Transportation Management Plan Effectiveness Framework and Pilot

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16. Abstract This report was prepared to help practitioners formulate and follow clear, consistent approach towards assessing the effectiveness of Transportation Management Plan (TMP) strategies. The report provides an inventory of the measures-of-effectiveness (MOEs) that each of the TMP strategies may affect at a particular work zone, depending on the characteristics of that work zone and other TMP strategies that are used. An overall framework is presented to guide analysts on the available approaches towards TMP strategy effectiveness evaluations, possible scopes of those evaluations, and potential analytical methods. A synthesis of evaluations is also for those TMP strategies for which previous and current literature and data were available.			
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EXECUTIVE SUMMARY

A Transportation Management Plan (TMP) lays out a set of coordinated transportation management strategies and describes how they will be used to manage the work zone impacts of a road project. The scope, content, and level of detail of a TMP may vary based on the State or local transportation agency's work zone policy, and the anticipated work zone impacts of the project. In some cases, a regional TMP may be developed to better mitigate the combined effects of several projects occurring within a corridor or roadway network.

Ideally, a practitioner developing a TMP would choose those TMP strategies that provide the best benefit-to-cost effect in terms of mitigating work zone impacts. Unfortunately, information on the actual effectiveness of many of the TMP strategy is lacking. TMP strategies attempt to mitigate impacts by:

- Increasing the amount of traffic-carrying capacity through the work zone or on alternative routes.
- Performing work that reduces capacity when traffic volumes are lower.
- Encouraging additional travel diversion away from the work zone beyond what would have happened otherwise.
- Reducing traveler surprise to unexpected conditions and features.
- Encouraging safer driving behavior through the work zone.
- Reducing the consequences of an errant vehicle leaving the travel lane relative to what would have happened if the mitigation strategy had not been employed.
- Reducing the consequences of crashes that do occur.
- Reducing other worker accident risks by providing more work space in which to operate.
- Reducing the duration of the work zone.
- Reducing public frustration and anxiety about the work zone.

Consequently, different measures-of-effectiveness (MOEs) are needed to evaluate the effectiveness of different strategies. In general, TMP strategies can be evaluated through one or more of the following MOE dimensions:

- Mobility.
- Safety.
- Customer satisfaction.
- Agency and contractor productivity and efficiency.

Many strategies affect MOEs in more than one of these dimensions, regardless of whether they are implemented specifically to mitigate work zone impacts within that dimension. Consequently, the effectiveness of multiple TMP strategies implemented at a work zone will often confound each other to generate an overall effect on impacts at that location. In some cases, methods do exist to dissect the influence of individual TMP strategies, but these typically require data from multiple projects and more advanced analytical techniques.

Multiple ways exist to assess whether a TMP strategy had some type of effect on one or more measures used to assess work zone safety and mobility impacts, specifically:

- Qualitative assessments.
- Quantitative assessments.
- Some hybrid of the two.

Meanwhile, assessments of TMP strategy effectiveness can also vary in scope. Common evaluation scopes include:

- Full-scale evaluation of all strategies on a project.
- Agency-wide evaluation of a single TMP strategy.
- Research evaluation of a single strategy implemented by several agencies.
- Case study of a single strategy at one location.
- Process review.

Ultimately, the selection of MOEs to use, assessment approach, and assessment scope varies depending on the question the practitioner is trying to answer, such as:

- Do we think this TMP strategy (or set of TMP strategies together) had some type of effect upon mobility, safety, customer satisfaction, and/or agency or contractor productivity and efficiency? In simplest terms, do we think this strategy was "effective?"
- How much of an effect did this TMP strategy/set of strategies have upon mobility, safety, customer satisfaction, and/or agency or contractor productivity and efficiency MOEs?
- How does the effectiveness of this TMP strategy/set of strategies upon mobility, safety, customer satisfaction, and/or agency or contractor productivity and efficiency vary as a function of differences in roadway, traffic, and work zone characteristics?

The challenges posed in assessing the effectiveness of TMP strategies to mitigate work zone impacts are particularly noteworthy. If introducing a work zone on a route adversely affects operating conditions on the route to a significant degree, a certain percentage of drivers will choose to alter their trip-making behavior by departing at a different time, changing their route, or perhaps even changing their choice of travel mode. This will occur even if no TMP strategies to encourage those changes are implemented. Conversely, the number of travelers modifying their trip-making behavior will affect how significantly the work zone itself affects operating conditions on that route. This same type of circular relationship between changes in trip-making decisions and the resulting operating conditions will also exist on alternative routes in the corridor. Therefore, strategies that attempt to also affect trip-making decisions and behaviors need to be measured not against what was happening before the work zone was introduced into the corridor, but rather measured relative to what would have occurred had the strategy not been implemented.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

OVERVIEW OF TRANSPORTATION MANAGEMENT PLANS

A Transportation Management Plan (TMP) lays out a set of coordinated transportation management strategies and describes how they will be used to manage the work zone impacts of a road project. The scope, content, and level of detail of a TMP may vary based on the State or local transportation agency's work zone policy, and the anticipated work zone impacts of the project. In some cases, a regional TMP may be developed to better mitigate the combined effects of several projects occurring within a corridor or roadway network. The requirements and guidance on developing and implementing TMPs exists elsewhere. [1,2]

Although TMPs are required for all federal-aid projects, those projects deemed as "significant" require a comprehensive TMP consisting of the following:

- A temporary traffic control (TTC) plan to address traffic safety and control needs through the work zone.
- A traffic operations (TO) component to address sustained operations and management of the work zone impact area (which can extend a substantial distance away from the actual project location).
- A public information (PI) and outreach component to address communication needs with the public and concerned stakeholders.

Under each of these items, two to four categories of strategies have been identified to help mitigate the impacts of the work zone. For example, three categories of strategies have been identified for possible use when developing the TTC plan:

- Project control strategies.
- Traffic control strategies.
- Project coordination, contracting, and innovative construction strategies.

Two categories of strategies have been identified for the public information and outreach component of the TMP:

- Public awareness strategies.
- Motorist information strategies.

Finally, four main categories of TO component strategies could be considered for implementation:

- Demand management strategies.
- Corridor/network management strategies.
- Work zone safety management strategies.
- Traffic incident management and enforcement strategies.

Within each of these categories, 11 to 19 individual strategies exist which could be implemented to help mitigate the safety and mobility impacts of a work zone. Table 1 through Table 3 present a compilation of the various strategies that can be used to mitigate work zone impacts. [2]

Table 1. Transportation Management Plan Strategies by Category – Temporary Traffic Control (TTC) Plan. [(2)]

Control Strategies	Traffic Control Devices	Project Coordination, Contracting, and Innovative Construction Strategies
• Construction phasing/staging • Full roadway closures • Lane shifts or closures ○ Reduced lane widths to maintain number of lanes (constriction) ○ Lane closures to provide worker safety ○ Reduced shoulder widths to maintain number of lanes ○ Shoulder closures to provide worker safety ○ Lane shift to shoulder/median to maintain number of lanes • One-lane, two-way operation • Crossover • Reversible lanes • Ramp closures/relocation • Freeway-to-freeway interchange closures • Night work • Weekend work • Work hour restrictions for peak travel • Pedestrian/bicycle access improvements • Business access improvements • Off-site detours/use of alternative routes	• Temporary signs ○ Warning ○ Regulatory ○ Guide/information • Changeable message signs • Arrow panels • Channelizing devices • Temporary pavement markings • Flaggers and uniformed traffic control officers • Temporary traffic signals • Lighting devices ○ Flashing lights on signs, channelizing devices ○ Sequential warning lights [a]	• Project coordination ○ Coordination with other projects ○ Utilities coordination ○ Right-of-way coordination ○ Coordination with other transportation infrastructure • Contracting strategies ○ Design-build ○ A+B bidding ○ Incentive/disincentive clauses ○ Lane rental • Innovative construction techniques (precast members, rapid cure materials)

[a] Strategy added since publication of (2).

Table 2. Transportation Management Plan Strategies by Category – Public Information (PI) and Outreach Component. (2)

Public Awareness Strategies	Motorist Information Systems
• Brochures and mailers • Press releases/media alerts • Paid advertisements • Public information center • Telephone hotline • Planned lane closure website • Project website • Public meetings/hearings • Community task forces • Coordination with media/schools/businesses/emergency services • Work zone education and safety campaigns • Work zone safety highway signs • Ride promotions • Visual information (videos, slides, presentations) for meetings and web	• Traffic radio • Changeable message signs • Temporary motorist information signs • Dynamic speed message signs • Highway advisory radio (HAR) • Extinguishable signs • Highway information network (web-based) • 511 traveler information systems (wireless, handhelds) • Freight travel information • Transportation management center (TMC) • Work zone intelligent transportation systems (ITS) [a]

[a] Strategy added since publication of (2).

Table 3. Transportation Management Plan Strategies by Category – Traffic Operations (TO) Component. (2)

Demand Management Strategies	Corridor/Network Management Strategies	Work Zone Safety Management Strategies[a]	Traffic/Incident Management and Enforcement Strategies

• Transit service improvements
• Transit incentives
• Shuttle services
• Ridesharing/ carpooling incentives
• Park-and-ride promotions
• High-occupancy vehicle (HOV) lanes
• Toll/congestion pricing
• Ramp metering
• Parking supply management
• Variable work hours
• Telecommuting
	• Signal timing/coordination improvements
	• Temporary traffic signals
	• Street/intersection improvements
	• Bus turnouts
	• Turn restrictions
	• Parking restrictions
	• Truck/heavy vehicle restrictions
	• Separate truck lanes
	• Reversible lanes
	• Dynamic lane merge system
	• Ramp metering
	• Temporary suspension of ramp metering
	• Ramp closures
	• Railroad crossing controls
	• Coordination with adjacent construction sites
	• Work zone ITS to provide real-time delay and travel times
		• Speed limit reduction/variable speed limits
		• Temporary traffic signals
		• Temporary traffic barrier
		• Moveable traffic barrier
		• Crash cushions
		• Temporary rumble strips
		• Intrusion alarms
		• Warning lights
		• Automated Flagger Assistance Devices (AFADs)
		• Work zone ITS to provide queue warning [b]
		• Project task force/committee
		• Construction safety supervisors/inspectors
		• Road safety audits
		• TMP monitor/inspection team
		• Team meetings
		• Project on-site safety training
		• Safety awards/incentives
		• Windshield surveys
			• ITS for traffic monitoring/management
			  ○ Use of permanent systems
			  ○ Temporary work zone systems [b]
			• Transportation management center (TMC)
			• Surveillance (closed-circuit television, detectors, probe vehicles)
			• Helicopter for aerial surveillance
			• Unmanned drones for aerial surveillance [b]
			• Traffic screens
			• Call boxes
			• Reference location signs
			• Tow/freeway service patrol
			• Total stations/photogrammetry
			• Coordination with media
			• Preplanned local detour routes
			• Contractor support for incident management
			• Incident/emergency plan coordinator
			• Incident response plan
			• Dedicated (paid) police enforcement
			• Cooperative police enforcement
			• Automated enforcement
			• Increased penalties for work zone violations

[a] Several of these strategies could also be considered for inclusion in the TTC plan

[b] Strategy added since publication of (2).

Some strategies are relatively minor in cost and implementation effort required, whereas others are more costly and require much more effort to implement. Many of the strategies listed under the TTC plan -Traffic Control Devices category are actually required through national and state standards, although some work zones might benefits from additional devices above and beyond the minimums called for in those standards. In some cases, the effectiveness of a strategy is independent of the implementation of any other strategies. However, in many other cases, the effectiveness of a particular strategy is dependent upon other strategies that are implemented. In addition, many strategies can have similar effects upon driving behavior, and thus similar potential mitigation benefits, under certain roadway, traffic, and work zone conditions.

CHALLENGES TO DEVELOPING WORK ZONE TRANSPORTATION MANAGEMENT PLANS

Ideally, a practitioner developing a TMP would choose those mitigation strategies that provide the best benefit-to-cost effect in terms of mitigating work zone impacts. This would be done in conjunction with an impacts analysis performed as part of the TMP development process. [(3)] Unfortunately, information on the actual effectiveness of many of the TMP strategy is lacking. Very few agencies evaluate how well their impacts analysis results compare to what actually happens in the field, let alone assess how well the mitigation strategies employed affected the impacts of the work zone. Even for those strategies for which some assessments have been performed, the methods used and measures-of-effectiveness (MOEs) evaluated have varied widely, making it difficult to draw conclusions about how well the strategies would work as part of the TMP for an upcoming project.

Certainly, there would be value to establishing a clear, consistent approach towards assessing the effectiveness of TMP strategies. This would assist analysts charged with quantifying the actual benefits of strategies implemented, as well as those who are charged with developing TMPs for future projects. Optimally, a set of performance metrics can then be established that would be transferable from one location to the next so that agencies could learn from each other's experiences and confidently apply estimates of strategy effectiveness in their impacts analyses during TMP development.

ORGANIZATION OF THIS REPORT

The remainder of this report provides guidance on assessing the effectiveness of TMP strategies. First, the MOEs appropriate for evaluating how the various TMP strategies affect work zone impacts are presented. A discussion of common interdependencies between the individual strategies used in a TMP is also provided to help practitioners better understand evaluation limitations that exist in some instances. Next, an overall framework is presented regarding the types of evaluations possible of the effectiveness of TMP strategies, and methods available for performing those different types of evaluations. A compilation of previous literature regarding TMP strategy effectiveness relative to the analysis framework is then presented, followed by an examination of the approach taken to develop and then assess the impacts of a TMP implemented on a recent major rehabilitation project in North Carolina.

CHAPTER 2. USEFUL MEASURES-OF-EFFECTIVENESS FOR EVALUATING TRANSPORTATION MANAGEMENT PLAN STRATEGIES

WAYS IN WHICH TRANSPORTATION MANAGEMENT PLAN STRATEGIES MITIGATE WORK ZONE IMPACTS

Not all of the available TMP strategies mitigate work zone impacts in the same way. In general terms, work zones can adversely impact safety and mobility by:

- Reducing available traffic-carrying capacity through the work zone, which can increase travel times and create traffic queues.
- Causing a redistribution (diversion) of travel to other routes, time periods, or travel modes.
- Creating unexpected driving conditions that surprise travelers and can increase crashes.
- Reducing available recovery areas for motorists who deviate from the designated travel path.
- Creating frustration and anxiety with the traveling public, residents, and businesses.

Consequently, TMP strategies attempt to mitigate impacts by:

- Increasing the amount of traffic-carrying capacity through the work zone or on alternative routes.
- Performing work that reduces capacity when traffic volumes are lower.
- Encouraging additional travel diversion away from the work zone beyond what would have happened otherwise.
- Reducing traveler surprise to unexpected conditions and features.
- Encouraging safer driving behavior through the work zone.
- Reducing the consequences of an errant vehicle leaving the travel lane relative to what would have happened if the mitigation strategy had not been employed.
- Reducing the consequences of crashes that do occur.
- Reducing other worker accident risks by providing more work space in which to operate.
- Reducing the duration of the work zone.
- Reducing public frustration and anxiety about the work zone.

Tables in Appendix A summarize how the different TMP strategies available attempt to mitigate work zone impacts. Some TMP strategies are highly-focused, attempting to address a single type of work zone impact. Other strategies, however, affect a broader range of work zone impacts. The tables also present subjective assessments as to the frequency with which the strategies are applied at work zones and the state-of-the-practice understanding of the effectiveness of the strategy in accomplishing these desired mitigation effects.

For many of the strategies that fall under the TTC plan categories, the effect of the strategy is on the available roadway capacity, either over an entire 24-hour period or during portions of the day when it is implemented. These strategies also affect the total number of capacity-reducing activities, or positively influence traveler awareness of the presence of capacity reducing activities, presumably also improving work zone safety. Assessment of the current level of understanding of the strategy effectiveness is qualitative, and all four dimensions of work zone effectiveness (mobility, safety, customer satisfaction, construction productivity and efficiency).

For example, the effect of closing a travel lane for worker safety is fairly well understood in terms of how that strategy will affect road capacity. However, its effect in terms of reducing worker accident risk, or on how such strategies are perceived by the customers (likely, this depends on whether it creates excessive congestion when implemented) is relatively low. Thus, an overall assessment of medium is provided. Strategies that require or encourage drivers to find another route are assigned a low level of understanding, as abilities to predict such route choice changes and the subsequent effects on mobility and safety in and around the work zone as well as on other routes in the corridor is very limited. Similar assessments apply to understanding of lane shifts, shoulder closures, crossovers, reversible lanes, and detours/use of alternative routes. In all cases, strategies in the temporary traffic control category are considered and assessed at the project level.

The intended effect of most strategies included in the public information and outreach component categories is to change travel patterns (route, departure time, trip location, or mode choice) that collectively affect mobility, and/or to increase driver caution and thus safety. To date, little is actually understood as to how much these strategies accomplish this intent.

Finally, the intent of the demand management strategies within the transportation operations component categories is to reduce vehicular use during peak travel times and thus improve both work zone safety and mobility. In general terms, capabilities exist to estimate how such changes will affect operating conditions (mobility), and to a lesser extent safety, once the amount of vehicle use change is known. What is not known is the extent to which such changes to usage will actually occur. In contrast, the intent of the corridor/network management strategies is to increase vehicular throughput (capacity) of the various alternative roadways to better handle increased traffic demands due to demand management efforts or natural diversion by drivers. Again, the ability to predict how traffic demands will change and to which routes, is very limited. Work zone safety strategies are implemented to reduce vehicle crashes, crash severities, or worker accidents. Use is generally fairly high, but effect on safety is relatively unknown. Finally, traffic/incident management strategies are typically implemented to improve reaction to incidents that occur, incidents that because of capacity reductions in the work zone or because of a shift in vehicle demand on alternative routes have an even greater impact on mobility and safety. So long as demand volumes can be estimated, knowledge of how these strategies can reduce response times can be used to estimate how mobility can be improved.

TYPES OF TRANSPORTATION MANAGEMENT PLAN STRATEGY MEASURES-OF-EFFECTIVENESS AVAILABLE FOR ASSESSING EFFECTIVENESS

Ideally, the MOEs used to evaluate the effectiveness of each TMP strategy should relate directly to these desired effects. For some of the strategies, the appropriate MOE to evaluate its effectiveness is fairly straightforward; for others, MOEs are much more challenging to identify and utilize. For example, measuring the amount of additional capacity that a particular strategy may provide at a work zone would be straightforward, but attempting to measure the amount by which a strategy may reduce traveler surprise to unexpected conditions would be more difficult. Further complicating matters is the fact that many of the strategies can have multiple impact mitigation effects. For instance, a work zone intelligent transportation system (ITS) deployment could potentially have a capacity-increasing effect, a traffic diversion-increasing effect, a safer driving effect, and a driver anxiety and frustration-reducing effect. Also, some of the mitigation strategies can have beneficial effects towards one or more of the types of work zone impacts listed above, while creating adverse effects upon others. An example of this situation are work hour restrictions that reduce the effects of project work activities upon commuter travel, but which may adversely affect the speed at which the agency and contractor can complete the project.

To best characterize different ways in which the various TMP strategies can influence work zone impacts, it makes sense to examine them within the context of previously-published FHWA guidance on work zone performance measures. [(4)] As part of that guidance, four dimensions of work zone impacts are identified:

- Mobility.
- Safety.
- Customer satisfaction.
- Agency and contractor productivity and efficiency.

