ROAD USER IMPACTS DUE TO SPEED LIMIT REDUCTION IN WORK ZONES WHICH TOOL IS BEST: QUICKZONE OR VISUM?

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ABSTRACT

The Utah Department of Transportation (UDOT) ExpressLink project on I−15 will increase capacity by adding express lanes in each direction from 500 North to I−215 ramp in Davis County, Utah. These express lanes will help ease the commute between Salt Lake County and Davis County. The construction requires planning work zone activities in such a way that user delay costs are minimized. Any lane reduction will increase congestion. So, UDOT instead of closing lanes will reduce both speed limits and lane widths. The paper presents an evaluation of UDOT's procedures for deriving the user delay costs due to reduced speed limits. UDOT user delay procedures are compared to estimates from two common simulation tools (VISUM and QuickZone (QZ)). The reliability of results from these tools depends upon the type of field conditions assumed. QZ results are reliable when detour traffic conditions are neither available nor assumed in the field due to work zones. VISUM provides accurate estimations, if there are detours. The UDOT's own procedure delivers results that are commensurate with those from QZ. In contrast, the paper shows how trip assignment modeling, through VISUM, is justified when a network provides drivers with alternate routes and diversionary paths.

Keywords: Work Zone, QuickZone, VISUM, Modeling, Delay Costs, User Impacts.

BACKGROUND

Over recent years, the number of reconstruction and rehabilitation projects has increased significantly due to increased travel demand and need for maintaining the highway infrastructure. With the increased road rehabilitation projects, reducing congestion and delay caused by work zones and improving mobility is more important than ever. According to research by the Federal Highway Administration (FHWA), about one-quarter of nonrecurring motorist delay is attributable to work zones, which are cited as second only to poor traffic flow as a source of traveler dissatisfaction (*1*). Highway work zones are costly: the actual construction and user delay. Slower speeds in work zones increase travel times and create localized bottlenecks. This increases costs because extra time and fuel are needed to traverse the work zone. These costs are substantial. As long ago as 1993, the financial loss was $51 billion (*2*). Today highway agencies quantify work zone related costs and investigate methods to reduce them, which is critical to successful work zone management. Road User Costs (RUCs) are essentially incurred by drivers due to reduced travel speed and capacity at work zones. RUCs include added vehicle operating costs and delay costs to highway users resulting from construction, maintenance, or rehabilitation activity. The RUCs are a function of the timing, duration, frequency, scope, and characteristics of the work zone, as well as the volume and operating characteristics of the traffic affected (*3*).

In Utah, the Utah Department of Transportation (UDOT) plans to add a northbound and a southbound Express Lane on I−15 from 500 North in Salt Lake County to I−215 in Davis County: the EXPRESSLink. The project will increase the capacity of I−15 by adding Express Lanes in each direction. The construction requires planning the work zone activities in such a way that the delay costs are minimized for road users. Any lane reduction due to the construction zones will result in substantial congestion. So, UDOT intends to reduce the width of the existing lanes and reduce the speed limit to either 45 mph or 50 mph, instead of closing lanes.

UDOT's procedures were assessed for calculating the user delay costs, with and without detour conditions, and due to reduced speed limits. Current UDOT's user delay procedures are compared to estimates from two simulation tools (VISUM and QuickZone). The delay costs are derived for both 15 and 20 mph speed reductions. Delay costs are provided for both detour and non-detour scenarios. The main goal of the paper is to refine the choice of tools to enable realistic work zone impacts.

A brief literature review is followed by the key methodology. Next we present the analyses based on QZ, VISUM and UDOT's standard procedure. The results from each analysis are summarized and discussed. We conclude with statements that address the goal of the paper.

