of my presentation where we talked about the using RUC or the surrogate RUC, which is the need to complete early, in the decision process and of selecting an appropriate delivery method. If you look at the chart, it does tie into selecting a project delivery method and selecting a method based on RUC.

In evaluating design-build contracts, there are many criteria that are in the RFP, and one of the main criteria is scheduled performance. If you look at it from that angle and you understand the scheduled performance and you understand the scope to complete early, and the bids come in focusing on schedule, because that's an evaluation criteria that gets tied into selection of the contract delivery method.

Jennifer Symoun
Will the reference documents be available from the FHWA website?

Jag Mallela
There are two documents. There's our base document on which this webinar is based, which is the "Work Zone Road User Costs: Concepts and Applications." It should be available on the website, and we will be it mailing out the link to that website to all the participants on this webinar once the document is released. They will be alerted to the availability of the document. The same document will also reside in a very concise form in FHWA Traffic Analysis Toolbox. There will be a new volume, called volume 12, and it will have condensed information from the baseline report that I just mentioned. Both are to be released in December.

Jennifer Symoun
Has RUC analysis been used in public-private partnership decisions?

Jag Mallela
To my knowledge, they have been used. I cannot tell you on exactly which projects.

Jennifer Symoun
Are you including the cost of extra travel time along a detour in the VOC for detours?

Jag Mallela
Yes, the VOC itself looks at the vehicle cost, but the delay due to detour is also accounted for in the delay cost computation. It is a double whammy.

Jennifer Symoun
How do these equations compare to those in the ASSHTO Red Book?

Jag Mallela
The equations in the AASTHO Red Book are based on the NCHRP 133 Report. They are the same. We provide additional resources in this report.

Jennifer Symoun
Are there recommended conversion factors for converting peak hour delay to daily delay?

Jag Mallela
Not to my knowledge, because that is a site-specific issue, and I think the Traffic Analysis Toolbox addresses that.

Jennifer Symoun
What percentage does emission costs add to RUCs?

Jag Mallela
It is unknown at this point. Right now, the debate is on the unit cost for emissions. The only unit cost data we have is based on health impacts. As we all know, emissions are a result of regulation policy as well as traffic congestion. So, it is not just mobility impacts and the density of population that decides where the work zone is situated. I have seen excellent recent

research, and they are doing a national study for the US EPA. Nick Muller is the author, and they are doing a county-based emission impacts for most of the United States. It is called the APEPE model, for those who are interested. It seems quite promising.

As far as a percentage, it depends upon the density of the population; it depends on the project budget constraints. That sounds like a wishy-washy answer, but it can be quite significant in high-density, high-volume population locations. It is a valid concern, at least on a qualitative basis.

Jennifer Symoun
Are all components of the work zone RUC based on Delta user costs (i.e., the difference between RUC during work zones and RUC during normal operating conditions)?

Jag Mallela
Yes, because the impacts are based on normal operating conditions.

Jennifer Symoun
Two more questions have come in. I am going to combine them. What are the plans for upcoming additional work zone RUC research, and is there software to simplify the use of work zone RUC?

Jawad Paracha
We are exploring ways on how to approach this. We do think there is a need for a tool, but there are some other efforts going on within the FHWA, and the plan is to sit down with them and see what the best approach for going forward is. There is a operations benefit-cost analysis tool and tools from infrastructure, there's RealCost, which was mentioned during the webinar. The plan is to actually see what is the best approach to develop a tool that takes into account the concepts that were discussed in today's webinar. There will be something, but we don't have a definitive answer this point.

Jennifer Symoun
Okay. I think that addresses all of the questions at this point. I think we can go ahead and close out for today. Today's webinar was recorded, and I believe the recording will be posted online in the next few weeks. We will send an e-mail out once those are available. Jawad and Jag, do you have any closing remarks?

Jag Mallela
I appreciate this opportunity and I thank everybody for participating and asking excellent questions. If there are more questions, I have provided our contact information on the screen.

Jawad Paracha
Thank you to everyone for participating and staying longer than we had planned. Feel free to send us any questions. We will get back to you when the documents are published and available online. Thank you very much.