Mobility MOEs are further defined in terms of:

- Throughput.
- Delay.
- Queues.
- Travel time reliability.

Similarly, *safety MOEs* are defined in terms of:

- Vehicle crashes.
- Operational surrogates of vehicle safety.
- Worker accidents.

These measures can then be further subdivided to reflect critical subsets of time (e.g., peak periods, when lane closures are present) as well as different facets of the feature (e.g., duration of queue presence, average delay per vehicle, crashes per million-vehicle-miles). The guidance document provides a number of suggested metrics [(4)], but there currently does not exist a nationally-agreed upon set of work zone MOEs that should be used for evaluating effectiveness.

In addition to mobility and safety impacts, many agencies are sensitive to how work zones affect public perceptions and opinions. *Customer satisfaction MOEs* are further defined in terms of:

- Work zone quality ratings (visual perceptions).
- Ratings of condition of travel through the work zone.
- Complaint frequency.

Finally, agency and contractor work productivity and efficiency represents the fourth dimension measures, and is most appropriate for evaluating strategies that reduce the duration of a work zone, or that phase of the work zone where safety and mobility impacts are most significant.

Agency/contractor productivity and efficiency measures are defined in terms of:

- Percent of allowable days worked.
- Percent of lane closure hours occurring outside of specially-allowed "work windows."
- Work productivity measures already tracked by an agency (e.g., tons of asphalt laid per day, cubic yards of concrete placed).
- Average hours of work during activities that adversely affect mobility and/or safety (i.e., lane closures).
- Average duration between road repairs on a facility.

Mapping all four these potential work zone MOE dimensions to each of the individual TMP strategies reveals a number of important considerations about how to best evaluate their effectiveness. First, for many of the strategies, one sees that their effect could be positive or negative, depending on the site conditions where it is implemented and how driver behavior is affected. As Table 4 illustrates, the effects of strategies that require detours or diversion, for example, may be positive for traffic safety at the work zone but increase crashes on alternative routes, possibly to the point that the net regional effect on safety is negative. Similarly, the effect of ramp metering on customer satisfaction will likely be positive for those travelers who experience better travel on the main lanes, but be negative for those who normally use the ramp. The table also illustrates that many of the strategies can have effects in some or even all of the four main dimensions of work zone safety and mobility performance. This means that, in many cases, the effects of individual TMP strategies that are implemented together as part of the overall TMP will often overlap and confound with one another and be more difficult to ascertain the relative contributions of a particular strategy upon the overall reduction in work zone impacts from what would have occurred otherwise.

Appendix B provides a series of tables that assess the MOEs likely to be influenced by the other TMP strategies available for use. Also included in these tables is a qualitative assessment of the relative costs of each of the potential TMP strategies available for use, and notes further explaining the effects expected (particularly when those effects are expected to be negative), and site conditions that would contribute to those effects. These tables should be useful to analysts when determining the type of assessments to be used in future TMP evaluations.

ACCOUNTING FOR TRANSPORTATION MANAGEMENT PLAN STRATEGY INTERDEPENDENCIES AND TYPICAL DEPLOYMENT "PACKAGES"

Although the confounding of effects of multiple TMP strategies does detract from efforts to assess the relative contribution of a particular strategy upon the overall success of a TMP, there are cases in which it does not make sense to attempt and isolate individual strategy effects. This is because many of the strategies themselves are highly interdependent. For example, the effectiveness of certain demand management strategies will depend on what other demand management strategies already exist or are being implemented for the project. Transit incentives might require improvements in transit service capacity in order to meet the anticipated increased demand, ridesharing/carpool incentives might likewise need to be coordinated with promotions of park-and-ride lots and programs, an overall public information and outreach campaign may be helpful to encourage travelers to shift to the newly-enhanced transit options. As another example, many of the traffic operations strategies can also be enhanced or coordinated with various types of public information strategies. In these situations, evaluating the overall effectiveness of the strategy “package” that was implemented would be the appropriate analysis approach.

Table 4. Examples of Possible TMP strategy effects upon work zone measures.

TMP Strategies	Costs	M	S	CS	PE	Notes
Full Roadway Closures	$$	◑	◑	◑	●	Impacts of full closures on mobility and safety measures throughout corridor may be positive or negative, and would need to be measured against other traffic-handling options available. Strategy would be expected to improve worker safety.
Off-site detours/use of alternate routes	$$	●	◑			Effects on safety depend on quality of detour/alternative route used.
Ramp metering	$$$	●	◑	◑	◕	Reduction in vehicle demand could yield reduction in crashes, but could also increase those on other routes if diversion occurs. Customer satisfaction would be positive for main lane drivers, but negative for ramp users. PE effects would exist if mobility improvements assist materials and equipment delivery.

M=Mobility, S=Safety, CS= Customer Satisfaction, PE=Agency or Contractor Productivity and Efficiency

● Significant positive effect expected

◕ Slight positive effect expected

◑ Effect could be positive or negative, depending on site conditions

◔ Slight negative effect expected

○ Significant negative effect expected

Appendix C provides an assessment of the more common interdependencies between strategies that might exist within an overall TMP. The identification of interdependence does not automatically imply that both strategies must be deployed, but both typically are assessed together to determine whether actions pertaining to both need to be implemented in a coordinated manner. For example, one sees that full road closures and freeway-to-freeway interchange closures are interdependent with many of the TMP strategies listed, whereas off-site detours/alternative route use has interdependencies with many corridor/network management strategies. Demand management strategies tend to also be highly interdependent, providing opportunities to shift modes while also providing incentives (either monetary or travel time) to make such a shift. Demand management strategies are also highly interdependent upon several public information strategies and a few traffic/incident management strategies. It should also be noted that some of the strategies serve primarily a dependent role within a given TMP relative to the other strategies. This does not mean that they cannot be selected and implemented on their own to address a specific need within the overall objectives of the TMP, but their selection does not typically invoke considerations of other supporting strategies.

CHAPTER 3. A FRAMEWORK FOR MEASURING WORK ZONE TRANSPORTATION MANAGEMENT PLAN STRATEGY EFFECTIVENESS

DEFINING THE DESIRED OUTCOME OF A TRANSPORTATION MANAGEMENT PLAN STRATEGY EFFECTIVENESS EVALUATION

Evaluating the effectiveness of a TMP strategy implementation can take several forms, depending on time and money available for evaluation, skill set of the evaluator(s), and most importantly, the desired outcome of the evaluation. This has resulted in multiple approaches and scopes being used for evaluating the effectiveness of TMP strategies.

In simple terms, evaluation outcomes are defined by the questions they try to answer, such as:

- Do we think this TMP strategy (or set of TMP strategies together) had some type of effect upon mobility, safety, customer satisfaction, and/or agency or contractor productivity and efficiency? In simplest terms, do we think this strategy was "effective?"
- How much of an effect did this TMP strategy/set of strategies have upon mobility, safety, customer satisfaction, and/or agency or contractor productivity and efficiency MOEs?
- How does the effectiveness of this TMP strategy/set of strategies upon mobility, safety, customer satisfaction, and/or agency or contractor productivity and efficiency vary as a function of differences in roadway, traffic, and work zone characteristics?

An answer to the first question would be much simpler to obtain than an answer to the third question.

COMMON APPROACHES TO ASSESSING TRANSPORTATION MANAGEMENT PLAN STRATEGY EFFECTIVENESS

From a practitioner's perspective, multiple ways exist to assess whether a TMP strategy had some type of effect on one or more measures used to assess work zone safety and mobility impacts. For example, a previously-published report regarding the feasibility, usefulness and possible approaches for assessing TMP strategy effectiveness described three possible approaches: [5]

- Qualitative assessments.
- Quantitative assessments.
- Some hybrid of the two.

Qualitative assessments rely on subjective statements (perhaps a simple "it worked well" or "it didn't work well" statement, along with an explanation) regarding a TMP strategy or strategy package. Those providing the qualitative assessment can be the traveling public, a work zone expert, or even project staff. Even positive or negative media reports about a project or series of projects are a type of qualitative assessment. Qualitative assessments are most often used when assessing the effectiveness of strategies that are not easily evaluated with quantitative methods, such as the effect of public information on motorist satisfaction, or when actual data are not available for a quantitative assessment. However, qualitative methods also tend to yield varying results from person to person because of personal biases and other factors, making comparison of strategy effectiveness across projects or regions difficult.

Quantitative assessments, on the other hand, utilize data-driven MOEs to evaluate the effectiveness of TMP strategies and strategy packages. Historically, agencies have not utilized quantitative assessments significantly for TMP strategy effective evaluations, due to the lack of available data, the high cost of obtaining such data, and complexities of how to best perform a quantitative assessment using that data. In those few instances where data and quantitative evaluation did occur, the MOEs used and reported varied and so the results across studies also have not been easily aggregated.

The hybrid approach as described in reference 5 combines qualitative and quantitative assessments to try to counter each of their weaknesses. Typically, qualitative information (public opinion surveys, agency staff feedback) are obtained to gauge effectiveness of a set of implemented strategies in general terms, while quantitative assessments assess certain strategies in more detail. It is important to recognize that this approach does maintain some subjectivity in the analysis that can influence conclusions. For instance, it could be difficult to determine the effectiveness of multiple strategies of a TMP that were implemented simultaneously with either a qualitative or a hybrid approach.

SCOPES OF TRANSPORTATION MANAGEMENT PLAN STRATEGY EVALUATIONS

The previously-published report [(5)] also discusses five scopes of evaluations that have, or could, be performed to assess TMP strategy effectiveness:

- Full-scale evaluation of all strategies on a project.
- Agency-wide evaluation of a single TMP strategy.
- Research evaluation of a single strategy implemented by several agencies.
- Case study of a single strategy at one location.
- Process review.

Full-scale evaluations can provide an indication about how well the collective set of TMP strategies implemented was able to manage and mitigate the impacts of the work zone. Qualitative assessments by project staff or the traveling public can provide a general sense as to whether or not the impacts were tolerable or within the expected range. Meanwhile, quantitative assessments may include an alternatives analysis of expected impacts (usually via simulation) of various possible TMP strategies and strategy packages, or may involve a comparison of actual impacts during the work zone to what existed prior to the start of the project or to what had been predicted to occur if the strategies had not been implemented. Typically, these types of evaluations are performed for only a limited number of projects due to a high level of effort required to accomplish them.

Agency-wide evaluations of a single TMP strategy involves the implementation of the strategy of interest across multiple projects and assessing (qualitatively or quantitatively) its effect on work zone impacts. This approach usually means that the strategy of interest is combined with other strategies and different roadway and traffic characteristics, which provides insight as to the effect of the strategy across the range of other confounding strategies and site characteristics. These types of evaluations can also be data and labor intensive, and so are used relatively infrequently by agencies.

Research evaluations of a single strategy implemented by several agencies are similar to, but slightly differ from, the agency-wide evaluation of a single TMP strategy. For one thing, this type of evaluation usually involves consultants or researchers who have increased evaluations skills. Also, this approach can introduce differences in how various agencies select, implement, and evaluate a strategy into the assessment. The range of information collected through this evaluation scope can enable the evaluation to provide a broader review of the strategy and maximize the applicability of the assessment. However, this evaluation scope may produce conflicting results if there are confounding variables influencing travel behaviors across the projects that cannot be accounted for in the analysis. This concern can also be present when performing agency-wide evaluations of a single TMP strategy.

Case study of a single strategy at one location allows for study depth in terms of how the strategy of interest performs under finite field conditions. An example of this would be the evaluation of the speed-reducing effects of a speed display sign implemented at a particular location. If properly designed, this type of evaluation could also assess how the strategy may be affected by other implemented strategies at the site. While case studies can yield highly-precise measures of strategy effectiveness at that location, they are not widely accepted by practitioners as a realistic evaluation tool for specific TMP strategies due to the concern that the results may apply only to that location and not be replicated at other locations.

Process reviews related to TMP strategy effectiveness are a broad-based assessment of the use of various strategies within an agency. For example, the agency may be able to define statewide trends in TMP practices and strategies, which could lead to adjustments in policy, guidelines, and required training of employees and its contractors. This broad-based assessment could reveal important information that would not have been discussed if only the specific TMP strategies were evaluated at the project level. However, this type of evaluation would require an agency to focus fairly extensively on the evaluation of TMP strategies in the review, and would likely require some planning to collect the type of data that would make an assessment within the process review worthwhile.

EVALUATION METHODS FOR ASSESSING TRANSPORTATION MANAGEMENT PLAN STRATEGY EFFECTIVENESS

Common Transportation Management Plan Strategy Effectiveness Evaluation Challenges

Evaluation of TMP strategy effectiveness poses a number of significant challenges. One of the key confounding factors to measuring the effectiveness of a TMP strategy are project-specific characteristics such as the roadway network where the work zone is location, type of roadway, work zone design features and work tasks that must be accomplished. To better measure the effectiveness of a TMP strategy, the project characteristics and geographic conditions surrounding the evaluation should be included as part of a strategy effectiveness assessment.

The dynamic nature of work zones in general is another significant challenge to assessing TMP strategy effectiveness. The effects of a work zone on travelers typically vary as a project progresses through the various construction stages or phases. Unless data are obtained during times when the impacts of a project are most significant, an assessment of TMP strategies may not provide a realistic indication of the effect of those strategies.

Finally, the confounding effect of several TMP strategies implemented together on a particular project is still another significant challenge to assessing strategy effectiveness. While researchers have had some success isolating and assessing the effectiveness of single TMP strategies in a few special case studies, practitioners often do not have that possibility on ongoing projects. Additionally, even after the effectiveness of a single TMP strategy is quantified through a research case study, the question remains as to how that effectiveness might change when coupled with others in a real-world work zone. This is particularly relevant to evaluations involving the safety effects of certain strategies, and to evaluations of mobility effects of strategies that are commonly implemented as "packages" and which influence motorist travel choice decisions and behaviors (route, departure, and mode of travel).

Methods of Determining "Do We Think This Strategy (or These Strategies) Had an Effect?"

Evaluations that focus on answering this type of question typically rely on qualitative methods. From a mobility and safety standpoint, the approach could be to interview or survey the project engineer and/or inspectors during or after the project, assessing their opinions as to whether the impacts during the project were acceptable and whether the implemented TMP strategy or strategies were helpful in keeping the impacts acceptable. At the end of a construction season or as part of an agency's bi-annual process review, opinions gathered across multiple projects could be consolidated and critiqued to further gauge whether strategies used on multiple projects consistently yielded project outcomes that were positive.

Other ways in which qualitative methods can be used to assess TMP strategy effectiveness involve the traveling public and other stakeholders such as nearby residents and business owners. In-person or on-line surveys can be used to gauge overall level of satisfaction with the TMP strategies implemented, as can an absence of citizen complaints. These types of assessments usually fall under the *full-scale evaluation of all strategies at a given location* scope of assessment, although survey questions can sometimes be formulated to examine whether the respondent liked or approved of a particular strategy or subset of strategies that were implemented.

It is important to recognize that the degree to which such analysis results will transfer from one location to the next for these types of assessments is likely to be limited, as societal norms themselves can differ from location to location. For instance, customer opinions about how beneficial the TMP strategies were at a work zone that increases travel times by 5 minutes in a large metropolitan are likely to be different than those where the same strategies and 5-minute travel time increase occurs in a small town. It is also important to remember that although the outcomes obtained from these types of assessments can give an agency some confidence when considering whether to utilize the strategy again on a project in the future, it does not provide feedback useful in gauging whether the costs of implementing the strategy will be offset by the benefits gained in terms of reduce user costs or reduced project costs, for example.

Methods of Determining "How Much of an Effect Did This Strategy (or These Strategies) Have?"

Efforts to answer this type of question require a quantitative approach. A case study evaluation of a single strategy that is implemented at a single project is a common example of this method, as is the agency-wide evaluation of a strategy across multiple projects and the research evaluation of a strategy across multiple agencies. A without-with (equivalent to a before-after) type of study design is perhaps the easiest way to accomplish this type of assessment of a strategy. Data relative to the MOE of interest is obtained when the work zone is present but without the strategy implemented. The strategy is then installed, and data again collected. The two sets of data are then compared, and the difference between the two assumed to represent the effect of the strategy. Traffic control device strategies are commonly evaluated with this method. The statistical strength of this study design is sometimes enhanced through the use of control sites that are believed comparable to the sites of interest but where the TMP strategy is not implemented.

Although the without-with study design works well for several of the TMP strategies, it does not for others. In particular, strategies implemented to mitigate mobility-related and safety-related impacts often cannot be initially withheld and then introduced in a controlled fashion to accomplish a without-with type of analysis, due to liability or public backlash concerns. In these cases, more extensive, research-based analyses are usually required.

For assessments of strategy effects upon traffic safety, guidance is available for designing and conducting evaluations that would yield crash reduction metrics. [(6)] However, these methodologies require data from multiple projects and expertise in statistical analyses. Even then, the results of an analysis of a particular strategy or strategy package will likely include considerable variability in the estimate, due to the many other work zone site-specific factors that confound to also affect crashes at each location. One of the difficulties of applying these methods is in obtaining adequate sample sizes of projects that are similar enough in scope, roadway characteristics, and similar TMP strategies to be grouped together for analysis.

Assessing the effectiveness of TMP strategies intended to mitigate mobility impacts likewise creates significant challenges. For some of the strategies, the selection of an appropriate MOE would seem fairly obvious. For example, the effects of strategies that alter the traffic-carrying capacity of the work zone or alternative routes are fairly well understood, and a MOE related to the change in throughput would be an obvious choice. In fact, the expected capacity reductions and enhancements of many of those types of strategies can now be estimated by applying methodologies found in the *Highway Capacity Manual* [(7)] or other resources.

Beyond the use of throughput MOEs, the main challenge to the use of mobility measures is the determination of the proper baseline against which the effect of a strategy or set of strategies should be compared. A TMP may have any number of strategies included to ultimately improve mobility. For example, those related to traffic demand management strive to reduce or spread out that demand to different routes and times as a way to reduce the delays and queues experienced, whereas other strategies focus on improving work zone or alternative route capacity and speeds and thus reduce those impacts. However, experiences have shown that even in the absence of a coordinated implementation of mitigation strategies, motorists will adjust their travel patterns in response to change in operating conditions due to a work zone. [(8)] Consequently, the goal of an evaluation would be to measure the effect of a strategy or set of strategies against what would have occurred if the strategy had not been implemented, rather than simply how conditions changed from what they were prior to when the work zone was present.

Unfortunately, it is currently difficult to accurately predict how a work zone will alter travel patterns. Figure 1illustrates this concept. If introducing a work zone on a route adversely affects operating conditions on the route to a significant degree, a certain percentage of drivers will choose to alter their trip-making behavior by departing at a different time, changing their route, or perhaps even changing their choice of travel mode. This will occur even if no TMP strategies to encourage those changes are implemented. Conversely, the number of travelers modifying their trip-making behavior will affect how significantly the work zone itself affects operating conditions on that route. This same type of circular relationship between changes in trip-making decisions and the resulting operating conditions will also exist on alternative routes in the corridor. Therefore, strategies that attempt to also affect trip-making decisions and behaviors are not measured against what was happening before the work zone was introduced into the corridor, but rather measured relative to what would have occurred had the strategy not been implemented.

