Estimating User Costs and Economic Impacts of Roadway Construction in Six Federal Lands Projects

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The Federal Lands Highway (FLH) Division staff faces myriad challenges when designing roadway construction projects for roads located on federal lands. An increasingly prevalent challenge is considering not only the "hard" costs of a construction project (e.g., labor and materials) but also the "soft" costs of user delay and the economic impacts on roadway users (e.g., residents, visitors, staff, and local businesses). These soft costs affect every roadway construction project but rarely are considered in design and operation because they often are difficult to estimate and justify. FHWA's 1998 report *Meeting the Customer's Needs for Mobility and Safety During Construction and Maintenance Operations* identifies this issue and recommends that engineers begin to address it, for small- as well as large-scale projects. As part of its responsibility to promote the development and deployment of applied research, FLH staff initiated the development of FLH–QuickZone to help estimate these soft costs of roadway construction. As part of its development, FLH–QuickZone was tested and prototyped in six FLH construction projects: three in national parks, two on forest highways, and one in a national recreation area. Where FLH–QuickZone fits in a spectrum of other estimation tools for work zone delay and how it was used in the six FLH roadway construction projects are summarized. Observations about the challenge of addressing the soft cost of roadway construction projects—with FLH–QuickZone or other analytical tools—also are presented.

The Federal Highway Administration (FHWA), through cooperative agreements with federal land agencies [e.g., National Park Service (NPS), U.S. Department of Agriculture (USDA) Forest Service, Military Surface Deployment and Distribution Command, U.S. Fish and Wildlife Service, and Bureau of Indian Affairs], administers a coordinated federal lands program. Collectively known as federal lands roads, this program consists of forest highways, public lands highways, park roads and parkways, refuge roads, and Indian reservation roads. This program provides technical support (e.g., planning, design, and construction oversight) for more than 90,000 mi of federally owned and public authority–owned roads that serve federal lands (*1*).

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Use has increased tremendously on many federal lands roads, especially those in heavily traveled recreational areas and U.S. national parks. For example, since NPS began in the early 1900s, the number of visitors has increased from a few hundred thousand to more than 270 million in 2005 (*2*). Concurrent with increased use, only 35% of NPS roads are estimated to be in good condition, whereas the remaining 65% are in poor to fair condition (*3*). Although equivalent statistics are not available for other federal lands roads, a similar observation about increasing demand and deteriorating road conditions can be made.

As more federal lands roads are reconstructed, Federal Lands Highway (FLH) engineers will face a unique challenge to ensure that reconstruction does not adversely affect road users. Because many federal lands roads have become integral to their local economies, FLH engineers must account for not only the "hard" costs of a construction project (e.g., labor and materials) but the "soft" costs of user delay and the economic impacts on users that are associated with roadway construction. These soft costs affect every roadway construction project but are rarely considered in design and operation because they are often difficult to estimate and justify. The 1998 FHWA report *Meeting the Customer's Needs for Mobility and Safety During Construction and Maintenance Operations* identified this issue and recommended that engineers begin to address it for small- as well as large-scale projects (*4*). For FLH staff, it means considering user costs and the economic impacts of many types of users, including residents, commercial vehicle operators, visitors, staff, businesses, federal agencies (e.g., the national park), and the local economy. *User costs* refer to extra time spent on detours or the time spent waiting in congestion resulting from work zones. *Economic impacts* refer to revenue losses for a local business or gateway community, because concerns over delays resulting from roadwork may reduce visitation.

To help address the soft cost of roadway construction and as part of its responsibility to promote the development and deployment of applied research, FLH staff at Central Federal Lands Highway Division (CFLHD) initiated the development of FLH–QuickZone to help FLH staff estimate the soft costs of roadway construction. FLH–QuickZone can be used by FLH planners and engineers in the planning, design, and operation of roadway construction projects (*5*). As part of its development, FLH–QuickZone was tested and prototyped in six FLH construction projects: three in national parks, two on forest highways, and one in a national recreation area.

This paper summarizes where FLH–QuickZone fits in a spectrum of estimation tools for work zone delay and how FLH–QuickZone was used in the six FLH roadway construction projects. It concludes with observations regarding the challenge of addressing the soft cost of roadway construction projects, through the use of FLH–QuickZone or other analytical tools.