LITERATURE REVIEW

There is a wide variety of approaches and methods that address user costs, in the literature. Ellis et al., (*4*) summarized six methods to calculate user costs: simple formulae, spreadsheets, high-level software, AASHTO red book method, flat rates and no formal method. Jiang et al., (*5*) developed a new microscopic computational model for estimating freeway work zone traffic delays and total work zone cost optimization using Boltzmann-simulated annealing neural network and optimization techniques. However, it does not model the impact of detours. Chitturi et al., (*6*) have presented a numerical methodology based on equations for computing delays and user costs in highway work zones. Chien et al., (*7*) presented a simplified and useful model for estimating the delay cost using the ADT and finding the optimum work zone segment length in a four-lane freeway with one lane closure. Jiang (*8*) developed a model for estimating the user costs at work zones. He showed that during congestion at work zones, delay costs of vehicle queues contributed to the total user costs. In an attempt to determine the user delay costs for a typical Ontario work zones, Huen et al., (*9*) evaluated the significance of delays and associated delay costs for a construction zone using predetermined models. Results showed that the magnitude of delay is directly related to the volume of daily traffic and the number of lanes in the facility. Memmott et al., (*10*) studied the effects of different lane closures strategies (one-, two-, or three-lane closures) in one or both directions of travel and the additional costs to users traveling in a highway work zone. Their model, Queue and User Cost Evaluation of Work Zones indicated that accuracy of cost calculations increases by using hourly instead of daily traffic volume. Saito et al., (*11*) compared four computer tools that determine user costs: MicroBENCOST, QuickZone (QZ), Delay Enhanced (Delay-E), and DUCK (Delay User Costs and is a simple Excel spreadsheet). They recommended that DUCK cost should be used for projects where the delay is caused by a reduction in speed while Delay-E should be used for projects where the source of delay stems from queues forming due to demand exceeding capacity. Najafi et al., (*12*) concludes that there is a need for user-friendly software applicable to work zone evaluations.

The literature shows that there is a wide variety of studies dealing with the evaluation of user costs related to work zones. Approaches vary from focusing exclusively on the work zone delay and user costs to evaluation by computer models. Generally, most studies that deal with the estimation of user costs derive the magnitude of delay and user costs on freeway work zones using different computational models (*4-10*). However, every model has its own limitations and assumptions that are inherent to its computational technique. Studies on the evaluation of software tools show that different software packages works under specific conditions (*11*). Some of these models have no option to reduce the capacity on the links due to speed limit reduction. QZ and VISUM are two exceptions that have options to reduce the capacity by lanes and number of vehicles, which is necessary for reducing speed limits.

METHODOLOGY

QZ is an analytical tool that estimates and quantifies work zone delays. A small program within Microsoft Excel, QZ assigns travel demand on an hourly basis to estimate delay and queue length. QZ accommodates both time of the day utilization and seasonal variation in travel demand. The delay is estimated using a simple deterministic queueing model for each link in the work zone impact area. The network in QZ can have up to 200 links and 100 nodes (*13*). So, QZ's network limitation restricts its ability to model detours. VISUM is a software system for transportation planning, travel demand modeling, network data management, and can be used to investigate work zone strategies (*14*). VISUM assigns link volumes based on the given Origin-Destination (OD) matrices. It is a broad based planning tool that can be used for larger networks. It provides a wide variety of assignment procedures, such as equilibrium, dynamic user equilibrium and incremental. Here, VISUM is used to model user costs for detour conditions. The methodology to estimate the delay costs is shown in the Figure 1.

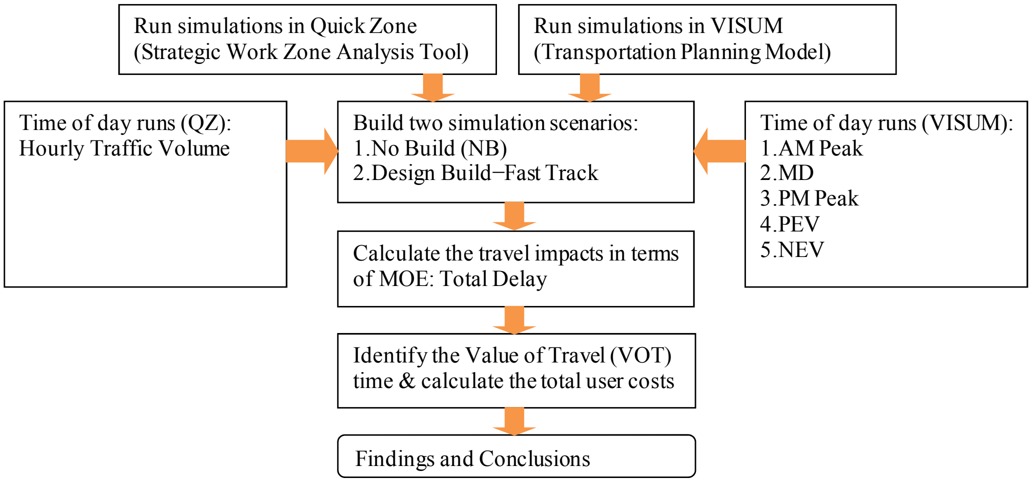

FIGURE 1 Flow Process of Methodology for Assessing User Delay Costs.