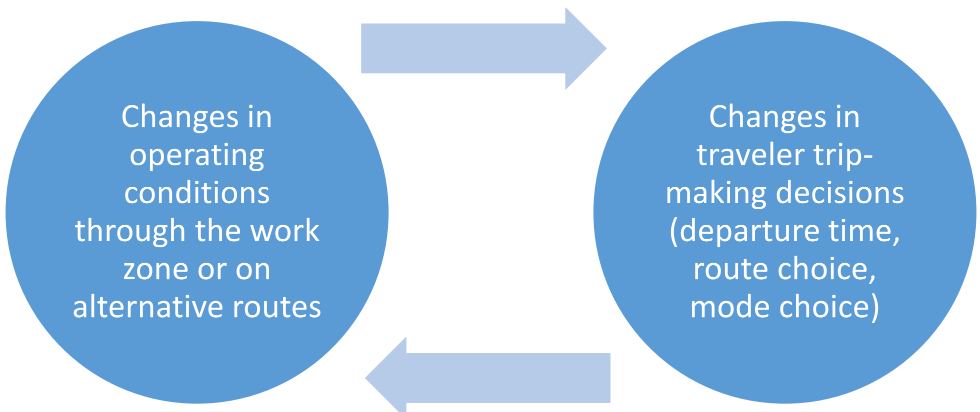

Figure 1. Diagram. Circular relationship between changes in operating conditions and traveler trip-making decisions due to work zones.

A few simulation analysis tools have been developed to attempt and evaluate such behavioral changes in response to changing operational conditions, but their validation for work zone situations has been fairly limited. [9, 10] Nevertheless, the flowchart provided in Figure 2 presents a logical process for using such analytical tools for estimating the incremental effectiveness of TMP strategies upon mobility. The methodology requires the use of a network-based model that performs route assignment and can also represent the effect of TMP strategies being considered for a project. The model is first calibrated and used to determine the TMP strategy or set of strategies that will be implemented for the project. After implementation, the model with the TMP strategies incorporated into it is recalibrated to conditions being observed at the project. The model is then used to systematically remove each strategy or strategy package and estimate what the mobility impacts would have been had the strategies not been implemented.

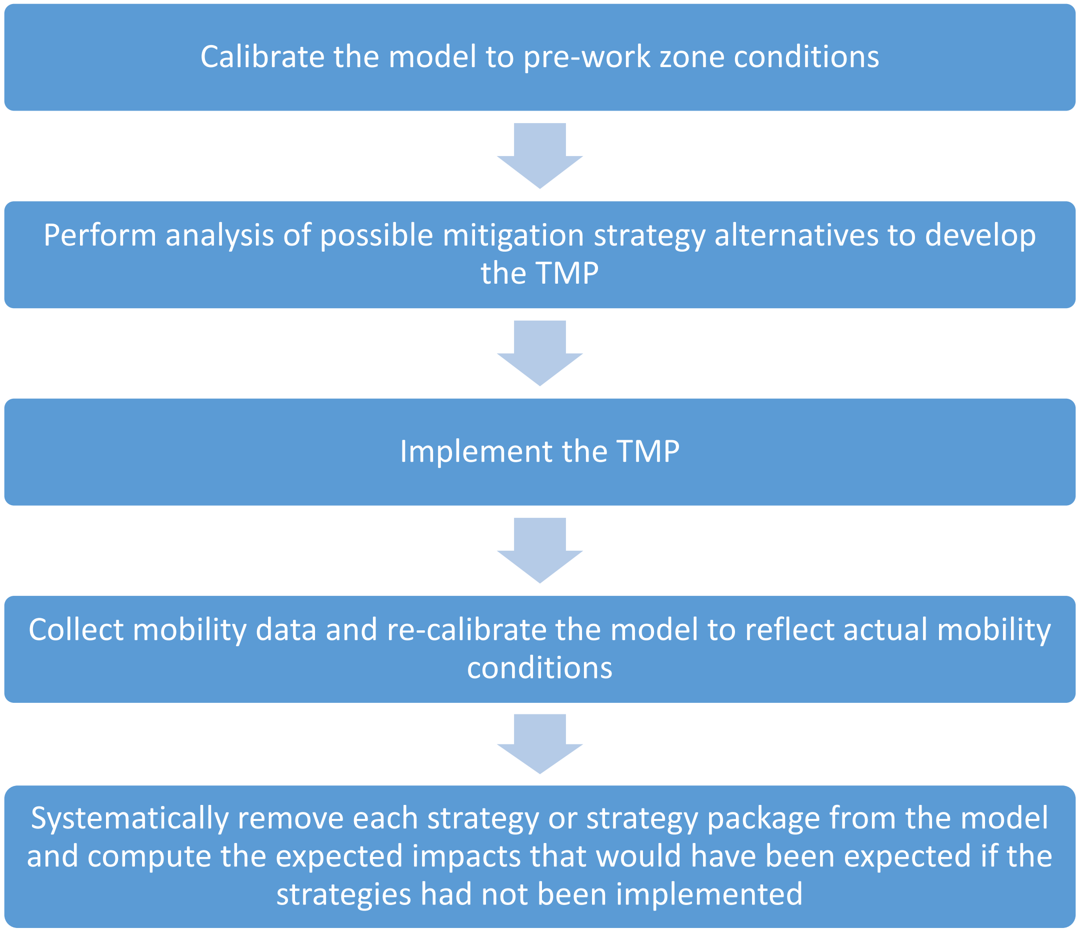

Figure 2. Diagram. Possible approach for estimating Transportation Management Plan strategy effectiveness upon mobility impacts.

Methods of Determining "How Does the Effectiveness of a Transportation Management Plan strategy Vary as a Function of Differences in Roadway, Traffic, and Work Zone Characteristics?"

For the reasons previously mentioned, it is likely that the effectiveness of some TMP strategies in mitigating work zone impacts is not constant, but rather varies as a function of roadway, traffic, work zone, and other implemented TMP strategy variables. Ideally, assessments of TMP strategy effectiveness would be constructed as predictive models based on these input variables, so that the effect of implementing that strategy at a future work zone could be accurately predicted. A theoretical example of such a relationship might be the effectiveness of temporary concrete barrier implemented to separate the traffic space from the work space as a function of traffic volumes, type of work operations (which would correlate to the amount and size of equipment and materials in the work space), and lateral distance of the barrier from the traffic space. It is anticipated that methods such as these would need to be established through a significant research effort, possibly across multiple agencies, in order to obtain enough data with the range of input variables needed to establish the relationships.

CHAPTER 4. USING THE FRAMEWORK TO SYNTHESIZE TRANSPORTATION MANAGEMENT PLAN STRATEGY ASSESSMENTS

OVERVIEW

Within an evaluation framework, two types of analyses are needed, depending on the strategies being evaluated and the metric that is used to assess effectiveness:

- Simple aggregation of evaluation results across multiple projects.
- Application of analytical models to extract strategy effectiveness results.

Different approaches are available to answer each of these two questions. To address the first question, researchers or practitioners identify one or more metrics that can be measured and which are known or expected to correlate to work zone impacts of concern (i.e., safety, mobility, customer satisfaction, and construction productivity and efficiency), and perform analyses to determine whether the implementation of a strategy affects that metric in some. In some cases, studies comparing conditions at the work zone before a strategy was implemented to those after the strategy was implemented is a common way to answer this question. The results of multiple studies can be examined, and the range of observed effects determined. When a number of similar studies reach similar conclusions, one can be fairly confident that the strategy does have some type of positive effect, even though it is not possible to predict with any degree of certainty how much of an effect there will be at any future deployment. As an example, a recent guidance document developed under the FHWA work zone safety grant program reviewed multiple studies of speed control strategies, and established a range of speed reductions that can be expected from each strategy type (see Table 5). [11] Although the studies focus on vehicle speed as the evaluation metric of interest, the underlying hypothesis is that reduced speeds result in fewer and less severe crashes.

Table 5. Evaluation of Speed Management Technique Effectiveness. [11]

Speed Management Technique	Potential Average Speed Reduction
CB radio information systems	0 to 2 mph
Narrowed lanes with channelizing devices	0 to 5 mph
Transverse pavement markings	0 to 5 mph
Portable changeable message sign with radar	0 to 6 mph
Drone radar	2 to 3 mph
Transverse rumble strips	2 to 5 mph
Speed display trailers	2 to 10 mph
Law enforcement	5 to 10 mph

The information presented in Table 5 represents a single type of data and metric that was evaluated (change in speeds). Not all strategies will be evaluated with identical metrics, or even with all quantitative data. Studies of strategies that target an improvement in driver awareness as a surrogate for improving safety might use vehicle operating characteristics (e.g., speeds, lane encroachments, and braking) or driver characteristics (e.g., eye-tracking, and changes in galvanic skin response measures). In those situations, it is possible to apply triangulation methods to assess whether the multiple approaches used to evaluate a particular strategy reach similar conclusions about that strategy. Triangulation methods have been successfully applied to the task of providing decision support regarding TMP strategy selection for construction activities on high-volume roadways. [12] The advantage of this approach is that it can accommodate both quantitative and qualitative results. However, this level of evaluation does not account for such things as potential marginal benefits of using multiple strategies together (such as law enforcement and speed display trailers from Table 1) or for confounding effects of using similar strategies together (i.e., using both portable changeable message signs with radar and speed display trailers in a work zone would not be expected to achieve 8 to 16 mph speed reductions). Perhaps equally important is the realization that speed reduction as a metric of effectiveness may not necessarily correlate to the real intent for applying the strategy, i.e., to reduce crash potential and severity.

The second type of evaluation approach uses complex analytical methods to directly evaluate how strategies directly influence the main work zone impact dimensions, rather than inferring how they might influence those impacts from surrogate metrics. For example, instead of examining vehicle speed reductions due to the strategies listed in Table 1 and then trying to estimate how much safety is likely to be improved, a statistical predictive model of crashes from many work zones where the different strategies have been implemented would be developed. Parameters computed for the assorted variables included in the model (exposure variables such as work zone length, duration, traffic volumes; strategy variables) and their interactions would be developed which would describe the relative contributions of each to the crashes that occur at work zones.

On the mobility impacts side, data from multiple evaluations of a TMP strategy can be used to develop predictive models of its typical effect across a range of work zone conditions and combinations with other TMP strategies, e.g. To accomplish this, data on those conditions and combinations are required from each project used in the analysis. Furthermore, a range of conditions and combinations are needed in order to assess how the effect of a strategy of interest may vary across those conditions. Although this approach as yet has not been attempted for work zone TMP strategies, an example of this approach would be the development of a model of work zone factors that affect vehicle speeds. [13]

The advantage of these approaches are a direct assessment of the actual mitigation effects of a strategy or set of strategies upon the work zone impacts of concern, as well as a more thorough understanding of the interactions between work zone features and other TMP strategies that may be implemented. Results from these types of evaluations are more useful in future TMP design efforts. Of course, the main disadvantages of these approaches are the level of technical expertise required to build and use the models, and the very large amounts of data that are needed to use them properly.

SYNTHESIS OF PAST TRANSPORTATION MANAGEMENT PLAN STRATEGY EVALUATIONS

There has been some, but not an extensive amount of, evaluation of some TMP strategies. A summary of those studies can be found in Appendix D. Most of these have been simpler "did the strategy have an impact" type of assessment for which a synthesis of the range of impacts and/or triangulation across different evaluation metrics is appropriate. There are a few examples where the more comprehensive analytical modeling approach has been used. In the following section, examples of both types for a finite set of TMP strategies have been synthesized.

A review of existing literature and data sources shows that many of the possible TMP strategies have yet to be evaluated in any manner. It is hoped that guidance being developed through this project will be useful to practitioners and researchers in the future for conducting strategy evaluations. Those limitations notwithstanding, the research team did identify the following strategies for which some information does exist. These evaluations are synthesized in this section. Some evaluations are of the simpler “did this have an effect?” type, whereas a few are available to illustrate the more complex modeling approach as well. The following strategies are discussed:

- Usage of work zone ITS to provide real-time traveler information.
- Effect of construction acceleration techniques to reduce project duration.
- Effectiveness of demand management – increase transit service strategy.
- Effectiveness of night work.
- Comparing different lane closure control strategy options considered for a roadway rehabilitation project.

Work Zone Intelligent Transportation System to Provide Real-Time Traveler Information

FHWA is currently encouraging the increased use of technology to improve work zone safety and mobility through the third round of the Every Day Counts (EDC-3) initiative. Efforts to develop and use work zone ITS have existed for nearly 20 years. Early efforts encountered a number of technological issues as well as skeptical perspectives of the benefits that could be achieved relative to their cost of deployment. Fortunately, technological issues have been mostly resolved over time. Enough deployments have occurred to allow an initial evaluation as to whether this strategy is effective when deployed at projects.

The provision of real-time information with these systems has focused mostly on estimating current travel times, delays, or reduced speeds and conveying that information to motorists upstream where they can make a decision to divert to another route if they so desire. Thus, diversion percentages have been a common metric examined to assess their effectiveness. Table 6 provides a summary of study results for this strategy, as well as key caveats noted in the analyses. Some of the evaluations were more robust than others, and some conclusions may be less defensible than others. However, the collective results imply that this strategy can create diversion away from the work zone when congestion is present. The evaluations imply a diversion effect of between 3 and 21 percent, with the median value reported as 10 percent. Only one of the evaluations utilized a before-after study approach across comparable operating conditions through the work zone. It was one of the evaluations that yielded a 10 percent diversion estimate, giving further credibility to that value as indicative of the typical level of effectiveness of this strategy.

Table 6. Synthesis of Work Zone Intelligent Transportation System Real-Time Travel Information on Diversion.

Study	Effect on Diversion	Notes
Effectiveness of Condition-Responsive Advisory Speed Messages in Rural Work Zones (2002). [14]	Use of an upstream exit ramp increased by 3% when messages posted	Rural interstate location. Presentation of speeds and delays. No comparable before data to know if some change in exit ramp use would have occurred if the system had not been deployed.
Diversion from a Rural Work Zone with Traffic-Responsive Message Signage System (2003). [15]	10% across a key cutline	Rural interstate location. Presentation of travel time to end of work zone. Before-after analysis performed to compare equivalent operating conditions.
Evaluation of Effectiveness of Automated Work Zone Information Systems (2005). [16]	Up to 21% during congested times.	Rural interstate. Presentation of roadway "jammed" messages when congested. No comparable before data to know what percent might have been without the system.
The Benefits of Using Intelligent Transportation Systems in Work Zones. (2008). [17]	10%	Rural interstate. Presentation of "Delay Ahead" messages. No comparable before data to know what percent might have been without the system.
Reconstruction of Fourteen Bridges on I-93 in Medford Using Accelerated Bridge Construction Techniques (2014). [18]	Estimated 15-20%	Urban freeway. Specific messages not documented. Diversion based on changes in mainlane volumes through project.
OVERALL	**Range: 3-21%** **Median: 10%**	

Effect of Construction Acceleration Techniques to Reduce Project Duration

Another temporary traffic control TMP strategy that has received a reasonable amount of attention in recent years is the utilization of construction acceleration techniques to reduce the duration of a project or a particular project phase and its impact upon traffic. Although listed as a single strategy, many different acceleration techniques actually make up this strategy. Recent examples include:

- Use of pre-formed deck panels to accelerate bridge rehabilitation and reconstruction.
- Use of pre-formed roadway slabs to accelerate rehabilitation of concrete pavement.
- Use of slide out-slide in bridge technology to reduce duration of bridge closures.

Table 7 provides a summary of the reductions in project durations that have recently been reported utilizing these techniques. Only two of the three evaluations provided estimates of the traditional methods as a way to assess the relative benefits of this technology. Overall, the evaluations listed illustrate effective project duration reductions. The range of effectiveness is very large, illustrative of the complexities involving in construction.

Table 7. Synthesis of Construction Acceleration Techniques on Project Duration.

Study	Effect on Duration	Notes
Improvements to the 24th Street- I-29/80 Interchange in Council Bluffs. (2009). [19]	Bridge deck replacement completed in 1 season versus 2 seasons (50% reduction)	Precast bridge deck panels. Included incentives and other contractual items that may also have reduced construction time
Reconstruction of Fourteen Bridges on I-93 in Medford Using Accelerated Bridge Construction Techniques (2014). [18]	14 bridges replaced in 5 months versus 48 months otherwise (89% reduction)	Precast bridge elements. Included design-build contracting to reduce overall time. Actual replacement time of all bridges was 550 hours (39 hours per bridge).
Alternate Project Delivery and Accelerated Bridge Construction on OR 38, Drain to Elkton (2013). [20]	Replacement of 5 bridges reduced by one year	Precast bridge components, slide-out slide in bridge replacement technology.
OVERALL	**Range: 50-89% reduction**	

Effectiveness of Demand Management – Increase Transit Service Strategy

Demand management strategies are another key component available to TMP developers and implementers. Most metropolitan areas have well-established transit service and ridesharing programs. Efforts are often made to increase utilization of these programs during construction as a way to reduce vehicular travel through and around the work zone and ultimately lower mobility impacts associated with a work zone. Table 8 provides a synthesis of one particular demand management strategy, efforts to increase transit service capacity.

Often, multiple demand management strategies are implemented together in a coordinated manner as part of a TMP to encourage reduce vehicle utilization in the corridor. As stated previously, the combined effect of these individual strategies usually requires that they be evaluated as a system, rather than as individual contributions to the overall effect. Also, effectiveness is usually measured in terms of increased ridership. As Table 8 illustrates, efforts to promote additional ridership during construction have yielded fairly small changes across the various projects examined. One of the items missing from the various data sources reviewed was an assessment of the level of transit utilization that existed in the corridor prior to the start of construction. Generally, it is difficult to get travelers out of their personal vehicles and to use transit options.

Table 8. Synthesis of Effect of Providing Increased Transit Service Capacity during Construction.

Study	Effect on Ridership	Notes
The Case of Poston's Southeast Expressway (1985). [21]	147 trips per day decrease	160,000 vehicles per day facility
Traffic Management During Reconstruction of I-91 in Connecticut (1987). [21]	330 trips per day increase	180,000 vehicles per day facility
Traffic Management for Major Freeway Reconstruction: I-94 Menomee Valley Bridge, Milwaukee (1984). [21]	1,100 trips per day increase	125,000 vehicles per day facility
Go Triangle/Go Durham Transit Agency Data During the Fortify 40 Project (2015). [22]	433 trips per day increase	113,000 vehicles per day facility. $12 million allocated to increase bus transit service in corridor
OVERALL	**Range: -147 to 1,100 trips per day increase Median: 433 trips per day increase**	

Effectiveness of Night Work

As traffic volumes and congestion have continued to grow nationally, the restriction of maintenance, utility, and construction activities that requires the temporary closure of a travel lane to nighttime hours have become more and more popular. Many agencies have policy restrictions to this effect in force within their jurisdictions, and take significant steps towards developing and implementing projects that can be accomplished by avoiding lane closures during daytime hours.

From a TMP perspective, the rationale for pushing lane closures to nighttime hours is simple. Traffic volumes are significantly lower at night than they are during the daytime, especially on week days. The amount by which moving to nighttime hours can avoid mobility impacts depends on traffic volumes on a facility, the number of lanes normally available for travel, the hours at night when lanes are allowed to be closed, and the number of lanes closed. In some densely-populated areas, congestion caused by a temporary lane closure cannot be avoided, even at night. However, the magnitude of congestion will be much less.