WORK ZONE MODELING SPECTRUM

FLH–QuickZone, one of many tools available to planners and engineers to address work zones, is illustrated in Figure 1 (*5*). On a continuum from simple to complex, 10 tools currently available that could be used to address the soft costs of roadway construction projects are illustrated in the spectrum. Sketch planning and analytic tools are simpler, whereas regional travel demand models (TDMs) and general purpose traffic simulations are more complex.

Before selecting a specific work zone modeling tool, one should consider five model selection criteria: functionality, results, time, training, and cost. Choosing a tool generally requires a trade-off among these five criteria. Functionality (i.e., capability to represent specific work zone attributes) and results (i.e., precision of analysis) are critical, because the tool would not be useful—regardless of the cost, training, or time applied—if it could not analyze a specific situation or provide the necessary results to the precision or accuracy required.

In some instances, such as when a project is in the construction phase, the timeliness of results may be critical. The time and resources required to rapidly assemble the required data and calibrate a simulation tool generally are much longer than to use a sketch planning tool. The need for timeliness must be balanced against the ability of the sketch planning tool to provide a precise solution that accurately reflects the problem under study.

Finally, the training and cost associated with a particular tool should be considered. Simulation tools often require a high level of expertise and training—skills that are possessed by a few individuals or consultants and can be costly to acquire. In contrast, many of the sketch planning and analytic tools are more accessible, can be mastered by a broad range of staff in a short time, and are inexpensive to purchase.

FLH–QuickZone represents one set of trade-offs among these five criteria and is not appropriate for all work zone applications. An analytic tool, FLH–QuickZone has more functionality specific to the analysis of work zones than HCS 2000 but is not as detailed as CORSIM or other traffic simulation tools. The results of FLH–QuickZone are calculated by link and by hour. This type of time-based granularity is similar to other work zone analysis tools, such as QUEWZ-98; however, FLH–QuickZone performs this level of analysis for one or many interacting work zones and estimates impacts over time, accounting for changes in traffic control and travel demand that can vary by day, week, or phase. This flexibility makes FLH–QuickZone a good choice when many work plans (which often span two or more construction seasons) must be evaluated. Although they can directly represent a wider range of work zone attributes, simulation programs require a significant investment of time and resources to build and analyze.

FLH–QUICKZONE

The development of FLH–QuickZone began in fall 2003 (*5*). FLH–QuickZone was customized for FLH and is based on the QuickZone v2.0 work zone delay estimation tool. QuickZone (and FLH–QuickZone) is a Microsoft Excel–based program that can be used to model various work zone configurations to estimate impacts that include queuing, user delay, and economic impacts. QuickZone offers many features, such as the ability to analyze multiple work zones in a corridor; optimization of two-way, one-lane operation; and a module for analyzing user costs and economic impacts (*6*).

QuickZone requires inputs that describe seasonal, day-of-week, and hour-of-day variations in travel demand and vehicle mix to calculate projected hourly travel demand (in passenger car equivalents). Demands are compared with roadway capacities on a series of links leading up to and through one or more work zones. Capacities for work zone links can be calculated internally (using HCM procedures) or estimated externally (*7*). Travel demand in excess of link capacities is held as queued vehicles to be served (along with additional arriving demand) in the next period. Sequential work zones are modeled using an inflow–outflow model (i.e., upstream work zones meter demand for downstream work zones). Additional details, including a complete algorithmic statement, are available (*6*).

To understand better the needs associated with a customized version of QuickZone for FLH, four initial case study analyses (Beartooth Highway, Montana–Wyoming; Louis Lake Road, Wyoming; Zion