Work Zone Analysis in VISUM

Figure 2 shows the VISUM network for the Salt Lake City region with the current project corridor encircled.

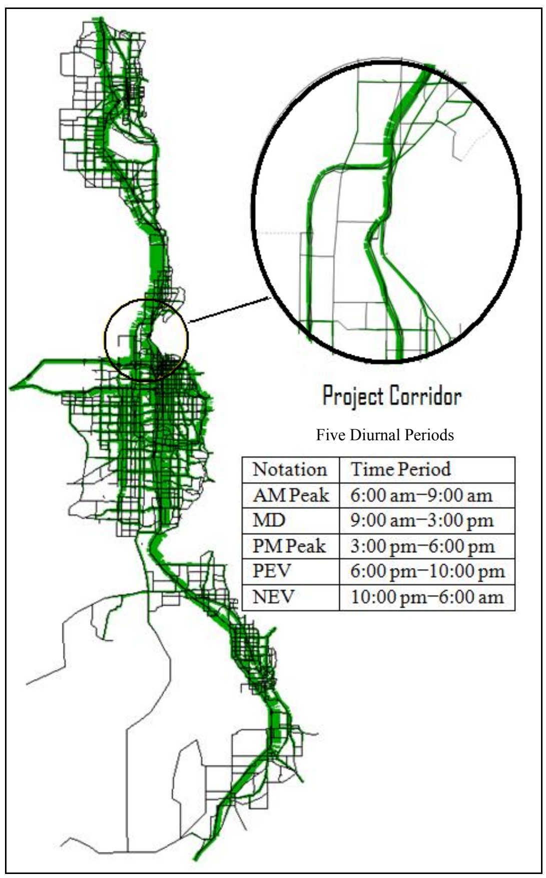

FIGURE 2 Original VISUM Network and Five Diurnal Periods.

VISUM transportation planning models address five diurnal periods: AM, MD, PM, PEV and NEV. The geometry of the networks is common. However, the traffic demand in each network changes from one model to the next.

The Highway Capacity Manual (HCM) derived the reduced capacities due to speed limit reductions (*15*). Figure 3 shows the relation between speed and capacity. Although this graph shows the reduced capacities due to different weather conditions, each condition is associated with a different flow speed. This graph is used to relate speeds to their reduced link capacities.