Although the mobility benefits of night work are readily apparent, the safety implications are not. Visibility is degraded while driving at night, which is especially a concern for older drivers, and the prevalence of drowsy or otherwise impaired driving tends to be higher as well. As a result, the relative risk of driving at night is higher (in terms of crash risk per mile driven) than it is during the day. However, from the perspective of the selection of night work as a TMP strategy, the question is whether the total societal costs that are incurred while working at night are greater or less than performing the same work during daytime hours. A National Cooperative Highway Research Program (NCHRP) project performed to answer that question provides an example of the more complex analyses that are required to assess the safety implications of TMP strategy choices. [23]

In that study, researchers gathered data from 92 projects in four states, representing 500 miles of roadways and over 80 years of project time. Over 17,000 crashes were included in this dataset. For each project, inspector diaries were reviewed to identify days and nights when:

- No work was occurring (the work zone was inactive).
- Work was occurring but no temporary lane closures were in place.
- Work was occurring that required a temporary lane closure.

Researchers stratified each project accordingly. Empirical-Bayesian statistical techniques were applied to estimate normal expected crash frequencies during the various time periods, and crash modification factors (CMFs) were developed for each condition for both daytime and nighttime operations. The results are summarized in Table 9. Interestingly, similar CMFs were found for both daytime and nighttime work hours when a temporary lane closure was required. Higher CMFs were found during the nighttime hours when lanes were not temporarily closed when compared to similar conditions during the day.

Table 9. Crash Modification Factors (CMFs) for Projects: Day versus Night.

Work Condition	Daytime	Nighttime
No work occurring	1.127 (0.014)	1.237 (0.029)
Work occurring but no temporary lane closures in place	1.314 (0.027)	1.577 (0.148)
Work occurring in temporary lane closures	1.663 (0.073)	1.609 (0.057)

Numbers in parentheses are the standard error of the CMF

Utilization of these CMFs as part of TMP development requires the practitioner to have a baseline estimate of crash frequency for their project location. Depending on the relative amounts of work to be performed under the above conditions versus the amount of time the project will be in place but not active, an overall estimate of crash frequency increases can be estimated from this evaluation.

Comparing Different Lane Closure Control Strategy Options Considered For a Roadway Rehabilitation Project

The final TMP strategy evaluation is also an example of the use of advanced modeling techniques for evaluating the effectiveness of a particular TMP strategy. Specifically, the use of traffic simulation tools to assess the likely impacts of alternatives, and an assessment of how well that assessment is matching actual conditions. [24,25,26] The decision about how to maintain traffic through the work zone project is one of the earliest and most fundamental decisions that has to be made in the project design process.

The I-40/I-440 project in North Carolina was a design-build concrete pavement rehabilitation project that had to be accomplished without the benefit of widening the roadway at the same time, and having new pavement on which to place traffic while the existing pavement was replaced. Appendix E provides a summary of the project, analyses performed, and an assessment of how actual impacts have compared to the analyses. Traffic impacts were expected to occur throughout the network, although the extent and location of those impacts were not known. Thus, the use of traffic simulation analysis with dynamic traffic assignment capabilities that could capture the interactions between changes in operating conditions due to the work zones and changes in motorist trip-making decisions was a wise choice. [(27)]

The project analysts constructed a network model of the Raleigh-Durham region for use in a mesoscopic traffic model that provided dynamic traffic routing in response to changes in traffic conditions in the network. They performed a series of analyses and concluded that the maintenance of three lanes through the project in each section was substantially preferable to keeping only two lanes open per direction. Maintaining three lanes per direction during construction was ultimately the option selected by the department.

Following project initiation, the analysts continued monitoring traffic conditions in the corridor. Their summaries are then compared with their original estimates. In this way, the actual data serves as a validation of their conclusions reached during the impacts analysis computations. The primary measure of effectiveness that can be compared is that of travel times through the corridor along the work zone (analysts are not monitoring actual travel times on the alternative routes in the corridor). Two routes of interest were modelled during the impact analyses and are also being monitored during construction, as shown in Figure 3.

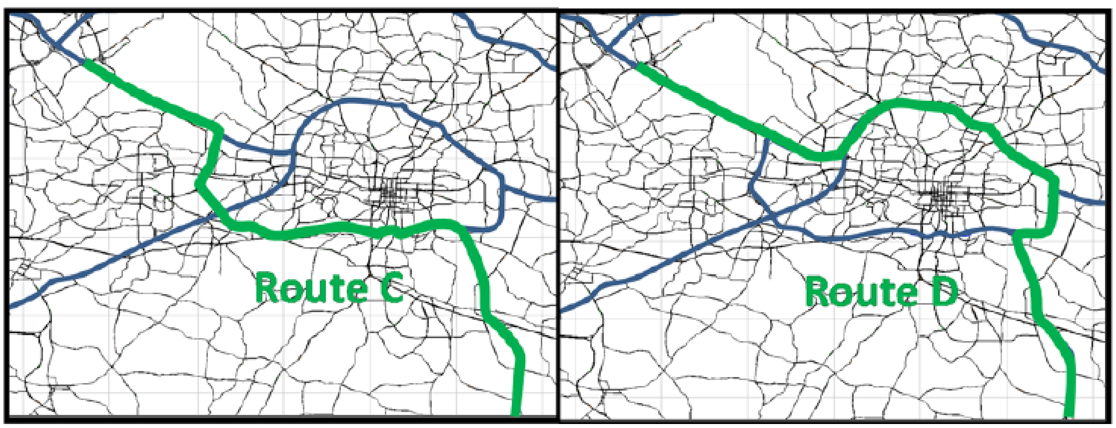

Figure 3. Map. Routes used for comparing travel times, predicted to observed.

The travel times predicted by the simulation tool were only marginally different than the baseline (pre-work zone) travel times in the corridor (see Table 10). For the most part, the magnitude of diversions predicted to occur offset the reduction in lane capacity through the project, and so the predicted travel times remained close to those existing prior to the start of construction. However, travel time data actually collected through the project on a weekday were found to be somewhat greater than was predicted or what existed prior to the start of construction. Unfortunately, information on any crashes or other incidents that may have also affected travel on this particular day were not available.

Table 10. Comparison of Predicted and Observed Peak Hour Travel Times.

Route, Peak Period, and Direction	Baseline (Pre-Work Zone) Travel Times, Min	Predicted Travel Times (with diversion), Min	Observed Travel Times, Min
Route C			
AM Peak			
Westbound	27.5	29.7	33.6-50.2
Eastbound	25.9	26.0	26.8-30.3
PM Peak		26.3	
Westbound	26.4	31.2	37.2-40.4
Eastbound	26.9		54.7-66.0
Route D			
AM Peak			
Westbound	30.1	30.0	39.9-48.3
Eastbound	29.3	29.5	29.6-36.2
PM Peak			
Westbound	36.7	29.4	40.8-59.6
Eastbound	30.6	30.3	52.9-89.6

The analysts are also monitoring traffic volumes on I-40/I-440 during construction and estimating observed diversion rates. Comparisons of diversion rates estimated via simulation to those actually being observed during the first part of work (in area 3) are provided in Table 11. Based on the data collected, it appears that the analytical model predicted a greater amount of diversion to other routes than what has actually occurred at the projects. Analysts have hypothesized that a significant amount of departure time diversion is occurring in lieu of route diversion as was predicted by the model. In other words. Rather than seeking out a different route for their peak period trips, more commuters are simply adjusting when they start their trip.

Table 11. Comparison of Predicted to Actual Diversion at the I-40/I-440 Project (October 2015)

Period and Direction	Predicted Diversion	Observed Diversion
AM Peak Period-Westbound	17-33%	19%
PM Peak Period-Eastbound	17-32%	16%

This comparison of predicted to actual condition emphasizes the importance of project and TMP monitoring and evaluation to improve understanding of the limitations of analytical tools and to determine how TMP strategy decisions actually affect safety and mobility impacts caused by work zones. To date, North Carolina Department of Transportation (NCDOT) has not made major changes to their TMP. The regional transit agency has made minor modifications to the increased transit service that was implemented, eliminating a few routes that had been initiated to provide an alternative to automobile travel through the project but which were never utilized to any meaningful degree.

CHAPTER 5. SUMMARY AND CONCLUSIONS

Presently, very few agencies evaluate how well their impacts analysis results compare to what actually happens in the field, let alone assess how well the mitigation strategies employed affected the impacts of the work zone. Even for those strategies for which some assessments have been performed, the methods used and MOEs evaluated have varied widely, making it difficult to draw conclusions about how well the strategies would work as part of the TMP for an upcoming project. Therefore, this report was prepared to help practitioners formulate and follow clear, consistent approach towards assessing the effectiveness of TMP strategies. The report provides an inventory of the MOEs that each of the TMP strategies may affect at a particular work zone, depending on the characteristics of that work zone and other TMP strategies that are used. An overall framework is presented to guide analysts on the available approaches towards TMP strategy effectiveness evaluations, possible scopes of those evaluations, and potential analytical methods. A synthesis of evaluations is also for those TMP strategies for which previous and current literature and data were available.

TMP strategies attempt to mitigate impacts by:

- Increasing the amount of traffic-carrying capacity through the work zone or on alternative routes.
- Performing work that reduces capacity when traffic volumes are lower.
- Encouraging additional travel diversion away from the work zone beyond what would have happened otherwise.
- Reducing traveler surprise to unexpected conditions and features.
- Encouraging safer driving behavior through the work zone.
- Reducing the consequences of an errant vehicle leaving the travel lane relative to what would have happened if the mitigation strategy had not been employed.
- Reducing the consequences of crashes that do occur.
- Reducing other worker accident risks by providing more work space in which to operate.
- Reducing the duration of the work zone.
- Reducing public frustration and anxiety about the work zone.

Consequently, different MOEs are needed to evaluate the effectiveness of different strategies. In general, TMP strategies can be evaluated through one or more of the following MOE dimensions:

- Mobility.
- Safety.
- Customer satisfaction.
- Agency and contractor productivity and efficiency.

Many strategies affect MOEs in more than one of these dimensions, regardless of whether they are implemented specifically to mitigate work zone impacts within that dimension. Consequently, the effectiveness of multiple TMP strategies implemented at a work zone will often confound each other to generate an overall effect on impacts at that location. In some cases, methods do exist to dissect the influence of individual TMP strategies, but these typically require data from multiple projects and more advanced analytical techniques.

Multiple ways exist to assess whether a TMP strategy had some type of effect on one or more measures used to assess work zone safety and mobility impacts, specifically:

- Qualitative assessments.
- Quantitative assessments.
- Some hybrid of the two.

Meanwhile, assessments of TMP strategy effectiveness can also vary in scope. Common evaluation scopes include:

- Full-scale evaluation of all strategies on a project.
- Agency-wide evaluation of a single TMP strategy.
- Research evaluation of a single strategy implemented by several agencies.
- Case study of a single strategy at one location.
- Process review.

Ultimately, the selection of MOEs to use, assessment approach, and assessment scope varies depending on the question the practitioner is trying to answer, such as:

- Do we think this TMP strategy (or set of TMP strategies together) had some type of effect upon mobility, safety, customer satisfaction, and/or agency or contractor productivity and efficiency? In simplest terms, do we think this strategy was "effective?"
- How much of an effect did this TMP strategy/set of strategies have upon mobility, safety, customer satisfaction, and/or agency or contractor productivity and efficiency MOEs?
- How does the effectiveness of this TMP strategy/set of strategies upon mobility, safety, customer satisfaction, and/or agency or contractor productivity and efficiency vary as a function of differences in roadway, traffic, and work zone characteristics?

The challenges posed in assessing the effectiveness of TMP strategies to mitigate work zone impacts are particularly noteworthy. If introducing a work zone on a route adversely affects operating conditions on the route to a significant degree, a certain percentage of drivers will choose to alter their trip-making behavior by departing at a different time, changing their route, or perhaps even changing their choice of travel mode. This will occur even if no TMP strategies to encourage those changes are implemented. Conversely, the number of travelers modifying their trip-making behavior will affect how significantly the work zone itself affects operating conditions on that route. This same type of circular relationship between changes in trip-making decisions and the resulting operating conditions will also exist on alternative routes in the corridor. Therefore, strategies that attempt to also affect trip-making decisions and behaviors need to be measured not against what was happening before the work zone was introduced into the corridor, but rather measured relative to what would have occurred had the strategy not been implemented. In order to effectively accomplish such a comparison, a network-based model that performs route assignment and which can also represent the effect of TMP strategies being considered for a project is required.

Several studies performed over the past 25 years have made some attempt to assess the effects of certain TMP strategies upon work zone impacts. Although most have, to date, not focused on the four main MOE dimensions described above, they do provide some insight into the strategy influences on travel behavior that could be used to assess actual impact mitigation effects. In a few instances, syntheses of multiple study results were possible. Specifically, a range of effectiveness were developed and presented for the following strategies:

- Speed management techniques.
- Work zone ITS.
- Construction acceleration techniques.
- Increased transit service capacity.
- Night work (on safety).

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APPENDIX A: EXPECTED STRATEGY IMPACTS, FREQUENCY OF USE, AND CURRENT UNDERSTANDING OF EFFECTIVENESS

Table A-1. Expected Temporary Traffic Control Strategy Impacts, Typical Frequency of Use on Significant Projects, and Expected Knowledge of Effectiveness.

Transportation Management Plan Strategies		Types of Impacts	Frequency of Use[1]	Current Understanding of Effectiveness[1]
Strategic construction phasing		Reduces project duration, frequency of capacity-reducing activities	H	H
Full Roadway Closures		Increases work productivity and efficiency, reducing project duration; reduces worker risks	M	M
Lane shifts or closures	Reduced lane widths to maintain number of lanes (constriction)	Maintains greater capacity than allowing lane(s) to be closed	H	H
Lane shifts or closures	Lane closures to provide worker safety	Increases buffer distance to reduce worker risks	M	M
Lane shifts or closures	Reduced shoulder width to maintain number of lanes	Maintains greater capacity than allowing lane(s) to be closed	H	H
Lane shifts or closures	Shoulder closures to provide worker safety	Increases buffer distance to reduce worker risks	M	M
Lane shifts or closures	Lane shift to shoulder/median to maintain number of lanes	Maintains greater capacity than allowing lane(s) to be closed.	H	M
One-lane, two-way operation		Increases capacity by allowing travelers to use facility instead of closing it completely while doing work	M	H
Two-way traffic on one side of divided facility (crossover)		Reduces worker risks; can reduce project duration	M	M
Reversible lanes		Allows additional capacity to be used for peak direction traffic flows (compared to a static lane closure condition)	M	H
Ramp closures/relocation		Can increase capacity by eliminating merging conflicts, smooth traffic flow; encourages diversion away from work zone at that location	M	M
Freeway-to-freeway interchange closures		Can increase capacity by eliminating merging conflicts, smooth traffic flow; encourages diversion away from work zone at that location	L	L
Night work		Capacity reductions occur when traffic volumes are lower	H	M

Transportation Management Plan Strategies		Types of Impacts	Frequency of Use[1]	Current Understanding of Effectiveness[1]
Weekend work		Capacity reductions occur when traffic volumes are lower	H	M
Work hour restrictions for peak travel		Capacity reductions occur when traffic volumes are lower	H	H
Pedestrian/bicycle accommodations		Reduces traveler surprise to unexpected conditions; reduces public frustration and anxiety	L	L
Business access improvements		Can increase capacity; reduces public frustration and anxiety	L	L
Off-site detours/use of alternate routes		Causes additional diversion away from work zone beyond what would have occurred otherwise; can reduce other worker risks by provide more work space	H	L-H[2]
Project Coordination	Coordination with other projects	Increases network/corridor capacity by reducing multiple capacity reductions happening at the same time	H	M
Project Coordination	Utilities coordination	Reduces the duration of the work zone	H	H
Project Coordination	ROW coordination	Reduces the duration of the work zone	H	H
Project Coordination	Coordination with other transportation infrastructure (e.g., rail transit, major generators)	Increases network/corridor capacity by reducing multiple capacity reductions happening at the same time on different parts of the infrastructure; can also involve doing capacity reductions when traffic volumes are lower (i.e., avoiding peak travel times of major generators)	H	M
Contracting Strategies	Design-build	Reduces the duration of the work zone	M	M
Contracting Strategies	A+B bidding	Reduces the duration of the work zone	M	M
Contracting Strategies	Incentive/disincentive	Reduces the duration of the work zone	M	M
Contracting Strategies	Lane rental	Capacity reductions occur when traffic volumes are lower	M	M
Innovative construction techniques (e.g., precast members, rapid cure materials)		Reduces the duration of the work zone	M	M

[1] L = Low; M = Medium; H = High

[2] Understanding of effectiveness of off-site detours and use of alternative routes depends on location and other factors, and so ranges from low to high

Table A-2. Expected Public Information and Outreach Strategy Impacts, Typical Frequency of Use on Significant Projects, and Expected Knowledge of Effectiveness.

Transportation Management Plan Strategies	Types of Impacts	Frequency of Use[1]	Current Understanding of Effectiveness[1]
Brochures and mailers	Reduce public surprise to unexpected conditions; encourage additional travel diversion; encourage safer driving behavior through the work zone; reduce public frustration and anxiety	M	L
Press releases/media alerts	Reduce public surprise to unexpected conditions; encourage additional travel diversion; encourage safer driving behavior through the work zone; reduce public frustration and anxiety	H	L
Paid advertisements	Reduce public surprise to unexpected conditions; encourage additional travel diversion; encourage safer driving behavior through the work zone; reduce public frustration and anxiety	M	L
Public information center	Reduce public surprise to unexpected conditions; encourage additional travel diversion; reduce public frustration and anxiety	M	L
Telephone hotline	Reduce public surprise to unexpected conditions; encourage additional travel diversion; reduce public frustration and anxiety	L	L
Planned lane closure map	Reduce public surprise to unexpected conditions; encourage additional travel diversion; reduce public frustration and anxiety	H	L
Project website	Reduce public surprise to unexpected conditions; encourage additional travel diversion; reduce public frustration and anxiety	H	L
Public meetings/hearings	Reduce public surprise to unexpected conditions; reduce public frustration and anxiety	M	L
Community task forces	Reduce public surprise to unexpected conditions; reduce public frustration and anxiety	M	L
Coordination with media/schools/ businesses/emergency services	Reduce public surprise to unexpected conditions; reduce public frustration and anxiety	H	L

Transportation Management Plan Strategies	Types of Impacts	Frequency of Use[1]	Current Understanding of Effectiveness[1]
Work zone education and safety campaigns	Encourage safer driving behavior through the work zone	H	L
Work zone highway safety signs	Encourage safer driving behavior through the work zone	H	L
Rideshare promotion information	Encourage additional travel diversion	M	L
Visual media information for meetings and web	Reduce public surprise to unexpected conditions; reduce public frustration and anxiety	M	L
Traffic radio	Encourage additional travel diversion	H	L
Changeable message signs	Reduce public surprise to unexpected conditions; encourage additional travel diversion; encourage safer driving behavior through the work zone; reduce public frustration and anxiety	H	L
Temporary motorist information signs (e.g., status of project, number of fatalities)	Encourage safer driving behavior through the work zone; reduce public frustration and anxiety	H	L
Dynamic speed display signs	Encourage safer driving behavior through the work zone	H	M
Highway advisory radio	Reduce public surprise to unexpected conditions; encourage additional travel diversion; encourage safer driving behavior through the work zone; reduce public frustration and anxiety	L	L
Highway information network (web-based)	Reduce public surprise to unexpected conditions; encourage additional travel diversion; reduce public frustration and anxiety	L	L
511 traveler information system	Reduce public surprise to unexpected conditions; encourage additional travel diversion; reduce public frustration and anxiety	H	L
Freight travel information	Encourage additional travel diversion; encourage safer driving behavior through the work zone	L	L
Transportation management center	Support use of motorist information strategies to encourage change in driving behavior (route, departure time, trip location)	NA	NA

[1] L = Low; M = Medium; H = High; NA = Not Applicable

Table A-3. Expected Traffic Operations Strategy Impacts, Likely Frequency of Use on Significant Projects, and Expected Knowledge of Effectiveness.