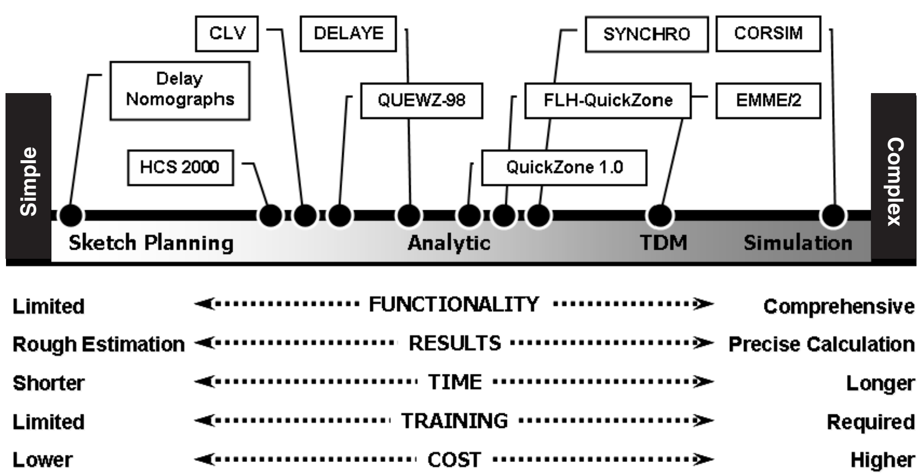

FIGURE 1 Work zone modeling spectrum. Terms in boxes are names of modeling tools used to model work zones.

National Park, Utah; and Yosemite National Park, California) were conducted in which QuickZone could be used to help FLH staff make decisions regarding the construction project. By using these case studies, developers were able to work with FLH staff to determine the needs and requirements of a customized version of QuickZone. On the basis of these four initial case studies, an initial prototype FLH–QuickZone was created that specifically addresses the unique needs of FLH associated with work zone delay and queue length estimation.

Although FLH–QuickZone uses the underlying QuickZone algorithm, it also includes a tailored analysis of user costs and economic impacts specific to FLH applications. The FLH–QuickZone analysis of user costs and economic impacts is more robust than other versions and expands on the components of user delay to account for trip purpose, vehicle operating costs, inventory costs (trucks), and local economic impacts. Although user delay is precisely measured over the entire project, local economic impacts are simplified and are based on reductions in traffic flow and other factors external to the program (e.g., business revenue).

MODEL VALIDATION

One important aspect of developing any new modeling tool is validation of the results against real-world conditions. The FLH–QuickZone validation effort focused on the ability to accurately predict queue length and delays under two-way, one-lane operations.

FLH–QuickZone was validated on the basis of queue length, flow, and delay data collected in conjunction with NPS staff at Glacier National Park (Montana) (*5*). In August 2005, NPS collected data at a two-way, one-lane work zone with flaggers along the Going-to-the-Sun-Road (GTSR) in Glacier National Park. Summer students collected data in two 3-h periods at the direction of NPS staff. Vehicle counts, delays, and queue lengths by flagging cycle were recorded in both directions. Statistics for these measures were aggregated to generate hourly ground truth values for the two model inputs (work zone capacity and travel demand variation) and model outputs (delays and queue length).

The accuracy of FLH–QuickZone, uncalibrated (using a priori estimates of flagger efficiency and demand) and calibrated (using ground truth travel demand and flagger efficiency parameters), was assessed. The uncalibrated model overstated average and total hourly delays and queue lengths by roughly 20% because the a priori estimates about how quickly the flaggers were able to safely conduct operations were too conservative. The calibrated model was far more accurate and understated queue length by less than 5% compared with ground truth (i.e., errors related to the FLH–QuickZone assumption of uniform travel demand arrival). These validation results were consistent with other QuickZone validation efforts in urban settings.

FEDERAL LANDS PROJECT SUMMARIES

To ensure that FLH–QuickZone could be used in various situations, six case studies were developed detailing how FLH–QuickZone was used to capture the soft cost of the roadway construction projects:

- Beartooth Highway. Major reconstruction required full closure and flagging operations of this scenic two-lane rural road throughout several construction seasons. The use of detour routes was generally infeasible throughout the length of the project. FLH–QuickZone was applied to quantify the expected total delay through multiple work zones and investigate whether concurrent flagging operations would generate unacceptable delays.
- Louis Lake Road. Major reconstruction of the entire facility required full closure of this two-lane rural road for long durations. A relatively long but feasible detour route was considered. FLH–QuickZone was used to assess delays and detour route use during construction and to address local concerns about economic impacts.
- Delaware Water Gap National Recreational Area (Pennsylvania). A relatively high-volume rural road that runs through this national recreation area was studied. FLH–QuickZone was used to assess the impact of roadwork on commuters and park visitors and to determine whether a proposed detour route was a viable option.
- Zion National Park. Planned milling and paving work around a primary entrance station was considered. FLH–QuickZone was applied to assess the likely extent of queues spilling back into a nearby gateway community.
- Glacier National Park. A planned multiyear rehabilitation of the GTSR—a scenic roadway that is one of the key attractions within the park—was considered. FLH–QuickZone was applied to assess the potential cumulative delays from multiple work zones over a multiphase project.
- Yosemite National Park. Recurrent delays occur on the scenic road leading to Yosemite Village, even without construction. FLH–QuickZone was applied to evaluate delays associated with two alternative construction plans: a season-long full closure and a more traditional maintenance-of-traffic approach conducted over two seasons.