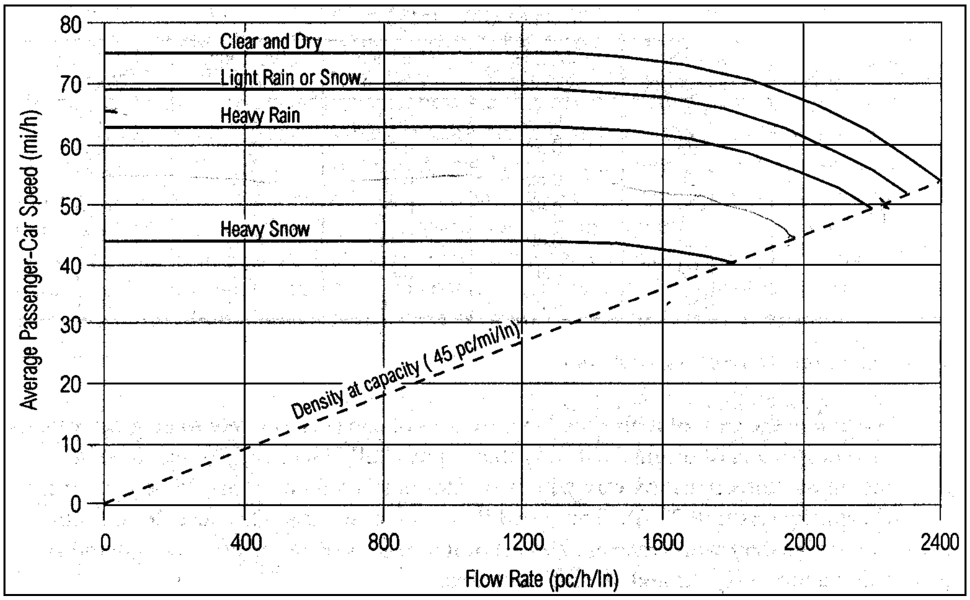

FIGURE 3 Reduced Capacities due to Reduced Speeds.
(Source: HCM 2000, Exhibit 22-7, Page 22-12)

The total network travel time in terms of Vehicle Hours Traveled (VHT) was calculated, before making any changes to the network. The adjustment factors due to reduced lane widths, shoulder closure and percent of truck traffic were obtained from HCM 2000 (*15*). From the graph it was estimated that the capacity decreases from 2250 to 1850 and 1800 vphpl when the free flow speed is reduced by 15 and 20 mph respectively. The combined reduction factors, for 15 and 20 mph speed reductions are 0.67 and 0.65 respectively.

The capacities of all links in the work zone were multiplied with the total combined reduction factor to provide the new capacities. These new capacities and the reduced free flow speeds were entered in the link properties of VISUM. All the other links properties were left unchanged and the analysis was run to find out the new total network travel time. The network was simulated with speed reductions for each direction separately, to reflect construction schedules. The traffic assignment in VISUM was run using the User Equilibrium method so that traffic demand between each OD pair is assigned according to the capacities available for each route. In this procedure, the originally assigned demand on links changes as VISUM assigns different routes based on available capacities. On completion of the assignments, the new VHT was recorded. The increased total network VHT, which is the difference between the original and later cases, was then calculated. The same analysis was repeated for the other four models and then the total daily delay travel time was calculated.

Work Zone Analysis in QuickZone

QZ requires several data inputs:

1. Network data (nodes and links) and their attributes
2. Annual Average Daily Traffic Data (AADT)
3. Hourly truck traffic proportions
4. Demand patterns
5. Seasonal variations of the traffic demand
6. Schedule of the project
7. Cost parameters − Value of Travel (VOT)

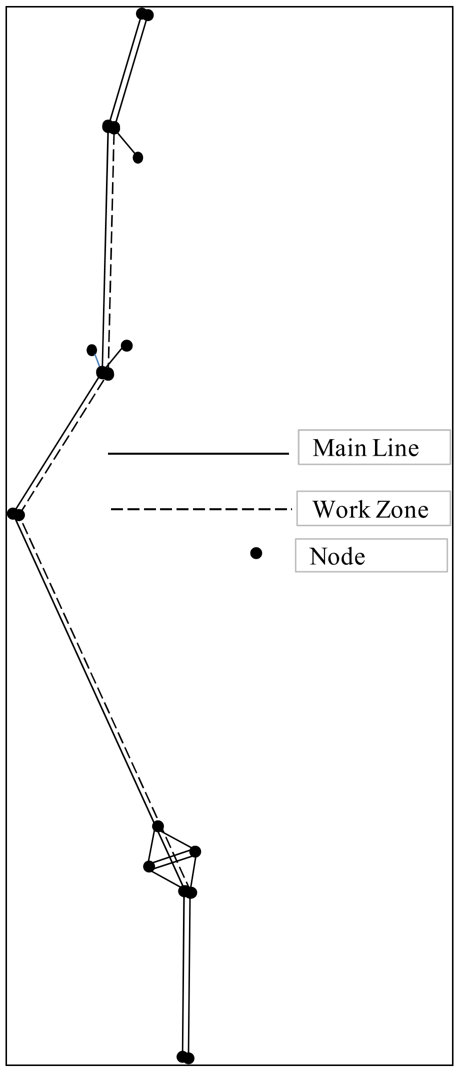

FIGURE 4 Network of the Project Corridor in QuickZone.