Transportation Management Plan (TMP) Strategies	Types of Impacts	Frequency of Use[1]	Current Understanding of Effectiveness[1]
Transit service improvements	Encourage additional travel diversion	M	M
Transit incentives	Encourage additional travel diversion	M	M
Shuttle services	Encourage additional travel diversion	M	M
Ridesharing/carpool incentives	Encourage additional travel diversion	M	M
Park-and-Ride promotions	Encourage additional travel diversion	M	M
High Occupancy Vehicle (HOV) lanes	Encourage additional travel diversion	M	M
Toll/congestion pricing (including High Occupancy Toll [HOT] lanes)	Encourage additional travel diversion; encourage safer driving behavior through the work zone	L	M
Ramp metering	Increase traffic-carrying capacity through the work zone; encourage additional travel diversion; encourage safer driving behavior through the work zone	M	M
Parking supply management	Encourage additional travel diversion	L	M
Variable work hours	Encourage additional travel diversion	L	M
Telecommuting	Encourage additional travel diversion	L	M
Signal timing/coordination improvements	Increase traffic-carrying capacity on alternative routes; encourage additional travel diversion	H	H
Temporary traffic signals	Encourage safer driving behavior on alternative routes	L	L
Street/intersection improvements	Increase traffic-carrying capacity on alternative routes; encourage additional travel diversion	H	H
Bus turnouts	Increase traffic-carrying capacity on alternative routes; encourage additional travel diversion	M	H
Turn restrictions	Increase traffic-carrying capacity on alternative routes; encourage additional travel diversion	H	H
Parking restrictions	Increase traffic-carrying capacity on alternative routes; encourage additional travel diversion	H	H
Truck/heavy vehicle restrictions	Increase traffic-carrying capacity on alternative routes; encourage additional travel diversion	M	H

Transportation Management Plan (TMP) Strategies	Types of Impacts	Frequency of Use[1]	Current Understanding of Effectiveness[1]
Separate truck lanes	Increase traffic-carrying capacity on alternative routes; encourage additional travel diversion	L	H
Reversible lanes	Increase traffic-carrying capacity on alternative routes; encourage additional travel diversion	M	H
Dynamic lane closure (merge) system	Increase traffic-carrying capacity through the work zone; encourage safer driving behavior; reduce public anxiety and frustration	L	M
Temporary suspension of ramp metering	Increase traffic-carrying capacity on alternative routes; reduce public anxiety and frustration	L	L
Ramp closures	Increase traffic-carrying capacity through the work zone; encourage additional travel diversion; encourage safer driving behavior	M	L
Railroad crossing controls	Encourage safer driving behavior	L	H
Coordination with adjacent construction sites	Increases network/corridor capacity by reducing multiple capacity reductions happening at the same time	M	M
Speed limit reductions/variable speed limits	Encourage safer driving behavior	H	L
Temporary traffic barrier	Reduce severity of crashes between vehicles and work space	H	L
Moveable traffic barrier	Reduce severity of crashes between vehicles and work space; allows capacity reductions to occur when traffic volumes are lower	M	M
Crash cushions	Reduce consequences of crashes that do occur	H	H
Temporary rumble strips	Encourage safer driving behavior	M	M
Intrusion alarms	Reduce worker accidents	L	L
Warning lights	Encourage safer driving behavior	H	L
Automated flagger assistance devices	Reduce worker accidents	L	M
Establishing project task force/committee	Support strategy to aid in identifying needs for other strategies	NA	NA

Transportation Management Plan (TMP) Strategies	Types of Impacts	Frequency of Use[1]	Current Understanding of Effectiveness[1]
Establishing construction safety supervisors/inspectors	Support strategy to aid in identifying needs for other strategies	NA	NA
Work zone safety audits	Support strategy to aid in identifying needs for other strategies	NA	NA
Establishing a TMP monitoring/inspection team	Support strategy to aid in identifying needs for other strategies	NA	NA
Stakeholder meetings	Support strategy to aid in identifying needs for other strategies	NA	NA
Project on-site safety training	Reduce worker accidents	H	L
Safety awards/incentives	Reduce worker accidents	M	L
Windshield surveys	Support strategy to aid in identifying needs for other strategies	NA	NA
Implementing intelligent transportation system (ITS) for traffic monitoring/management (such as queue warning systems)	Increase traffic-carrying capacity through the work zone; encourage additional traveler diversion; encourage safer driving behavior; reduce public anxiety and frustration	M	M
Using/enhancing existing transportation management center	Encourage additional traveler diversion; encourage safer driving behavior; reduce public anxiety and frustration	M	L
Traffic surveillance	Support use of work zone ITS or existing transportation management center	NA	NA
Helicopter for aerial surveillance	Support use of work zone ITS or existing transportation management center	NA	NA
Location reference signs	Reduce the consequences of crashes that occur	H	L
Tow/freeway service patrol	Reduce the consequences of crashes that occur	H	M
Total station units	Reduce the consequences of crashes that occur	M	M
Photogrammetry	Reduce the consequences of crashes that occur	M	M
Coordination with media	Reduce the consequences of crashes that occur	H	L
Preplanned local detour routes	Reduce the consequences of crashes that occur	M	H
Contract support for incident management	Method of procuring incident management services	NA	NA

Transportation Management Plan (TMP) Strategies	Types of Impacts	Frequency of Use[1]	Current Understanding of Effectiveness[1]
Incident/emergency management coordinator	Support for incident management strategies	NA	NA
Incident/emergency response plan	Reduce the consequences of crashes that occur	M	H
Dedicated (paid) police enforcement	Encourage safer driving behavior through the work zone	H	M
Automated enforcement	Encourage safer driving behavior through the work zone	L	M
Increased penalties for work zone violations	Encourage safer driving behavior through the work zone	H	L

[1] L = Low; M = Medium; H = High; NA = Not Applicable

APPENDIX B: EXPECTED STRATEGY EFFECTS ON MOBILITY (M), SAFETY (S), CUSTOMER SATISFACTION (CS), AND AGENCY/CONTRACTOR PRODUCTIVITY AND EFFICIENCY (PE)

Table B-1. Potential Measures of Effectiveness: Temporary Traffic Control – Control Strategies.

Transportation Management Plan Strategies		Costs	M	S	CS	PE	Notes
Strategic construction phasing		$	◕	◕	◕	●	Decisions that improve productivity and efficiency could have significant project cost implications.
Full Roadway Closures		$$	◑	◑	◑	●	Impacts of full closures on mobility and safety measures throughout corridor may be positive or negative, and would need to be measured against other traffic-handling options available. Strategy would be expected to improve worker safety.
Lane shifts or closures	Reduced lane widths but maintain number of lanes	$	●	◑		◕	Effects evaluated relative to other traffic-handling options being considered. Lane width reductions can be particularly challenging for drivers of large trucks.
Lane shifts or closures	Lane closures to provide worker safety	$	◔	◑[1]		◕	Effects evaluated relative to a reduced work space traffic handling option.
Lane shifts or closures	Reduced shoulder width to maintain number of lanes	$	●	◕[2]		◕	Effects evaluated relative to a reduced work space traffic handling option.
Lane shifts or closures	Shoulder closures to provide worker safety	$		◕[1]		◕	Effects evaluated relative to a reduced work space traffic handling option.
Lane shifts or closures	Lane shift to shoulder or median to maintain number of lanes	$	●	◕[2]		◕	Safety and PE effects evaluated relative to a reduced work space traffic handling option. Mobility effects evaluated against a lane closure option.
One-lane, two-way operation		$	◕	◑	◔		Effects evaluated relative to a full road closure option.
Two-way traffic on one side of divided facility (crossover)		$$	◑	◕[1]		◕	Effects evaluated relative to part-width construction on each side of facility.
Reversible lanes		$$$	●		◕	◕	Effects evaluated relative to a reduced peak period lane configuration.

Transportation Management Plan Strategies	Costs	M	S	CS	PE	Notes
Ramp closures/relocation	$$	◑	◕[2]	◑	◕	Ramp closures will be negatively perceived by travelers who normally use those ramps, and positively perceived by other travelers who experience smoother traffic flow on the freeway.
Freeway-to-freeway interchange closures	$$	○	◕[2]	◑	◕	Ability of travelers to adapt also depends on advance notice provided.
Night work	$$	●	◑[2]	◕	◑	Working at night can have negative worker and productivity/efficiency effects if not performed correctly.
Weekend work	$$	◕	◑[2]	◕	◑	Effects evaluated relative to other times when work could be accomplished.
Work hour restrictions for peak travel	$	●	●	●	◔	Effects on PE may be negative (work progress must be divided and scheduled appropriately).
Pedestrian/bicycle accommodations	$	◕	◕	◕	◔	Effect dependent on type of accommodation made in addition to the minimum requirements (Americans with Disabilities Act [ADA], Manual of Uniform Traffic Control Devices [MUTCD]). Mobility improvements would occur only if accommodations result in mode change or elimination of pedestrian/bike-vehicle conflicts that impede traffic.
Business access improvements	$$			●		Effect dependent on type of improvement made in addition to the minimum requirements (MUTCD, agency policies or standards).
Off-site detours/use of alternate routes	$$	●	◑			Effects on safety depend on quality of detour/alternative route used.

● Significant positive effect expected

◕ Slight positive effect expected

◑ Effect could be positive or negative, depending on site conditions

◔ Slight negative effect expected

○ Significant negative effect expected

[1] Primarily affects worker safety

[2] Primarily affects traffic safety (crashes)

Table B-2. Potential Benefit Measures of Effectiveness: Temporary Traffic Control – Project Coordination, Contracting, and Innovative Construction Strategies.

Transportation Management Plan (TMP) Strategies		Costs	M	S	CS	PE	Notes
Project Coordination	Coordination with other projects	$	●	◕	●	◑	Lane closure impacts can be measured for what occurs and extrapolated to additional closures avoided through coordination.
Project Coordination	Utilities coordination	$	◕	◕	◕	●	Effects depend on how they affect duration of conditions impacting mobility and safety.
Project Coordination	Right-of-way coordination	$	◕	◕	◕	●	Effects depend on how coordination affects duration of conditions impacting mobility and safety.
Project Coordination	Coordination with other transportation infrastructure	$	●	◕	●	◑	Effects depend on how coordination affects duration of conditions impacting mobility and safety
Contracting Strategies	Design-build	$$$	◑	◑	◑	●	Effects on safety, mobility, and customer satisfaction depend on quality of other TMP strategies implemented.
Contracting Strategies	A+B bidding	$$	●	●	◕	●	
Contracting Strategies	Incentive/Disincentive	$$	●	●	◕	●	
Contracting Strategies	Lane rental	$$	●	●	◕	◔	Effects on PE may be negative if contractor is not able to efficiently fit tasks within allowable work windows.
Innovative construction techniques (e.g., precast members, rapid cure materials)		$$$$	◕	◕	◕	●	Effect is primarily upon project duration. Indirect effects on other measures may result from a shorter duration project.

● Significant positive effect expected
◕ Slight positive effect expected
◑ Effect could be positive or negative, depending on site conditions
◔ Slight negative effect expected
○ Significant negative effect expected

Table B-3. Potential Benefit Measures of Effectiveness: Public Information - Public Awareness Strategies.

Transportation Management Plan Strategies	Costs	M	S	CS	PE	Notes
Brochures and mailers, press releases/media alerts, paid advertisements, public information center, public meetings/hearings, community task forces, work zone education and safety campaigns, work zone highway safety signs that identify work zone fatalities, visual media information for meetings and web	$$			●		Ability to measure M, S, or PE effects at the project level does not exist.
Telephone hotline, planned lane closure map, project website, coordination with media/schools/ businesses/emergency services, rideshare promotion information	$$	◕	◕	●		Ability to measure M, S, or PE effects at the project level would be limited

● Significant positive effect expected

◕ Slight positive effect expected

◑ Effect could be positive or negative, depending on site conditions

◔ Slight negative effect expected

○ Significant negative effect expected

Table B-4. Potential Benefit Measures of Effectiveness: Public Information - Motorist Information Strategies.

Transportation Management Plan Strategies	Costs	M	S	CS	PE	Notes
Traffic radio	$	●[1]	◕	●	◕	Ability to estimate what would happen if radio not used is limited. PE effects would exist if mobility improvements assist materials and equipment delivery.
Changeable message signs	$$	●[1]	◕[2]	●	◕	Ability to estimate what would happen if signs are not used is limited. PE effects would exist if mobility improvements assist materials and equipment delivery.
Dynamic speed message signs	$		◕[2]			Effects depend on need to warn of excessive speeds.
Highway advisory radio	$$	●[1]	◕	●	◕	Ability to estimate what would happen if radio not used is limited. PE effects would exist if mobility improvements assist materials and equipment delivery.
Highway information network (web-based)	$	●[1]	◕	●	◕	Ability to estimate what would happen if network not used is limited. PE effects would exist if mobility improvements assist materials and equipment delivery.
511 traveler information system	$$	●[1]	◕	●	◕	Ability to estimate what would happen if system not used is limited. PE effects would exist if mobility improvements assist materials and equipment delivery.
Freight travel information	$	◕		◕		Customer satisfaction and mobility effects mostly limited to freight drivers.
Transportation management center	$$$$	●	◕	◕	◕	PE effects would exist if mobility improvements assist materials and equipment delivery.

● Significant positive effect expected

◕ Slight positive effect expected

◑ Effect could be positive or negative, depending on site conditions

◔ Slight negative effect expected

○ Significant negative effect expected

[1] Effect primarily upon delays, queues, and travel time reliability; effect on throughput is limited

[2] Typically evaluated using safety surrogates such as changes in speed or driver opinion.

Table B-5. Potential Benefit Measures of Effectiveness: Traffic Operations – Demand Management Strategies.

Transportation Management Plan Strategies	Costs	M	S	CS	PE	Notes
Transit service improvements (e.g., increased capacity), transit incentives, and new or enhanced shuttle services	$$$$	◕ 1	◕ 2	◕	◕	Mobility effects dependent on ability to shift mode choice. Reduction in vehicle demand could yield reduction in crashes. PE effects would exist if mobility improvements assist materials and equipment delivery.
Ridesharing/carpool incentives, park-and-ride promotions, high-occupancy vehicle lane (new or enhanced)	$$$	◕ 1	◕ 2	◕	◕	Mobility effects dependent on ability to shift mode choice. Reduction in vehicle demand could yield reduction in crashes. PE effects would exist if mobility improvements assist materials and equipment delivery.
Toll/congestion pricing (including high-occupancy toll [HOT] lanes)	$$$$	◕	◑ 2	◕	◕	Mobility effects dependent on ability to shift departure time, route, and mode choice. Reduction in vehicle demand could yield reduction in crashes, but could also increase on other routes. PE effects would exist if mobility improvements assist materials and equipment delivery.
Ramp metering	$$$	●	◑ 2	◑	◕	Reduction in vehicle demand could yield reduction in crashes, but could also increase those on other routes if diversion occurs. Customer satisfaction would be positive for main lane drivers, but negative for ramp users. PE effects would exist if mobility improvements assist materials and equipment delivery.
Parking supply management	$$$	◕ 1	◕ 2	◑	◕	Mobility effects dependent on ability to shift mode choice. Reduction in vehicle demand could yield reduction in crashes. PE effects would exist if mobility improvements assist materials and equipment delivery.
Alternate work hours	$	● 1		◕	◕	Mobility effects dependent on ability to shift departure times. PE effects would exist if mobility improvements assist materials and equipment delivery.
Telecommuting	$	◕ 1	◕ 2	◕	◕	Mobility and safety effects dependent on ability to reduce total trips made. PE effects would exist if mobility improvements assist materials and equipment delivery.

● Significant positive effect expected

◕ Slight positive effect expected

◑ Effect could be positive or negative, depending on site conditions

◔ Slight negative effect expected

○ Significant negative effect expected

[1] Effect primarily upon delays, queues, and travel time reliability; effect on throughput is limited
[2] Primarily affects traffic safety (crashes) by reducing number of vehicle-miles of exposure

Table B-6. Potential Benefit MOEs: Traffic Operations – Corridor/Network Management Strategies.

Transportation Management Plan Strategies	Costs	M	S	CS	PE	Notes
Signal timing/ coordination improvements	$$	●	◑	◕	◕	PE effects would exist if mobility improvements due to reduced volumes assist materials and equipment delivery.
Temporary traffic signals	$$	◑	◑	◕	◕	Mobility and safety effects dependent upon whether comparison is to a non-controlled or flagger/officer controlled condition. PE effects would exist if mobility improvements due to reduced volumes assist materials and equipment delivery.
Street/intersection improvements	$$	●	◑	◕		Ability to estimate what would have occurred without the improvement is limited.
Bus turnouts	$$$	●	◕	◕		
Turn restrictions	$	●	◕	◑		CS effects may be positive or negative depending on user group considered (through drivers versus turning traffic drivers).
Parking restrictions	$	●	◕	◑		CS effects may be positive or negative depending on user group considered (through drivers versus parking drivers).
Truck/heavy vehicle restrictions	$	◕	◕	◑		CS effects may be positive or negative depending on user group considered (passenger vehicle drivers versus truck drivers).
Separate truck lanes	$$$$	◕	◕	◑		CS effects may be positive or negative depending on user group considered (passenger vehicle drivers versus truck drivers).

Transportation Management Plan Strategies	Costs	M	S	CS	PE	Notes
Reversible lanes	$$$	●	◑			Safety effects depend on whether positive effects from improving peak direction capacity are offset or exceeded by negative effects of capacity loss in off-peak direction.
Dynamic lane closure system	$$	◕	◕			Mobility and safety effects dependent upon operating condition at lane closure prior to change (extent to which queue jumping occurs).
Ramp metering	$$	●	◑	◑	◕	Effects on CS could be positive (for main lane drivers) or negative (for entering drivers). Reduction in vehicle demand could yield reduction in crashes, but could also increase those on other routes if diversion occurs. PE effects would exist if mobility improvements due to reduced volumes assist materials and equipment delivery.
Temporary suspension of ramp metering	$	◕	◑	◑		Safety and CS effects may be positive or negative (positive if suspension reduces queue spillback to upstream intersections, negative if ramp platoons create additional turbulence at the ramp merge point).
Ramp closures	$$	●	●		◕	PE effects depend on whether work activities have to occur on ramp, or if operating condition improve materials and equipment delivery.
Railroad crossing controls	$	◕	◕	◕		Effects limited to conditions where work zone increases potential for vehicles to stop on tracks.
Coordination with adjacent construction sites	$	◕	◕	●	◕	Lane closure impacts can be measured for what occurs and extrapolated to additional closures avoided through coordination.