Table 1 lists a summary of work zone characteristics of each case study (*5*).

Beartooth Highway: Multiple Work Zones

CFLHD has been working with the USDA Forest Service and Yellowstone National Park to reconstruct an 18.6-mi section of the Beartooth Highway that has not been rebuilt since its construction in 1936. This scenic alpine highway is a popular destination roadway for travelers, including many in recreational vehicles far larger than the original designers had anticipated. The reconstruction project will consist of upgrading the current roadway with improvements to the alignment, grade, and width of the road.

The construction season for Beartooth Highway is limited; the highway is closed from November to May each year because of heavy snowfall. Gateway communities and local businesses near the highway were concerned that construction on this scenic two-lane highway would cause major delays for and trip avoidance by the local public and vacationers, resulting in serious economic impacts. The motivation for using FLH–QuickZone was to evaluate a series of four distinct but sequential flagging operations near the Beartooth Ravine, which is part of the proposed 18.6-mi section. Key information that FLH staff sought from a FLH–QuickZone analysis included a quantitative estimate of anticipated delay under peak travel (and other) conditions for travelers encountering all four work zones.

Results of the analysis revealed that no single flagging operation caused major delay; however, the four flagging operations in series combined to produce delays large enough to be considered significant to local stakeholders. This finding was an important one to convey, because the local public and businesses are unused to congestion

TABLE 1 FLH–QuickZone Case Study Overview

	Project Life Cycle[a] (P D C)	FLH–QuickZone Analysis Key Observations			Key Measures of Effectiveness	Traffic Control Elements
		Motivation	Impact	Finding		
Beartooth Highway		Address local concerns of overall construction impact on multiple concurrent work zones.	No single flagging operation caused major delay problems. Combination of four work zones did produce unacceptable delay.	A series of concurrent work zones can be quickly evaluated without using complex simulation models.	User delay (total) Saturated delay Vehicles in queue	Periodic full closures Two-way, single-lane operations
Louis Lake Road		Address local concerns on the economic loss and delays associated with a series of work zones and lengthy detour.	Public relations around work zones can be effectively mitigated when quantified estimates of delay are presented.	Various traffic control strategies can be effectively modeled using FLH–QuickZone.	User delay (maximum) User delay (total) Economic impacts	Periodic full closures Two-way, single-lane operations Long detour at 50 km (31 mi)
Delaware Water Gap National Recreational Area		Differentiate possible delays between commuter traffic and weekend visitors.	Multiple sources of demand data can be utilized to fill in gaps where few or no data are available.	Demand information can help identify potential congestion issues by time of day and day of week.	User delay (maximum) Vehicles in queue	Two-way, single-lane operations Detour
Zion National Park		Address local concerns on entrance station refurbishment and resulting queue lengths.	Quantitative estimates of impacts to both the park and visitors were determined, motivating project staff to seek alternative work zone designs.	Project specific capacity elements can be easily modified in FLH–QuickZone.	Queue length Vehicles in queue Economic impacts	Partial closure
Glacier National Park		Estimate end-to-end delays during a multi-year roadway rehabilitation of interacting work zones	Impact of congestion mitigation strategies can be quantified to justify their deployment.	Visitation databases can be used to rapidly develop robust multi-year travel demand predictions.	User delay (maximum)	Two-way, single-lane operations
Yosemite National Park		Address user delay impacts of a proposal to shorten construction duration.	Identified a single-season construction schedule, reducing impacts to visitors and total project duration/costs.	Using FLH–QuickZone early in the project life cycle can motivate its use and refinement in subsequent project phases.	User delay (total)	Partial closure Long-duration full closure Two-way, single-lane operations

[a]P = planning; D = design; C = construction.

and have relatively low tolerance for work zone delays. The FLH–QuickZone analysis results indicated a consistent (peak and off-peak) expected delay of roughly 14 min (in addition to an uncongested travel time of 25 min)—a potential source of concern because frequent users of the road are accustomed to free-flow conditions. This analysis helped FLH staff develop maintenance and traffic specifications consistent with public expectations.