Figure 4 shows the QZ network with both Mainline (without work zones) and Work Zone links. QZ needs hourly traffic volume, with separate truck traffic volume, for each link and each day in a week. The freeway Performance Measurement System (PeMS) serving UDOT's Salt Lake Metro Region supplied hourly traffic volume (*16*). PeMS can collect, filter, process, aggregate and examine traffic data. The data collected includes continuous measurements recorded by vehicle detectors and tag readers. The Value of Travel (VOT) time per hour was taken as $20.09 which is based on Texas Department of Transportation (TXDOT) guidelines (*17*). QZ contains a different input module for truck traffic data so delay costs can be calculated separately. PeMS was used to collect this data which has the facility of extracting data for both weekdays and weekends. As the construction of additional express lanes in each direction requires at least 6 months, the seasonal demand variation has a substantial impact on the final estimated delay costs. So, the seasonal demand patterns were also collected from PeMS. As the North Bound (NB) and South Bound (SB) reconstruction was scheduled for different periods, the analysis was separated into NB and SB work zones. As in the VISUM analysis, HCM provided reduced capacities.

Work Zone Analysis by UDOT

UDOT estimated the approximate delay costs using Microsoft Excel spread sheets which are essentially based on Delay-E. UDOT calculated the average daily user costs due to speed reductions of both 15 mph and 20 mph. However the delay costs were calculated for the entire project instead of calculating separately for both NB and SB work zones.

TABLE 1 Daily User Costs Estimated by UDOT

	15 mph Reduction	**20 mph Reduction**
Speed Limits (mph)		
Unrestricted Running Speed		
Cars	65	65
Trucks	55	55
Restricted Running Speed		
Cars	50	45
Trucks	40	35
User Costs ($)		
Unrestricted Cost	313,718	313,718
Restricted Cost	410,161	457,089
Total Daily User Cost	96,443	143,371
Traffic Data (for both 15 and 20 mph reductions)		
Traffic Volume (AADT)	124,946	
Percent Trucks	8.5%	
Passenger Car VOT (/Hr)	$20.09	
Trucks VOT (/Hr)	$20.09	
Length of Segment (Miles)	8	

Table 1 shows the calculations included for different speed limits for trucks and passenger cars. The vehicle operating costs were calculated for both original and reduced-speed conditions and the difference between them gives the total daily user costs. The traffic volume for the project corridor is assumed to be a single value, ignoring directional and temporal variations.

RESULTS

Figure 5 shows the comparison of daily user costs between 15 and 20 mph speed limit reduction scenarios for the total project (including NB and SB). After estimating the user costs from QZ and VISUM, the results were compared with the delay costs calculated by UDOT in order to verify that the costs were relatively accurate and reliable. Figure 6 shows the summary of estimated delay costs using VISUM, QZ and UDOT data for various lengths of the project.