● Significant positive effect expected

◕ Slight positive effect expected

◑ Effect could be positive or negative, depending on site conditions

◔ Slight negative effect expected

○ Significant negative effect expected

Table B-7. Potential Benefit MOEs: Traffic Operations – Work Zone Safety Management Strategies.

Transportation Management Plan Strategies	M	S	CS	PE	Notes
Speed limit reductions/ variable speed limits		◕			Relationship between speed limits and safety is not well defined (ability to predict what would occur if not implemented is limited).
Variable speed limits	◕	◕			Hypothesized to have potential effects on crash reductions, and possibly throughput.
Temporary traffic signals	◕	◑		◕	Mobility benefits dependent upon whether comparison is to a non-controlled or flagger/officer controlled condition. Safety effects for travelers could be positive or negative depending on how signal operates relative to a non-controlled or flagger/officer controlled intersection. PE effects would exist because flaggers can be used for other work duties.
Temporary traffic barrier		●		◕	Slight improvements in PE may occur because workers feel more protected while working.
Moveable traffic barrier	◕	◕		◕	Effects would be computed relative to a long-term barrier lane closure (for mobility and safety effects), or to use of no barrier (for safety effects only).
Crash cushions		●			Generally required by state standards.
Temporary rumble strips		◕			
Intrusion alarms		◕			False alarms have limited the effectiveness of this strategy in past assessments. Potential exists to possibly improve worker safety.
Warning lights		◕			Effect on safety will typically be measureable through safety surrogates.
Automated flagger assistance devices		◕		◕	PE effects would occur if the number of flaggers used can be reduced.
Project on-site safety training		◕			
Safety awards/incentives		◕			

● Significant positive effect expected
◕ Slight positive effect expected
◑ Effect could be positive or negative, depending on site conditions
◔ Slight negative effect expected
○ Significant negative effect expected

Table B-8. Potential Benefit MOEs: Traffic Operations – Traffic/Incident Management and Enforcement Strategies.

Transportation Management Plan Strategies	Costs	M	S	CS	PE	Notes
ITS for traffic monitoring/ management	$$$	●	◑	◕	◕	Effects dependent on how frequently events occur that trigger system responses, and how components affect response time or route diversion, e.g. PE effects would exist if mobility improvements assist materials and equipment delivery.
Helicopter for aerial surveillance	$$$	◕		◕		Not often used due to high costs
Unmanned drones for aerial surveillance	$	◕		◕		Currently experimental.
Reference location signs	$	◕	◕	◕		Effects dependent on how much strategy improves response time.
Tow/freeway service patrol	$$	◕	◕	◕		Effects dependent on how much strategy improves response time.
Total station units, photogrammetry	$	◕	◕	◕		Effects dependent on how much strategy improves response time.
Coordination with media	$	●	◕	◕		Effects dependent on how much actions and strategies improve motorist information system dissemination.
Preplanned local detour routes, contractor support for incident management, incident/emergency management coordinator, incident response plan	$$	◕	◕	◕		Effects dependent on how much actions and strategies improve response (implementation of detours) time or motorist information dissemination, e.g.
Dedicated (paid) police enforcement	$$	◑	●	◑	◑	Effects on M, CS, PE may be positive if presence leads to more consistent speeds and cooperative driving behavior around work zone, or negative if enforcement efforts are too aggressive.
Automated enforcement	$$	◑	●	◑		Limited applicability to due legislative changes required.
Increased penalties for work zone violations	$		◕	◑		Primarily programmatic effect across region. Effect on CS depends on whether or not driver has received a citation.

● Significant positive effect expected

◕ Slight positive effect expected

◑ Effect could be positive or negative, depending on site conditions

◔ Slight negative effect expected

○ Significant negative effect expected

APPENDIX C: TRANSPORTATION MANAGEMENT PLAN STRATEGY INTERDEPENDENCIES

Table C-1. Control Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Strategic construction phasing	Full Roadway Closures	Lane shifts or closures					One-lane, two-way operation	Two-way traffic on one side of divided facility (crossover)	Reversible lanes	Ramp closures/relocation	Freeway-to-freeway interchange closures	Night work	Weekend work	Work hour restrictions for peak travel	Pedestrian/bicycle accommodations	Business access improvements	Off-site detours/use of alternate routes
				Reduced lane widths to maintain number of lanes	Lane closures to provide worker safety	Reduced shoulder width to maintain number of lanes	Shoulder closures to provide worker safety	Lane shift to shoulder/ median to maintain number of lanes											
Strategic construction phasing		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Full roadway closures			●									◆		◆	◆				●
Lane shifts or closures	Reduced lane widths to maintain number of lanes (constriction)			●															
Lane shifts or closures	Lane closures to provide worker safety				●									◆	◆				
Lane shifts or closures	Reduced shoulder width to maintain number of lanes					●													
Lane shifts or closures	Shoulder closures to provide worker safety						●												
Lane shifts or closures	Lane shift to shoulder/median to maintain number of lanes							●											
One-lane, two-way operation									●										
Two-way traffic on one side of divided facility (crossover)										●									
Reversible lanes											●								
Ramp closures/relocation												●		●	●				
Freeway-to-freeway interchange closures													●	●	●				
Night work														●					
Weekend work															●				
Work hour restrictions for peak travel																●			
Pedestrian/bicycle accommodations																	●	◆	
Business access improvements																		●	
Off-site detours/use of alternate routes																			●

● Strong interdependence between TMP strategies ◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-2. Control Strategy/Project Coordination, Contracting, and Innovative Construction Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Project Coordination				Contracting Strategies				Innovative construction techniques (e.g., precast members, rapid cure materials)
		Coordination with other projects	Utilities coordination-	Right-of-way coordination	Coordination with other transportation infrastructure	Design-build	A+B bidding	Incentive/disincentive	Lane rental	
Strategic construction phasing		●	●	●	●	●	●	●	●	●
Full roadway closures		●				●	●	●		●
Lane shifts or closures	Reduced lane widths to maintain number of lanes (constriction)									
	Lane closures to provide worker safety	◆								
	Reduced shoulder width to maintain number of lanes									
	Shoulder closures to provide worker safety									
	Lane shift to shoulder/median to maintain number of lanes									
One-lane, two-way operation										
Two-way traffic on one side of divided facility (crossover)										
Reversible lanes										
Ramp closures/relocation										
Freeway-to-freeway interchange closures		●			●					
Night work		◆			◆					
Weekend work		◆			◆					
Work hour restrictions for peak travel										
Pedestrian/bicycle accommodations										
Business access improvements										
Off-site detours/use of alternate routes										

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-3. Control Strategy/Public Awareness Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Brochures and mailers, press releases/media alerts, paid advertisements, public information center, public meetings/hearings, community task forces, work zone education and safety campaigns, work zone highway safety signs that identify work zone fatalities, visual media	Telephone hotline, planned lane closure map, project website, coordination with media/schools/businesses/emergency services, rideshare promotion information
Strategic construction phasing		●	●
Full roadway closures		●	●
Lane shifts or closures	Reduced lane widths to maintain number of lanes (constriction)		
	Lane closures to provide worker safety		
	Reduced shoulder width to maintain number of lanes		
	Shoulder closures to provide worker safety		
	Lane shift to shoulder/median to maintain number of lanes		
One-lane, two-way operation			
Two-way traffic on one side of divided facility (crossover)			
Reversible lanes			
Ramp closures/relocation		●	●
Freeway-to-freeway interchange closures		●	●
Night work			
Weekend work			
Work hour restrictions for peak travel			
Pedestrian/bicycle accommodations			
Business access improvements		●	
Off-site detours/use of alternate routes		●	

● Strong interdependence between TMP strategies

Table C-4. Control Strategy/Motorist Information Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Traffic radio	Changeable message signs	Dynamic speed message signs	Highway advisory radio	Highway information network (web-based)	511 traveler information system	Freight travel information	Transportation management center
Strategic construction phasing									
Full roadway closures		●	●			●	●	●	●
Lane shifts or closures	Reduced lane widths to maintain number of lanes (constriction)								
	Lane closures to provide worker safety								
	Reduced shoulder width to maintain number of lanes								
	Shoulder closures to provide worker safety								
	Lane shift to shoulder/median to maintain number of lanes								
One-lane, two-way operation									
Two-way traffic on one side of divided facility (crossover)									
Reversible lanes			●						
Ramp closures/relocation									
Freeway-to-freeway interchange closures									
Night work		●	●		●	●	●	●	●
Weekend work		●	●		●	●	●	●	●
Work hour restrictions for peak travel									
Pedestrian/bicycle accommodations									
Business access improvements									
Off-site detours/use of alternate routes		◆	◆		◆	◆	◆		◆

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-5. Control Strategy/Demand Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Transit service improvements	Ridesharing/carpool incentives, park-and rid promotions	Toll/congestion pricing (including high-occupancy toll [HOT] lanes)	Ramp metering to promote high-occupancy vehicle (HOV) use	Parking supply management	Alternate work hours	Telecommuting
Strategic construction phasing								
Full roadway closures		◆	◆	◆	◆	◆	◆	◆
Lane shifts or closures	Reduced lane widths to maintain number of lanes (constriction)							
Lane shifts or closures	Lane closures to provide worker safety	◆	◆	◆	◆	◆	◆	◆
Lane shifts or closures	Reduced shoulder width to maintain number of lanes							
Lane shifts or closures	Shoulder closures to provide worker safety							
Lane shifts or closures	Lane shift to shoulder/median to maintain number of lanes							
One-lane, two-way operation								
Two-way traffic on one side of divided facility (crossover)								
Reversible lanes								
Ramp closures/relocation								
Freeway-to-freeway interchange closures		◆	◆	◆	◆	◆	◆	◆
Night work								
Weekend work								
Work hour restrictions for peak travel		●	●	●	●	●	●	●
Pedestrian/bicycle accommodations								
Business access improvements								
Off-site detours/use of alternate routes								

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-6. Control Strategy/Corridor and Network Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Signal timing/coordination improvements	Temporary traffic signals	Street/intersection Improvements	Bus turnouts	Turn restrictions	Parking restrictions	Truck (especially overweight, over height) restrictions	Separate truck lanes	Reversible lanes	Dynamic lane closure	Ramp metering	Temporary suspension of ramp metering	Ramp closures	Railroad crossing controls	Coordination with adjacent construction sites
Strategic construction phasing																
Full roadway closures																
Lane shifts or closures	Reduced lane widths to maintain number of lanes (constriction)															
	Lane closures to provide worker safety															
	Reduced shoulder width to maintain number of lanes															
	Shoulder closures to provide worker safety															
	Lane shift to shoulder/median to maintain number of lanes															
One-lane, two-way operation			●													
Two-way traffic on one side of divided facility (crossover)																
Reversible lanes																
Ramp closures/relocation																
Freeway-to-freeway interchange closures																
Night work																
Weekend work																
Work hour restrictions for peak travel																
Pedestrian/bicycle accommodations		◆		◆												
Business access improvements															◆	
Off-site detours/use of alternate routes		●		●	◆	●	●	●		●	◆	◆	◆	◆		●

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-7. Control Strategy/Work Zone Safety Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Speed limit reductions	Variable speed limits	Temporary traffic signals	Temporary traffic barrier	Moveable traffic barrier	Crash cushions	Temporary rumble strips	Intrusion alarms	Warning lights	Automated flagger assistance devices	Project on-site safety training	Safety awards/incentives
Strategic construction phasing													
Full roadway closures													
Lane shifts or closures	Reduced lane widths to maintain number of lanes (constriction)				●								
Lane shifts or closures	Lane closures to provide worker safety				●	●							
Lane shifts or closures	Reduced shoulder width to maintain number of lanes				●								
Lane shifts or closures	Shoulder closures to provide worker safety				◆								
Lane shifts or closures	Lane shift to shoulder/median to maintain number of lanes												
One-lane, two-way operation											●		
Two-way traffic on one side of divided facility (crossover)					●								
Reversible lanes						◆							
Ramp closures/relocation					◆								
Freeway-to-freeway interchange closures													
Night work										●			
Weekend work													
Work hour restrictions for peak travel													
Pedestrian/bicycle accommodations													
Business access improvements													
Off-site detours/use of alternate routes													

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-8. Control Strategy/Traffic Incident Management and Enforcement Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Intelligent transportation system for traffic monitoring and management	Helicopter for aerial surveillance	Unmanned drones for aerial surveillance	Reference location signs	Tow/freeway service patrols	Total station units, photogrammetry	Coordination with media	Preplanned detour routes, incident management coordinator	Paid police enforcement	Automated enforcement	Increased penalties for work zone violations
Strategic construction phasing												
Full roadway closures		●						●		◆		
Lane shifts or closures	Reduced lane widths to maintain number of lanes (constriction)											
	Lane closures to provide worker safety									◆		
	Reduced shoulder width to maintain number of lanes											
	Shoulder closures to provide worker safety											
	Lane shift to shoulder/median to maintain number of lanes											
One-lane, two-way operation										◆		
Two-way traffic on one side of divided facility (crossover)												
Reversible lanes												
Ramp closures/relocation												
Freeway-to-freeway interchange closures												
Night work										●		
Weekend work										●		
Work hour restrictions for peak travel												
Pedestrian/bicycle accommodations												
Business access improvements												
Off-site detours/use of alternate routes										◆		

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-9. Project Coordination Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Project Coordination				Contracting Strategies				Innovative construction techniques to reduce work duration (e.g., precast members, rapid cure materials)
		Coordination with other projects	Utilities coordination	ROW coordination	Coordination with other transportation infrastructure	Design-build	A+B bidding	Incentive/disincentive	Lane rental	
Project coordination	Coordination with other projects	●								
	Utilities coordination		●				●	●		
	Right-of-way coordination			●			●	●		
	Coordination with other transportation infrastructure				●					
Contracting strategies	Design-build					●				◆
	A+B bidding						●			◆
	Incentive/disincentive clauses							●		◆
	Lane rental								●	
Innovative construction techniques to reduce work duration (e.g., precast members, rapid cure materials)										●

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-10. Project Coordination/Public Awareness Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Brochures and mailers, press releases/media alerts, paid advertisements, public information center, public meetings/hearings, community task forces, work zone education and safety campaigns, work zone highway safety signs that identify work zone fatalities, visual media information for meetings and web.	Telephone hotline, planned lane closure map, project website, coordination with media/schools/ businesses/emergency services, rideshare promotion information
Project coordination	Coordination with other projects	◆	◆
	Utilities coordination		
	Right-of-way coordination		
	Coordination with other transportation infrastructure	◆	◆
Contracting strategies	Design-build		
	A+B bidding		
	Incentive/disincentive clauses		
	Lane rental		
Innovative construction techniques to reduce work duration (e.g., precast members, rapid cure materials)		◆	◆

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-11. Project Coordination/ Motorist Information Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Traffic radio	Changeable message signs	Dynamic speed message signs	Highway advisory radio	Highway information network (web-based)	511 traveler information system	Freight travel information	Transportation management center
Project coordination	Coordination with other projects	◆	◆		◆	◆	◆	◆	◆
	- Utilities coordination								
	- Right-of-way coordination								
	- Coordination with other transportation infrastructure	◆	◆		◆	◆	◆	◆	◆
Contracting strategies	Design-build								
	- A+B bidding								
	- Incentive/disincentive clauses								
	- Lane rental								
Innovative construction techniques to reduce work duration (e.g., precast members, rapid cure materials)									

◆Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-12. Project Coordination/ Demand Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Transit service improvements	Ridesharing/carpool incentives, park-and rid promotions	Toll/congestion pricing (including high-occupancy toll [HOT] lanes)	Ramp metering to promote high-occupancy vehicle (HOV) use	Parking supply management	Alternate work hours	Telecommuting
Project coordination	Coordination with other projects							
	Utilities coordination							
	Right-of-way coordination							
	Coordination with other transportation infrastructure	◆	◆	◆		◆		
Contracting strategies	Design-build							
	A+B bidding							
	Incentive/disincentive clauses							
	Lane rental							
Innovative construction techniques to reduce work duration (e.g., precast members, rapid cure materials)								

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-13. Project Coordination/ Corridor and Network Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Signal Timing/coordination improvements	Temporary traffic signals	Street/intersection Improvements	Bus turnouts	Turn restrictions	Parking restrictions	Truck (especially overweight, over height) restrictions	Separate truck lanes	Reversible lanes	Dynamic lane closure system	Ramp metering	Temporary suspension of ramp metering	Ramp closures	Railroad crossing controls	Coordination with adjacent construction sites
Project coordination	Coordination with other projects	◆					◆			◆			◆	◆		
	Utilities coordination															
	Right-of-way coordination															
	Coordination with other transportation infrastructure	◆		◆	◆	◆	◆	◆	◆	◆		◆	◆	◆	◆	◆
Contracting strategies	Design-build															
	A+B bidding															
	Incentive/disincentive clauses															
	Lane rental															
Innovative construction techniques to reduce work duration (e.g., precast members, rapid cure materials)																

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-14. Project Coordination/Traffic Incident Management and Enforcement Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies		Intelligent transportation system for traffic monitoring and management	Helicopter for aerial surveillance	Unmanned drones for aerial surveillance	Reference location signs	Tow/freeway service patrols	Total station units, photogrammetry	Coordination with media	Preplanned detour routes, incident management coordinator	Paid police enforcement	Automated enforcement	Increased penalties for work zone violations
Project coordination	Coordination with other projects							◆				
	Utilities coordination											
	Right-of-way coordination											
	Coordination with other transportation infrastructure							◆				
Contracting strategies	Design-build											
	A+B bidding											
	Incentive/disincentive clauses											
	Lane rental											
Innovative construction techniques to reduce work duration (e.g., precast members, rapid cure materials)		◆								◆		

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-15. Public Awareness Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Brochures and mailers, press releases/media alerts, paid advertisements, public information center, public meetings/hearings, community task forces, work zone education and safety campaigns, work zone highway safety signs that identify work zone fatalities, visual media information for meetings and web.	Telephone hotline, planned lane closure map, project website, coordination with media/schools/ businesses/emergency services, rideshare promotion information
Brochures and mailers, press releases/media alerts, paid advertisements, public information center, public meetings/hearings, community task forces, work zone education and safety campaigns, work zone highway safety signs that identify work zone fatalities, visual media information for meetings and web	●	◆
Telephone hotline, planned lane closure map, project website, coordination with media/schools/ businesses/emergency services, rideshare promotion information		●

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-16. Public Awareness/Motorist Information Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Traffic radio	Changeable message signs	Dynamic speed message signs	Highway advisory radio	Highway information network (web-based)	511 traveler information system	Freight travel information	Transportation management center
Brochures and mailers, press releases/media alerts, paid advertisements, public information center, public meetings/hearings, community task forces, work zone education and safety campaigns, work zone highway safety signs that identify work zone fatalities, visual media information for meetings and web	◆				◆		◆	
Telephone hotline, planned lane closure map, project website, coordination with media/schools/ businesses/emergency services, rideshare promotion information				◆	◆	●	●	◆