Louis Lake Road: Local Economy

Louis Lake Road links the town of Lander to the Shoshone National Forest in Fremont County, Wyoming. This narrow two-lane gravel road carries increasingly large traffic volumes as more visitors are drawn to the national forest. Louis Lake Road provides the most direct access to an abundance of recreational opportunities. Increasing interest in the recreational opportunities provided along Louis Lake Road indicates a potential for local economic growth in the form of lodging, restaurants, outfitters, and other businesses and services.

A great amount of public concern was raised over the economic impacts on the area during construction, and CFLHD used FLH–QuickZone to address these concerns. Because the road is such a vital link in the area, Lander residents were concerned that real and perceived delays associated with the work zones or detours would deter vacationers, and in turn, local businesses would lose revenue. FLH–QuickZone was applied to provide evidence to local stakeholders that the work zone phasing and traffic control plan developed for Louis Lake Road was the best available option in terms of minimizing user delay throughout the project. Furthermore, it allowed FLH engineers the opportunity to shape local expectations about delays predicted (by hour) over the course of the project and to help travelers better plan their trips.

The analysis also was used to examine two traffic control alternatives: one with access maintained throughout but with sequential flagging operations (referred to as the flagging operation) and another featuring a series of periodic full closures of the facility with a signed detour (referred to as full closure). Under the flagging operation, estimated road user delays accumulated throughout the project were $688,000, comprising passenger car user delay ($652,000 = 27,651 h × $23.58/h) and truck delay ($36,000 = 1,467 h × $24.53/h). Full closure was estimated to have lower user costs ($43,000) and to result in a combination of increased travel time and vehicle operating costs for vehicles taking the detour. Economic impacts from the decrease in road volume on Louis Lake Road during full closures were estimated at $9,000. This amount was calculated on the basis of local tax receipts to estimate business loss proportional to the decrease in traffic. Overall, the combined user costs and economic impacts of the full closure alternative were found to be lower than the flagging operation alternative.

Although the costs were lower in the full closure alternative, a key observation was that the different costs were borne by different stakeholders. The flagging operation had significant user delay costs borne by travelers but no economic impact on businesses (i.e., because the flow of vehicles on Louis Lake Road would be maintained, it was assumed that traffic volume would not drop). The quantification of user costs and economic impacts was used to help FLH determine when flagging operations and full closures might be allowed and to better understand the potential impacts on travelers and businesses in the area.

Another benefit of the FLH–QuickZone analysis was the ability to examine the feasibility of the construction specification prepared by FLH engineers. The specifications provided specific allowances for the frequency and times of day the road could be closed and the maximum allowable delay for a traveler traversing the project area. This analysis assisted FLH engineers in developing traffic control plans and specifications that reduced project costs.

Delaware Water Gap: Commuter Traffic

US-209 runs through the Delaware Water Gap National Recreational Area, located in eastern Pennsylvania, between the cities of Stroudsburg and Milford. It provides an alternate route for many area commuters despite the park entrance fee. The Eastern Federal Lands Highway Division (EFLHD) is working with the National Park Service to modernize a 6.5-mi section of US-209 to meet new highway standards. The goals of the project include improving pavement conditions, eliminating poor sight distances, and updating inadequate shoulders and bridge crossings while minimizing impacts to park visitors.

EFLHD decided to evaluate traffic conditions within the park before construction and to estimate the likely impacts the proposed work zone activity would have on travelers. FLH staff wanted to address two areas of concern:

- The impact of commuter traffic on the timing and phasing of reconstructing US-209 and
- The effect of instituting a temporary bypass around a bridge so that it may be replaced.

An analysis of travel demand data showed that commuters using US-209 as a connection between Stroudsburg and Milford would not cause any problems for construction phasing during the week; weekday demand is significantly lower than on the weekend. The demand data analysis demonstrated that the low volume during the winter months, which is approximately half that of the summer peak, would allow for the work zone to stay up during this time with little impact on park visitors and commuters. The FLH–QuickZone analysis indicated that the capacity of the proposed temporary bypass would be insufficient to accommodate the estimated detour volume and thus was eliminated from consideration.

Zion National Park: Queue Length

CFLHD worked closely with staff of Zion National Park to design a construction plan to rehabilitate the main route through the park, beginning at the south entrance. This entrance is used by approximately 90% of park visitors to access the park and consists of two visitor entrance lanes, one employee lane (controlled by a radio-frequency tag system), and one exit lane. During peak season, the recurring queue can extend as much as 0.25 mi from the entrance gate along Utah Route 9 toward the town of Springdale.