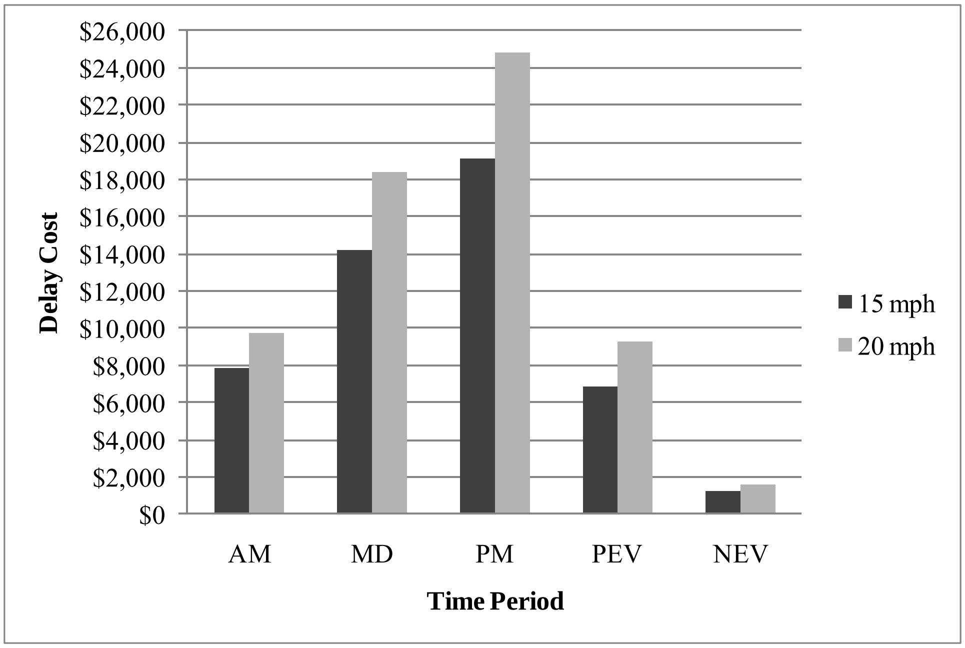

FIGURE 5 Daily User Delay Costs from VISUM

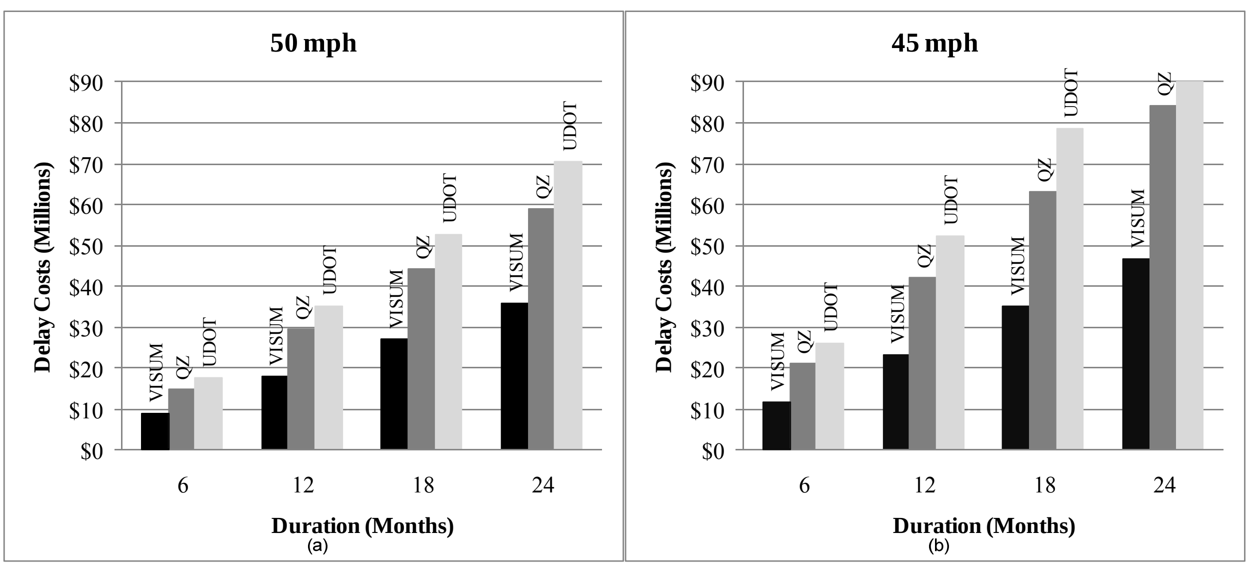

FIGURE 6 Summary of Projected User Delay Costs from VISUM, QZ and UDOT
(a) 15 mph Speed Reduction (b) 20 mph Speed Reduction

The daily user delay costs in VISUM were estimated for both NB and SB work zones. Results obtained through the analysis were projected for 6, 12, 18 and 24 months using a linear relationship. Then the total project costs were obtained by adding the individual NB and SB delay costs.

The delay costs in QZ were estimated for both NB and SB work zones. Results obtained through the analysis include total delay costs for 6, 12, 18 and 24 months. The total project costs were obtained by adding the individual NB and SB delay costs.

CONCLUSIONS

In this paper we described a work zone plan for the construction of additional lanes on a freeway segment. The plan reduces the speed limits, instead of closing lanes on both directions of travel. A simple estimate of the daily user delay costs delivers results as reliable as QZ. A much more complex traffic assignment model is applied to the same problem. Based on the simulation results and comparisons we reached the following conclusions:

1. The QuickZone analysis shows that the estimated user delay costs are nearer to the user delay costs estimated by Delay-E method; for simple networks with no detours.

2. If a work zone plan needs detours, an assignment analysis, with a tool such as VISUM, is appropriate.

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