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-17. Public Awareness/Demand Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Transit service improvements	Ridesharing/carpool incentives, park-and ride promotions	Toll/congestion pricing (including high-occupancy toll [HOT] lanes)	Ramp metering to promote high-occupancy vehicle (HOV) use	Parking supply management	Alternate work hours	Telecommuting
Brochures and mailers, press releases/media alerts, paid advertisements, public information center, public meetings/hearings, community task forces, work zone education and safety campaigns, work zone highway safety signs that identify work zone fatalities, visual media information for meetings and web	◆	◆	◆	◆	◆	◆	◆
Telephone hotline, planned lane closure map, project website, coordination with media/schools/ businesses/emergency services, rideshare promotion information		◆		◆	◆		

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-18. Public Awareness/Corridor and Network Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Signal Timing/coordination improvements	Temporary traffic signals	Street/intersection Improvements	Bus turnouts	Turn restrictions	Parking restrictions	Truck (especially overweight, over height) restrictions	Separate truck lanes	Reversible lanes	Dynamic lane closure system	Ramp metering	Temporary suspension of ramp metering	Ramp closures	Railroad crossing controls	Coordination with adjacent construction sites
Brochures and mailers, press releases/media alerts, paid advertisements, public information center, public meetings/hearings, community task forces, work zone education and safety campaigns, work zone highway safety signs that identify work zone fatalities, visual media information for meetings and web															
Telephone hotline, planned lane closure map, project website, coordination with media/schools/ businesses/emergency services, rideshare promotion information		◆	◆	◆	◆	◆	◆	◆	◆		◆	◆	◆	◆	

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-19. Motorist Information/Demand Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Transit service improvements	Ridesharing/carpool incentives, park-and rid promotions	Toll/congestion pricing (including high-occupancy toll [HOT] lanes)	Ramp metering to promote high-occupancy vehicle (HOV) use	Parking supply management	Alternate work hours	Telecommuting
Traffic radio							
Changeable message signs			◆		◆		
Dynamic speed message signs							
Highway advisory radio							
Highway information network (web-based)	◆	◆					
511 traveler information system							
Freight travel information							
Transportation management center				◆			

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-20. Motorist Information/Corridor and Network Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Signal Timing/coordination improvements	Temporary traffic signals	Street/intersection Improvements	Bus turnouts	Turn restrictions	Parking restrictions	Truck (especially overweight, over height) restrictions	Separate truck lanes	Reversible lanes	Dynamic lane closure system	Ramp metering	Temporary suspension of ramp metering	Ramp closures	Railroad crossing controls	Coordination with adjacent construction sites
Traffic radio					◆	◆			◆		◆		◆		
Changeable message signs					◆	◆			◆		◆	◆	◆		
Dynamic speed message signs															
Highway advisory radio													◆		
Highway information network (web-based)					◆	◆							◆		
511 traveler information system													◆		
Freight travel information															
Transportation management center															

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-21. Motorist Information/Work Zone Safety Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Speed limit reductions	Variable speed limits	Temporary traffic signals	Temporary traffic barrier	Moveable traffic barrier	Crash cushions	Temporary rumble strips	Intrusion alarms	Warning lights	Automated flagger assistance devices	Project on-site safety training	Safety awards/incentives
Traffic radio												
Changeable message signs	◆	●										
Dynamic speed message signs												
Highway advisory radio												
Highway information network (web-based)												
511 traveler information system												
Freight travel information												
Transportation management center												

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-22. Motorist Information/Traffic Incident Management and Enforcement Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Intelligent transportation system for traffic monitoring and management	Helicopter for aerial surveillance	Unmanned drones for aerial surveillance	Reference location signs	Tow/freeway service patrols	Total station units, photogrammetry	Coordination with media	Preplanned detour routes, incident management coordinator	Paid police enforcement	Automated enforcement	Increased penalties for work zone violations
Traffic radio	◆							◆			
Changeable message signs	●							◆			
Dynamic speed message signs											
Highway advisory radio	●							◆			
Highway information network (web-based)	●							◆			
511 traveler information system	●							◆			
Freight travel information											
Transportation management center	●							◆			

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-23. Demand Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Transit service improvements	Ridesharing/carpool incentives, park-and rid promotions	Toll/congestion pricing (including high-occupancy toll [HOT] lanes)	Ramp metering to promote high-occupancy vehicle (HOV) use	Parking supply management	Alternate work hours	Telecommuting
Transit service improvements (e.g., increased capacity), transit incentives, and new or enhanced shuttle services	●	●	●	◆	◆		
Ridesharing/carpool incentives, park-and-ride promotions, high-occupancy vehicle lane (new or enhanced)		●	●	●	◆		
Toll/congestion pricing (including high-occupancy toll [HOT] lanes)			●	◆			
Ramp metering				●			
Parking supply management					●		
Alternate work hours						●	
Telecommuting							●

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-24. Demand Management/Corridor and Network Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Signal Timing/coordination improvements	Temporary traffic signals	Street/intersection Improvements	Bus turnouts	Turn restrictions	Parking restrictions	Truck (especially overweight, over height) restrictions	Separate truck lanes	Reversible lanes	Dynamic lane closure system	Ramp metering	Temporary suspension of ramp metering	Ramp closures	Railroad crossing controls	Coordination with adjacent construction sites
Transit service improvements (e.g., increased capacity), transit incentives, and new or enhanced shuttle services				◆											
Ridesharing/carpool incentives, park-and-ride promotions, high-occupancy vehicle lane (new or enhanced)															
Toll/congestion pricing (including high-occupancy toll [HOT] lanes)															
Ramp metering											●				
Parking supply management															
Alternate work hours															
Telecommuting															

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-25. Demand Management/Traffic Incident Management and Enforcement Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Intelligent transportation system for traffic monitoring and management	Helicopter for aerial surveillance	Unmanned drones for aerial surveillance	Reference location signs	Tow/freeway service patrols	Total station units, photogrammetry	Coordination with media	Preplanned detour routes, incident management coordinator	Paid police enforcement	Automated enforcement	Increased penalties for work zone violations
Transit service improvements (e.g., increased capacity), transit incentives, and new or enhanced shuttle services	◆										
Ridesharing/carpool incentives, park-and-ride promotions, high-occupancy vehicle lane (new or enhanced)											
Toll/congestion pricing (including high-occupancy toll [HOT] lanes)											
Ramp metering	◆										
Parking supply management											
Alternate work hours											
Telecommuting											

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-26. Corridor and Network Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Signal Timing/coordination improvements	Temporary traffic signals	Street/intersection Improvements	Bus turnouts	Turn restrictions	Parking restrictions	Truck (especially overweight, over height) restrictions	Separate truck lanes	Reversible lanes	Dynamic lane closure system	Ramp metering	Temporary suspension of ramp metering	Ramp closures	Railroad crossing controls	Coordination with adjacent construction sites
Signal timing/coordination improvements	●		●	◆	●	◆			◆		◆	◆	◆		
Temporary traffic signals		●									◆				
Street/intersection improvements			●	◆	●	●	◆		◆			◆	◆		
Bus turnouts				●	◆	◆									
Turn restrictions					●				●						
Parking restrictions						●			◆						
Truck/heavy (especially overweight, over height) vehicle restrictions							●	●							
Separate truck lanes								●							
Reversible lanes									●						
Dynamic lane closure system										●					
Ramp metering											●				
Temporary suspension of ramp metering												●			
Ramp closures													●		
Railroad crossing controls														●	
Coordination with adjacent construction sites															●

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-27. Corridor and Network Management/Incident Management Enforcement Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Intelligent transportation system for traffic monitoring and management	Helicopter for aerial surveillance	Unmanned drones for aerial surveillance	Reference location signs	Tow/freeway service patrols	Total station units, photogrammetry	Coordination with media	Preplanned detour routes, incident management coordinator	Paid police enforcement	Automated enforcement	Increased penalties for work zone violations
Signal timing/coordination improvements	◆										
Temporary traffic signals											
Street/intersection improvements											
Bus turnouts											
Turn restrictions											
Parking restrictions											
Truck/heavy (especially overweight, over height) vehicle restrictions											
Separate truck lanes											
Reversible lanes											
Dynamic lane closure system											
Ramp metering											
Temporary suspension of ramp metering							◆				
Ramp closures							◆				
Railroad crossing controls											
Coordination with adjacent construction sites							◆				

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-28. Work Zone Safety Management Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Speed limit reductions	Variable speed limits	Temporary traffic signals	Temporary traffic barrier	Moveable traffic barrier	Crash cushions	Temporary rumble strips	Intrusion alarms	Warning lights	Automated flagger assistance devices	Project on-site safety training	Safety awards/incentives
Speed limit reductions	●	●										◆
Variable speed limits		●										◆
Temporary traffic signals			●									◆
Temporary traffic barrier				●								◆
Moveable traffic barrier					●							◆
Crash cushions						●						◆
Temporary rumble strips							●			◆		◆
Intrusion alarms								●				◆
Warning lights									●			◆
Automated flagger assistance devices										●		◆
Project on-site safety training											●	◆
Safety awards/incentives												●

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-29. Work Zone Safety Management/Incident Management and Enforcement Strategy Interdependencies

Transportation Management Plan (TMP) Strategies	Intelligent transportation system for traffic monitoring and management	Helicopter for aerial surveillance	Unmanned drones for aerial surveillance	Reference location signs	Tow/freeway service patrols	Total station units, photogrammetry	Coordination with media	Preplanned detour routes, incident management coordinator	Paid police enforcement	Automated enforcement	Increased penalties for work zone violations
Speed limit reductions									●	●	◆
Variable speed limits									●	●	◆
Temporary traffic signals											
Temporary traffic barrier											
Moveable traffic barrier											
Crash cushions											
Temporary rumble strips											
Intrusion alarms									◆	◆	◆
Warning lights											
Automated flagger assistance devices											
Project on-site safety training											
Safety awards/incentives	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆

● Strong interdependence between TMP strategies

◆ Minor to moderate interdependence may exist between TMP strategies under certain conditions

Table C-30. Incident Management and Enforcement Strategy Interdependencies.

Transportation Management Plan (TMP) Strategies	Intelligent transportation system for traffic monitoring and management	Helicopter for aerial surveillance	Unmanned drones for aerial surveillance	Reference location signs	Tow/freeway service patrols	Total station units, photogrammetry	Coordination with media	Preplanned detour routes, incident management coordinator	Paid police enforcement	Automated enforcement	Increased penalties for work zone violations
Intelligent transportation system for traffic monitoring/ management (transportation management center operations, traffic surveillance)	●	●	●				●				
Helicopter for aerial surveillance		●									
Unmanned drones for aerial surveillance			●								
Reference location signs				●							
Tow/freeway service patrol					●						
Total station units, photogrammetry						●					
Coordination with media							●				
Preplanned local detour routes, contractor support for incident management, incident/emergency management coordinator, incident response plan								●			
Dedicated (paid) police enforcement									●		
Automated enforcement										●	
Increased penalties for work zone violations											●

● Strong interdependence between TMP strategies

APPENDIX D: TRANSPORTATION MANAGEMENT PLAN STRATEGY EVALUATION APPROACHES AND SCOPES

Table D-1. Summary of Transportation Management Plan Strategy Evaluation Approach, Scope, and Metrics in the Literature.

Publication	Approach			Evaluation Scope					Notes
	Qualitative	Quantitative	Hybrid	Full-Scale Evaluation of Multiple Strategies at a Project	Agency-Wide Evaluation of Strategies Across Projects	Research Evaluation	Case Study of Single Strategy	Process Review	
Synthesis of Traffic Management Techniques For Major Freeway Construction (1989). [21]			X			X			Compilation of strategies employed at 12 freeway reconstruction projects nationally. Data on costs and effectiveness of free tow truck service within the work zone, traffic signal timing improvements, commuter rail service, improved transit service (including additional park-and-ride lot spaces), improved ridesharing programs, project public information efforts.
Work Zone Lane Closure Warning Light System (1999). [28]			X		X	X			Evaluation of a sequential warning light system for nighttime lane closures at two work zones. Examined lane-changing behavior of automobiles and large trucks.
Analysis of the Impacts of Freeway Reconstruction Closures in Urban Areas (1999). [29]			X	X		X			Evaluation of motorist diversion behavior and opinions of full roadway closure in Seattle. Effectiveness of Transportation Management Plan (TMP) strategies assessed in terms of reported changes in behavior, survey opinions.
Evaluation of Traffic Control Devices for Rural High-Speed Maintenance Work Zones (2000). [30]			X		X	X			Evaluation of several traffic control devices across multiple projects in Texas. Examined speeds, conflicts, driver opinions, agency staff assessments.

Publication	Approach			Evaluation Scope					Notes
	Qualitative	Quantitative	Hybrid	Full-Scale Evaluation of Multiple Strategies at a Project	Agency-Wide Evaluation of Strategies Across Projects	Research Evaluation	Case Study of Single Strategy	Process Review	
Effectiveness of Condition-Responsive Advisory Speed Messages in Rural Work Zones (2002). [14]		X					X		Rural interstate location. Presentation of speeds and delays. Use of an upstream exit ramp increased by 3% when messages posted. No comparable before data to know if some change in exit ramp use would have occurred if the system had not been deployed.
Diversion from a Rural Work Zone with Traffic-Responsive Message Signage System (2003). [15]		X				X	X		Evaluation of a work zone intelligent transportation system (ITS) providing real-time travel time information through a work zone. Data suggested that system encouraged 10 percent of motorists to divert who would not have otherwise.
Guidelines for Application of Portable Work Zone Intelligent Transportation Systems (2003). [31]			X			X			Evaluation of the results of several operational test deployments of work zone ITS nationally. Examined agency staff comments, diversion, driver comments, and speeds.
Effectiveness of Extra Enforcement in Construction and Maintenance Work Zones (2003). [32]	X					X			Evaluation of agency perceptions of benefits of enforcement in work zones.

Publication	Approach			Evaluation Scope					Notes
	Qualitative	Quantitative	Hybrid	Full-Scale Evaluation of Multiple Strategies at a Project	Agency-Wide Evaluation of Strategies Across Projects	Research Evaluation	Case Study of Single Strategy	Process Review	
Evaluation of Effectiveness of Automated Work Zone Information Systems (2005). (16)			X			X	X		Evaluation of a work zone ITS providing real-time information when traffic through work zone was "jammed." Encouraged use of alternative route. Examined volumes, speeds, and driver opinions. Concluded that system smoothed speeds and encouraged diversion. Drivers rated the system positively.
Evaluation of Intelligent Transportation System Deployments for Work Zone Operations (2005). (33)			X		X	X			Evaluation of a dynamic late merge system, real-time travel time information system, and a license-plate recognition system for providing real-time travel times. Examined throughput, lane distribution and merging, queue lengths.
Automated Work Zone Information System: California Implementation (2006). (34)		X				X	X		Evaluation of a work zone ITS providing real-time travel time information through the work zone. Travel times and volumes indicated delays were reduced and diversion did occur to alternative freeways.
Dynamic Late Merge Control at Highway Work Zones: Evaluations, Observations, and Suggestions (2006). (35)			X				X		Evaluation of a dynamic late merge system. Effectiveness based on increase in throughput, lane distribution, and maximum queue length.

Publication	Approach			Evaluation Scope					Notes
	Qualitative	Quantitative	Hybrid	Full-Scale Evaluation of Multiple Strategies at a Project	Agency-Wide Evaluation of Strategies Across Projects	Research Evaluation	Case Study of Single Strategy	Process Review	
Evaluation of the Dynamic Late Lane Merge System at Freeway Construction Work Zones (2007). (36)					X	X			Evaluation of dynamic late lane merge at freeway lane closures (2-to-1 lane closures). Effectiveness based on throughput, merge location, and speeds.
Development and Field Evaluation of Variable Advisory Speed Limit System for Work Zones (2007). (37)		X					X		Evaluation of a real-time variable advisory speed limit system. Effectiveness based on speed reductions, traffic throughput, and speed compliance by drivers.
Evaluation of Strategies for Manage Speed in Highway Work Zones (2007). (38)		X			X	X			Evaluation of speed display trailers and enforcement strategies. Effectiveness based on changes in speeds/travel times.
Matrix-Based Decision Support Tools for Construction Activities on High-Volume Roadways (2008). (39)	X					X			Evaluation of multiple strategies across multiple projects. Effectiveness based on project personnel opinions.
Comparative Analysis Report: The Benefits of Using Intelligent Transportation Systems in Work Zones (2008). (17)			X			X			Compilation of evaluations of multiple types of work zone ITS nationally. Effectiveness based on driver surveys, diversion rates, forced merges, and queue lengths.

Publication	Approach			Evaluation Scope					Notes
	Qualitative	Quantitative	Hybrid	Full-Scale Evaluation of Multiple Strategies at a Project	Agency-Wide Evaluation of Strategies Across Projects	Research Evaluation	Case Study of Single Strategy	Process Review	
Traffic Safety Evaluation of Nighttime and Daytime Work Zones (2008). (40)		X				X			Evaluation of the crash effects of nighttime work zones. Effectiveness based on development of crash modification factors for inactive, active but no temporary lane closure, and active with temporary lane closure conditions.
National Evaluation of the Safe Trip-21 Initiative: I-95 Corridor Coalition Test Bed, Final Report Evaluation: North Carolina Deployment of Portable Traffic-Monitoring Devices (2010). (41)			X		X				Evaluation of the usefulness of a portable traffic monitoring device for work zones. Effectiveness based on accuracy of collecting speed data and agency staff opinions.
Final Report: Cost-Benefit Analysis of Sequential Warning Lights in Nighttime Work Zone Tapers (2011). (42)		X			X	X			Evaluation of sequential warning light system at nighttime lane closures. Effectiveness based on speeds and lane change behavior.
Real-Time Measurement of Travel Time Delay in Work Zones and Evaluation Metrics Using Bluetooth Probe Tracking (2010). (43)		X					X		Evaluation of effect of messages regarding current travel times and recommended alternative route messages on PCMS. Effectiveness based on travel time changes, volumes, assessment of crashes.

Publication	Approach			Evaluation Scope					Notes
	Qualitative	Quantitative	Hybrid	Full-Scale Evaluation of Multiple Strategies at a Project	Agency-Wide Evaluation of Strategies Across Projects	Research Evaluation	Case Study of Single Strategy	Process Review	
Guidelines for Managing Speeds in Work Zones (2010). (44)			X			X			Compilation of evaluations of various speed management strategies in work zones.
Evaluation of the Effectiveness of a Variable Advisory Speed System on Queue Mitigation in Work Zones (2011). (45)		X				X	X		Evaluation of a variable advisory speed system at a location. Effectiveness based on analysis of speeds.
Evaluation of Spatial and Temporal Speed Limit Compliance in Highway Work Zones (2011). (46)		X					X		Evaluation of police enforcement effect on speeds (surrogate of safety).
Driver Feedback on Monetary Penalty and Its Impact on Work Zone Speed (2011). (47)		X					X		Evaluation of an innovative motorist information strategy to notify speeders of potential fines. Effectiveness based on speed reductions achieved.
Low Volume Highway Work Zone Evaluation of Temporary Rumble Strips (2011). (48)		X					X		Evaluation of portable (non-adhesive) transverse rumble strips. Effectiveness based on vehicle brake light application, speeds, and adjacent lane encroachments.