The proposed rehabilitation improvements included roadway reconditioning, milling and paving, roadside drainage, and bridge repairs. The park was concerned about the additional queuing and visitor delay at the south entrance as a result of construction and the potential impact on the gateway town of Springdale, approximately 0.5 mi from the south entrance; Zion National Park did not want queues to extend into Springdale. A queue of this length would affect not only visitor and business traffic in town but also employees getting to the park and the shuttle bus service operating from town to park.

The original work zone plan closed one visitor entrance lane at a time for construction. FLH staff needed to estimate the length of the queue and number of vehicles in it if one of the two visitor entrance lanes were to be closed. Construction was estimated to last 1 month for both lanes and would occur sometime between June and October.

Results of the FLH–QuickZone analysis indicated that queues would form long enough to affect the town of Springdale in each of the 5 months analyzed (*5*). These results were deemed unacceptable by FLH engineers, who began considering alternative work zone plans, including making the employee lane available to all visitors and performing the work at night. On the recommendation of FLH engineers, the park selected the nighttime work alternative.

Glacier National Park: End-to-End Delays

Located in Glacier National Park, the GTSR is a prime attraction for park visitors and the only east–west link within the park. Completed in the 1930s, the scenic 50-mi roadway traverses the park and provides access to the Logan Pass Visitors Center from the St. Mary's (east) entrance or the west entrance. Although portions of GTSR are open throughout the year, in the higher alpine sections, the roadway is closed and often snow-covered throughout the winter months. The roadway offers the visitor numerous incredible vistas as well as access to trailheads and other facilities along its length. The GTSR itself and facilities along its length are the destinations of most vehicles visiting the park.

The GTSR is slated for an extensive 7- to 8-year rehabilitation project, during which time visitation is projected to remain constant. Because the GTSR is a key reason for visiting Glacier National Park and no alternative route is available, the roadway must remain open throughout the project. The steep terrain, the complexity and duration of the work to be performed, and the limited construction season for roadwork in the summer (coinciding with peak visitor travel demand) were factors to be considered in the planning stage to determine whether the GTSR Rehabilitation Project could be completed in a timely manner while maintaining an acceptable level of delay to visitors. NPS, Western Federal Lands Highway Division (WFLHD), and local community representatives reached an agreement before the study that outlined the extent to which GTSR closures and delays would be tolerated. One key tenet of this agreement was to limit end-to-end delays on the GTSR in one direction to no more than 30 min (total).

The role of FLH–QuickZone in the GTSR Rehabilitation Project was to assess likely travel delays (particularly the end-to-end delays from multiple work zones) expected over the course of the multiyear project. Because the project was in a relatively early planning phase at the time, numerous assumptions were made regarding roadwork phasing and staging. Given the outline of a likely phasing plan and expected traffic control that WFLHD developed, FLH–QuickZone was used to identify projected delays and queue length over the course of the project. It also was used to assess the likely effects of actuated signal control for two-way, one-lane operations as well as the impact of reduced travel demand. Reduced travel demand was projected during roadwork as a result of the new park shuttle system.

In the analysis, eight alternatives were coded and examined using FLH–QuickZone (Table 2) (*5*). The eight alternatives combine four expectations for reduced travel demand with the use of fixed-time or actuated signal control. The various reductions in demand are from two potential sources. The first reflects an estimate in the EIS that the presence of major roadwork will cause overall GTSR travel demand to decline by approximately 6%, and the second is a planning level target by planners to reduce travel demand by 2% to 7% by shifting visitors into shuttle buses. In Table 2, the –8% and –13% demand reduction cases reflect a combination of general decline (–6%) with the high and low estimates of shuttle bus demand shift.

For GTSR analysis, two critical measures of effectiveness had to be considered, both related to the designation of a delay of 30 min or more in either direction as "unacceptable" throughout the project. To describe the worst delay seen in a given construction phase, "maximum user delay" was used. This measure reflects the longest possible delay on the GTSR from all work zones encountered in one direction. During two-way, one-lane operations, the assumption implies that some unlucky traveler will arrive at a work zone to experience the longest wait possible in that period. The second measure of effectiveness is the number of hours per week that the maximum delay exceeds the 30-min threshold in one or both directions. This measure provides insight into how long unacceptable delays are in effect throughout the week.

Results of this planning-phase analysis of the GTSR revealed that the base alternative (Alternative 1 in Table 2) regularly resulted in unacceptable delays during both nighttime and daytime work zone operations. Actuated signals (Alternative 2) are predicted to reduce delay greatly, given the high variability of travel demand expected during the course of the project. If actuated signals cannot be reliably implemented, then a fixed plan that varies by time of day also could

TABLE 2 GTSR Alternatives Evaluated with FLH–QuickZone

			Work Zone Traffic Control	
	Alternative	Travel Demand	Weekday Day, 7a.m.–7p.m.	Weekend (all hours) and Weekday Night, 7p.m.–7a.m.
1	Base	2004 level	Flaggers	Fixed time signals
2	Actuated signal	2004 level	Flaggers	Actuated signals
3	–6% demand	–6%	Flaggers	Fixed time signals
4	–6% dem + actuated	–6%	Flaggers	Actuated signals
5	–8% demand	–8%	Flaggers	Fixed time signals
6	–8% dem + actuated	–8%	Flaggers	Actuated signals
7	–13% demand	–13%	Flaggers	Fixed time signals
8	–13% dem + actuated	–13%	Flaggers	Actuated signals

be implemented to mitigate delays, but such a plan has not yet been evaluated. Signal actuation alone is not enough to eliminate unacceptable delays during July and the late summer peak, particularly in 2011 and later, when construction intensity would be at its peak (travel demand would exceed the capacity of the expected work zones, regardless of signal timing).

The reduction in demand is effective in reducing daytime delay during flagger operations but has no effect on night operations when fixed-timing plans are in place (Alternatives 3, 5, and 7). This effect is highest with the −13% demand case and somewhat lower in the other two cases. Overall, the demand reduction is a critical factor only when the expected seasonal travel demand is highest (July); in other months, the delay from the flagger operations is often at acceptable levels. Combined with −13% reduced demand (Alternative 8), actuated signals eliminate unacceptable delays in all phases except for in July 2011, when five concurrent work zones are in place. Overall, other mitigation measures beyond those studied here will need to be considered if all potential instances of user delay exceeding 30 min are to be eliminated. The analysis confirmed the WFLHD engineers' intuition that the base plan would exceed acceptable delay and underscored that a fixed-timing approach for traffic signal control was not viable.

Yosemite National Park: Construction Alternatives

Yosemite National Park is one of the most popular national park destinations in the nation, averaging more than 40,000 visitors through its entrance gates daily throughout the year (*2*). One of the primary entrance destinations for park visitors is Yosemite Village, the primary hub of activity within the park and home to the Valley Visitors Center, lodging and dining options, trailheads, and other visitor services.

The shape of Yosemite Valley makes access to Yosemite Village scenic for the park visitor but limiting for a traffic manager. Given the steep terrain around the valley, the only roadways into and out of Yosemite Village are Northside and Southside Drives. Both facilities are primarily two-lane, one-way facilities with stop-controlled intersections along their lengths and at two bridge crossings. The roads routinely experience significant recurring weekend congestion and delays during peak travel months.

These two key valley roadways were scheduled for a significant repaving and rehabilitation project starting in 2006. Concern regarding significant delays in the construction phase led CFLHD staff and NPS personnel to consider a range of phasing and staging alternatives. The first alternative considered was an alternating full-closure plan in which work would be conducted on Southside Drive first, while all traffic would be directed onto Northside Drive (temporarily configured to support two-way traffic), then Northside Drive would be closed and all traffic diverted onto Southside Drive. The advantage of this alternative was that the project could be completed faster (in one season) and at a lower cost. The disadvantage was that capacity reductions from the roadwork had to be in place around the clock and could not be timed to avoid weekly and daily peaks in travel demand.

A second alternative was to pursue project planning under a more traditional approach, whereby one lane of each facility would be repaved while the other remained open to traffic. This approach would allow for work to be suspended during peak demand hours but would be less efficient to conduct, lengthen the project duration to two seasons, and incur additional costs.

The first (single-season) alternative was estimated to provide some cost savings and shorter total duration but also was predicted to generate long and unacceptable delays (more than 30 min without construction and more than 90 min with construction) for park visitors, particularly on weekend afternoons during the summer months. The second (two-season) alternative produced no more than 10 min of additional road user delay per vehicle. The difference in road user delay between the single-season and two-season alternative appeared too large to justify the reduced cost of the single-season alternative.

A review of the results clearly indicated that the full-closure elements of the single-season alternative could be viable if the delay during the peak months of July, August, and September could be avoided. In response, FLH staff developed a hybrid third alternative that combined full closure during the months with relatively low demand (March to June and October to November) with traditional one-lane paving operations during the peak summer months.

ADDRESSING SOFT COSTS

In *Traffic Analysis Toolbox Volume I: Traffic Analysis Tools Primer,* FHWA provides guidance on the opportunities and challenges of using the modeling tools presented in Figure 1 (*8*). The six case studies summarized in this paper reinforce many of these issues, regardless of whether FLH–QuickZone or any other modeling tool or approach is used. When using such tools to address the soft cost of roadway construction projects,

- Become familiar with the quality of data versus the accuracy of results. As with any modeling tool, higher-quality data will produce results that are more accurate; however, expensive project-specific data collection is not always required to obtain the required results accuracy. For Zion National Park, good-quality park visitation records were used to estimate the demand and capacity of the facility.
- Preferably, use an incremental approach. When the soft cost is considered, the analysis does not have to be as complex as the one for Glacier National Park or as simple as the one for Zion National Park. The best approach is an incremental one, whereby higher-quality data are collected, a more-accurate modeling tool is used, and higher-precision results are required as the project becomes more complex. This way, resources can be committed as the results are calibrated and validated in the field, and more trust is placed in the results.
- Understand the need to conduct a sensitivity analysis. Modeling tools are sensitive to many of the input data. It is important to understand which of these data are most important on the basis of the key measures selected. In many situations, all data required for a project will not be easily accessible; therefore, knowing which data should be most accurate is important. It can easily be accomplished through a sensitivity analysis.
- Know the various measures. All modeling tools calculate some measures that are important to a given project and some that are not, and FLH–QuickZone is no different. In some cases, user costs (e.g., total delay and length of queue) are the key measures and economic impacts are less important. Identifying the key measures for a specific project is critical so that the required data can be collected and the results interpreted.
- Devise new work zone designs. Use the modeling tool not only as an analysis tool but also as a design and operational tool. For example, FLH–QuickZone was used to make the argument for a

different operational strategy (conduct night construction for Zion National Park) and a new phasing and staging plan tailored to travel demand patterns (hybrid alternative for Yosemite National Park) to reduce user costs and economic impacts.

CONCLUSIONS

User costs and economic impacts will become a larger part of all roadway construction projects. As FHWA identified, these soft costs affect every roadway construction project but have not been consistently considered or integrated into the FLH project planning and design process for every project because of the lack of methods and tools to account for them. The six case studies presented in this paper provide an overview of one approach that FLH staff has used to account for soft costs: the FLH–QuickZone work zone delay modeling tool.

The six case studies are unique and highlight different aspects of analyzing user costs and economic impacts using FLH–QuickZone. They also illustrate that construction planning means dealing with different stakeholders, some of whom have competing interests. Because of the analyses, the design and operation of the roadway construction was optimized to mitigate user costs and economic impacts as much as possible in many of the case studies.

An important aspect of accounting for the soft cost of roadway construction projects is selecting or justifying the need for an analysis. For the six case studies, the motivation to conduct the analysis varied and was not based on a set formula or criteria; however, some commonalities were noted. First, projects with significant public visibility are most often the ones considered important enough to warrant an analysis of user costs and economic impacts (e.g., Glacier National Park). Second, for projects with high visibility but low demand, local concern about the impacts of roadway construction on the local economy is significant (e.g., Louis Lake). Many national parks also are concerned about the user costs associated with delays that affect park visitors and their experiences. Third, some projects have such high visibility that they have potential political ramifications as well as user costs and economic impacts (e.g., Beartooth Highway and Glacier National Park).

Given the available resources in terms of time and funding, not all roadway construction projects warrant a detailed analysis of user costs and economic impacts using analytic tools. To flag potential projects, a more systematic method of selecting projects for analysis and the progressive use of more refined data and complex models should be developed. Project characteristics that include size, traffic volume, and visibility are all useful in determining the need for an analysis; however, as many of these case studies demonstrate, responding to local concerns is also a logical method for determining which projects are analyzed, regardless of the project characteristics.

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