Publication	Approach			Evaluation Scope					Notes
	Qualitative	Quantitative	Hybrid	Full-Scale Evaluation of Multiple Strategies at a Project	Agency-Wide Evaluation of Strategies Across Projects	Research Evaluation	Case Study of Single Strategy	Process Review	
Evaluation of Temporary Ramp Metering for Work Zones (2012). [49]		X			X	X			Evaluation of a temporary ramp metering system at multiple sites in Missouri. Effectiveness based on driver compliance rate, speeds and speed differentials, platoon size, and merging headways.
Effectiveness of a Control Strategy for Forced-Detour n Continuous Lane Closure Within a Rural Work Zone (2012). [50]		X					X		Evaluation of a TMP strategy to keep large trucks on interstate through work zone and divert automobiles on an alternative route. Effectiveness based on diversion rates and travel times.
Commuter Impacts and Behavior Changes during a Temporary Freeway Closure: the 'Fix I-5' Project in Sacramento, CA (2012). [51]			X		X				Evaluation of the effect of multiple strategies implemented for I-5 reconstruction in Sacramento. Effectiveness based on survey of traveler changes to commuting patterns during construction.
Formalized Process for Performance Assessment of Work Zone Transportation Management Plans in Virginia (2013). [52]			X				X		Provided a TMP evaluation framework and demonstrated its use on two case studies (one of a forced detour strategy and one of a recommended detour for a long-term lane closure condition). Effectiveness based on project staff assessment of impacts, diversion rates, and travel times.

Publication	Approach			Evaluation Scope					Notes
	Qualitative	Quantitative	Hybrid	Full-Scale Evaluation of Multiple Strategies at a Project	Agency-Wide Evaluation of Strategies Across Projects	Research Evaluation	Case Study of Single Strategy	Process Review	
Effectiveness of Temporary Rumble Strips in Alerting Motorists in Short-Term Surveying Work Zones (2015). (53)		X			X	X			Evaluation of portable rumble strips in New Jersey. Effectiveness based on speeds and braking activity.

Table D-2. Summary of Data from Highways for Life Project Evaluations

Project	Control Strategy Used	Other Impact Mitigation Strategies Used	Notes
I-15, Ontario, CA. (54)	Nighttime, Weekend Lane Closures (Super Slab replacement) within the I-10/I-15 interchange	Moveable barrier to create safe work space for workers. Public information for the project (e.g., brochures, website, news releases, PCMS messages, paid advertising)	Depending on interchange movement, travel times were 5 to 7 minutes longer during construction. No attempt had been made to estimate what impact would have been without going to night and weekend work. User surveys indicated use of information and general satisfaction with project. Crash data inconclusive.
DC 295 Kenilworth Ave., Washington, DC. (55)	Long-term and short-term lane closures.	Traffic split to use one frontage road lane as a main lane	Closure of cross-streets to the frontage road allowed traffic to flow freely. Travel times increased only by 1 min.
I-80, Council Bluffs, IA. (19)	Shoulder closures, lane closures on 24th street overpass	Use of modular precast elements to reduce overall construction time. Website developed to keep public informed, and held regular meetings.	I-80 traffic not affected. Traffic exiting I-80 to 24th delayed 2-3 min. 24th street traffic over I-80 delayed 3 min. Project duration estimated to be reduced from 6 months to down to two weeks. User survey indicated 89 percent happy with way project was performed.
I-93, Medford, MA. (18)	Weekend closures of several bridges for accelerated bridge replacement	Work zone ITS deployed, some changes to traffic signal timings on alternative routes, free parking for transit users (and some route changes), some local streets closed to help flow on alternative routes, perimeter fencing to reduce rubbernecking, incident command center at the jobsite, public information program implemented (e.g., website, news releases)	Delays on the weekends on I-93 varied from7 to 15 minutes, with queues ranging between 2 and 4 miles. Estimates of diversion rates of 15-20 percent occurred, but not verified with actual counts. 95 percent of users satisfied with how project was performed, large percentages received information from public information effort and were happy with information provided.

Project	Control Strategy Used	Other Impact Mitigation Strategies Used	Notes
MD 295, Baltimore, MD. (56)	Full weekend road closure	Self-propelled modular transport (SPMT) to minimize duration of road closure. Detour routes defined around closure. Public information plan implemented (fliers, newsletters, emails, MDSHA website updates, a project website, and detour cards for area hotels, restaurants, and theaters.)	Detours increased travel times by about 4 minutes per vehicle. No complaints from local businesses or residents.
TH 36, St. Paul, MN. (57)	Full long-term road closure	Defined detour routes. Intelligent transportation system (ITS) to monitor traffic on alternative routes and provide motorists with travel times. Public information/notification efforts (specifics not documented)	Reductions in screen line volumes across TH 36 and alternative routes of 28 percent. Increases in travel times of 7 minutes or less in corridor. Reduced project duration by 3 to 3.5 months. Public generally positive about how project was handled.
I-590 Interchange, Rochester, NY. (58)	Occasional ramp closures on I-590; occasional full road closure. Lane closures on Winton Road.	Defined detour routes when full road closures defined. Public information/notification efforts (specifics not documented)	Travel times during full road closures increased 3 to 11 minutes, depending on maneuver.
OR 38, Elkton, OR. (20)	24/7 alternating one-way operation. Full road closures on weekends.	Accelerated bridge replacement. Public information/notification efforts (specifics not documented)	5 to 9 minutes of delay when alternating one-way operation occurred. 45 minutes delay due to lengthy diversion route when full road closure occurred. User survey indicated 86 percent satisfaction with approach taken to replace bridges.
SC 703, Sullivan's Island, SC. (59)	Full roadway closure for bridge replacement	Defined detour routes implemented.	Travel times increased by 3 minutes or less due to the added distance traveled and minimal congestion. Essentially all of the traffic on the closed roadway could be accounted for on the detour route.

Project	Control Strategy Used	Other Impact Mitigation Strategies Used	Notes
I-215, Salt Lake City, UT. [60]	Nighttime lane closures	Use of pre-cast concrete panels to repair bridge decks faster. Use of moveable barrier to protect work space during panel replacement activities.	Nighttime lane closures had no effect on travel times or volumes. If performed during daytime hours, it was estimated that delays would have approached 25 minutes per vehicle in the am peak period, at a minimum.
VA 15/29, Buckland, VA. [61]	Full road closure on weekends.	Defined detour routes implemented. Public information/notification efforts (press releases, use of portable changeable message signs).	Travel times increased, depending on travel route around closure, by 14 minutes or less. Effect of a designated detour route had not been established, or if public notification had not occurred, was not estimated.
I-66, Washington, DC. [62]	Nighttime lane closures for pre-cast concrete pavement repair.	Detour route defined when a ramp closure was required. Public information/notification efforts (specifics not documented).	Delays varied by night, and reached 20 minutes per vehicle in some cases. Queue lengths reached a maximum of 1.5 miles. Comparison to what would have occurred if pre-cast panels were not used and long-term lane closures had been required was not computed.

APPENDIX E: TRANSPORTATION MANAGEMENT PLAN STRATEGY DEVELOPMENT AND EVALUATION EXAMPLE: I-40/I-440 ("FORTIFY 40") PAVEMENT REHABILITATION PROJECT, RALEIGH, NC

An illustration of a pre-project Transportation Management Plan (TMP) impact analyses and during-project monitoring to assess the validity of the strategy estimates is the ongoing design-build rehabilitation project being performed by the North Carolina Department of Transportation (NCDOT) on an 11.5 mile stretch of I-40/I-440 in Raleigh, NC. This section of freeway serves between 90,000 and 113,000 vehicles per day, and creates recurrent congestion in several sections within the project limits. The project includes replacement of existing concrete pavement that has deteriorated over time, extension of auxiliary lanes between some ramps, extension of a deceleration lane to better accommodate exiting traffic demands, and rehabilitation of 14 bridges within the project limits. An initial stage replaced a 3-mile section east of the interchange to serve as a better diversion route when the remaining segments are being rehabilitated. The remaining project stage 2 got underway in late 2014 and is scheduled to be completed in late 2016 or early 2017. Figure E-1 illustrates the limits of the project.

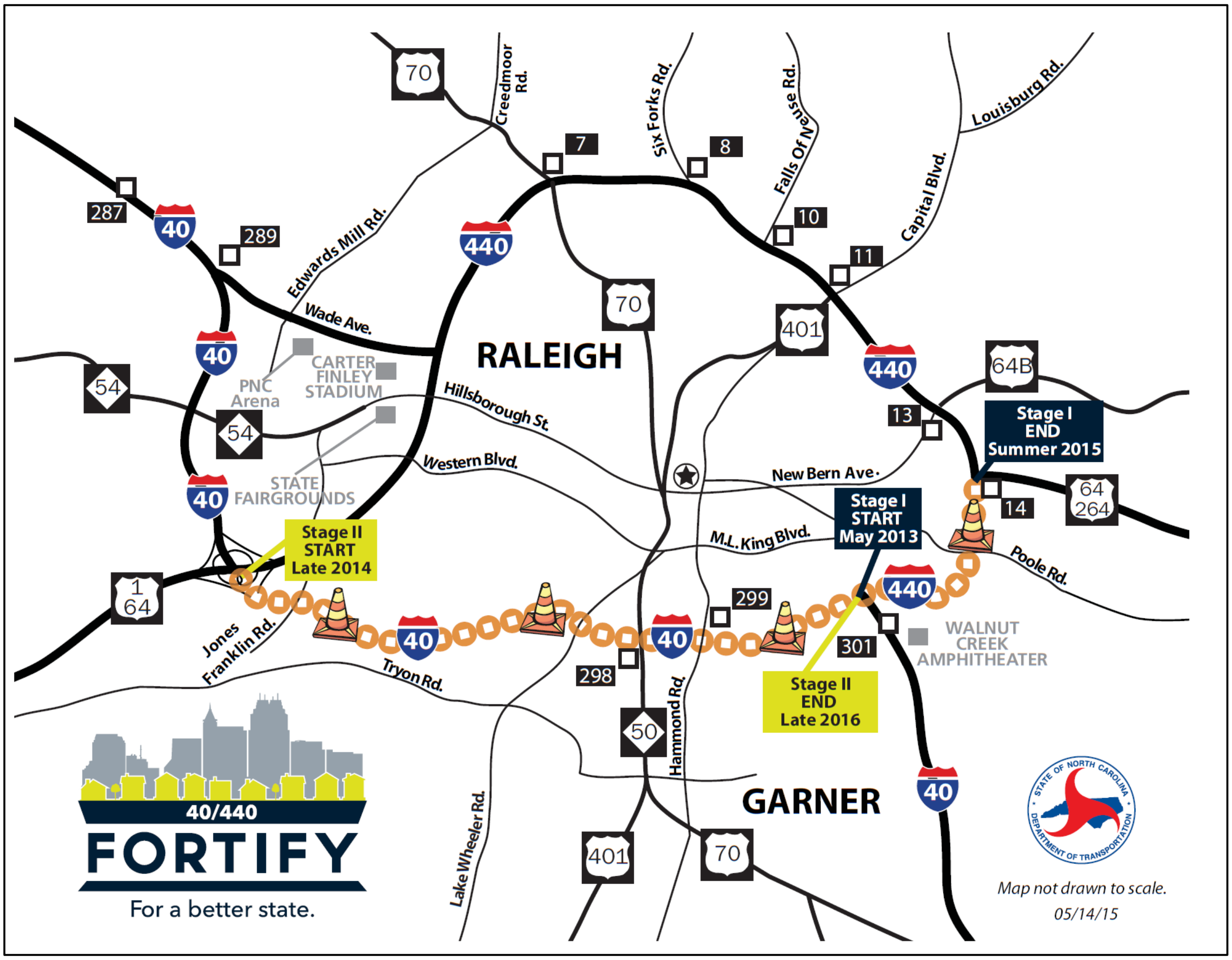
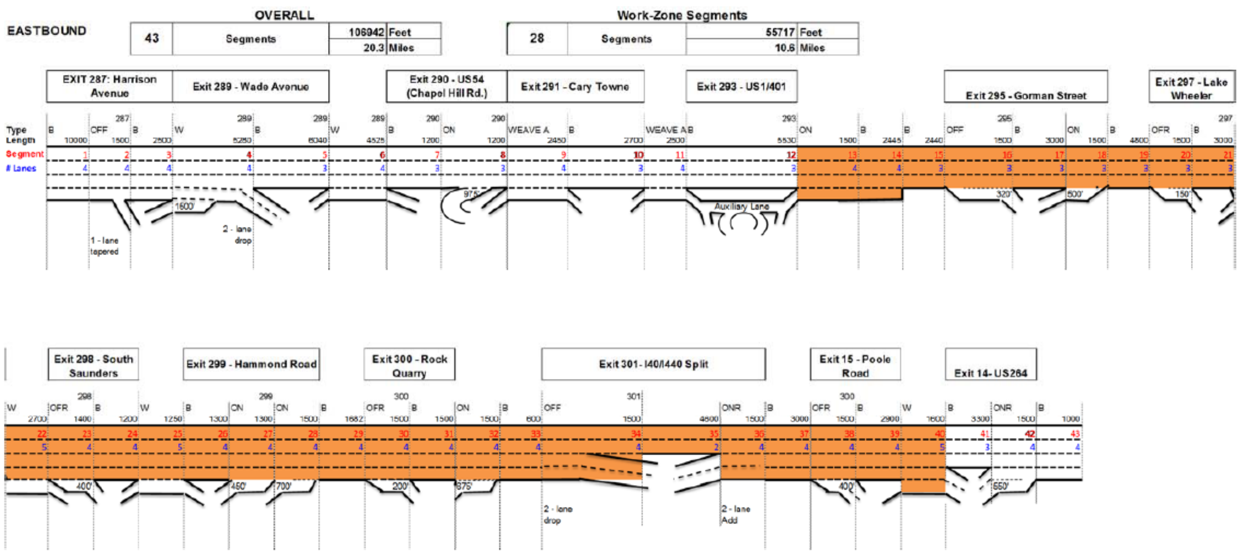
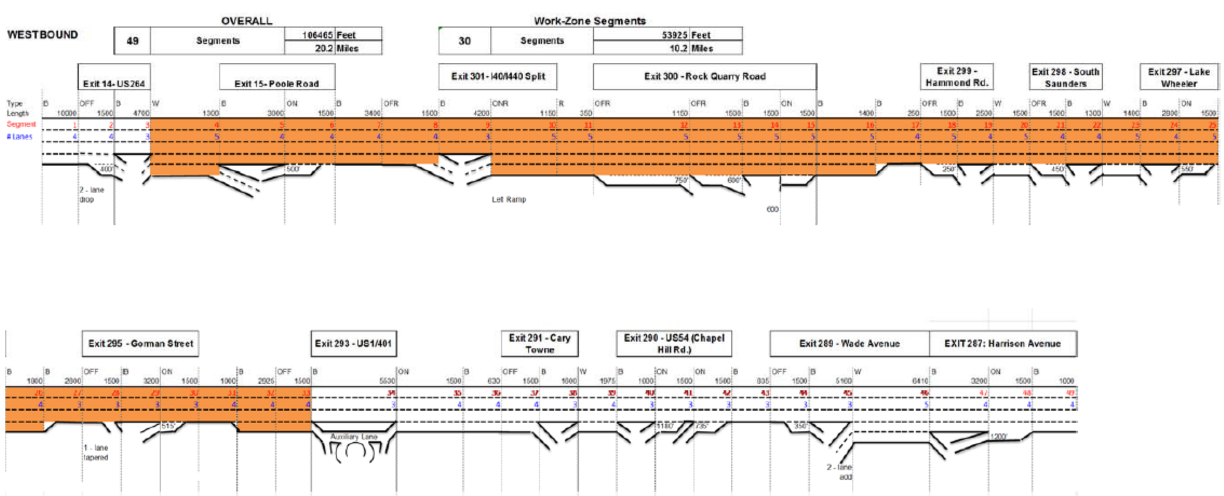


Figure E-1. Map. The Forty 40 Project Limits. [(63)]

Since the project is primarily a rehabilitation effort and not a widening activity, it presented a challenge in terms of how to accommodate the lane closures that would be required to break up and remove the pavement, place new concrete, and reopen the lanes to traffic. This stretch of interstate varies in cross-section from three to four lanes in each direction. The roadway does drop to two through lanes through the I-40/I-440 interchange, and does have some areas where there is an auxiliary lane between adjacent on and off ramps that essentially create a 5-lane cross section. Figure E-2 illustrates the lane geometries of this segment of roadway. [64]



(a) eastbound



(b) westbound

Figure E-2. Diagram. Lane geometries for the project. [64]

Researchers at the Institute for Transportation Research and Education (ITRE) at North Carolina State University were contracted to evaluate the potential traffic impacts that would arise from various lane closure strategies that were being contemplated for the project. Researchers developed a mesoscopic traffic simulation model of the Raleigh, NC roadway network in

DynusT, which was extracted large from the Triangle Regional Model. The model was set up to examine both the morning and evening peak periods. Researchers examined both a no-diversion scenario and a user-equilibrium scenario for each period. A second model, DTALite, was also employed to provide additional insights into how motorist might respond to conditions arising from the different lane closure configurations being contemplated. The FREEVAL model developed by the researchers on another project was also used to evaluate traffic operations details under the no-diversion scenario.

A total of seven work zone lane closure scenarios were examined with these models:

- Westbound with 2 lanes remaining open throughout the project limits, and an offshoot of this option to increase the number of lanes open in the few weaving areas;
- Eastbound with 2 lanes remaining open throughout the project, and an offshoot with an additional lane kept open in the weave areas (note that this option would require the contractor to put one lane of traffic onto the shoulder between mile marker 301 and the I-40/I-440 interchange);
- Westbound with 2 lanes kept open where 3 lanes originally existed, and 3 lanes open where there was normally 4 or 5 lanes;
- Eastbound with 2 lanes kept open where 3 lanes originally existed, and 3 lanes open where there was normally 4 or 5 lanes (this option would also require the contractor to put one lane of traffic onto the shoulder between mile marker 301 and the I-40/I-440 interchange);
- Westbound with 3 lanes kept open throughout;
- Eastbound with 3 lanes kept open throughout (this option would also require the contractor to put one lane of traffic onto the shoulder between mile marker 301 and the I-40/I-440 interchange);
- Eastbound with a cross-over section towards one end of the project (this option would also require the contractor to put one lane of traffic onto the shoulder between mile marker 301 and the I-40/I-440 interchange).

The researchers examined the peak period “normal” conditions as well as potential incident scenarios that could arise and block additional lanes during a particular peak period. A series of travel “routes” were established to assess how the project would affect different subsets of users traveling partially or wholly through the project.

Overall, the analyses indicated that diversion rates of 33 percent for the 3-lane work zone configurations would possibly occur, and 56 percent diversion rates would occur for the 2-lane configurations. Even with these diversion rates, the models estimated that westbound travel times would increase between 8.6 and 15.1 minutes for the 2-lane configuration, and 12.7 minutes for the 3-lane configuration. Considerable variability was evident in the analysis results, as the different configurations generated different queue spillback patterns. These levels of diversion resulted in significant (up to 115 percent) estimated volume increases on several adjacent arterial streets, 44 percent increases in travel times on some of those arterials. The conclusion of the research team was that maintaining three lanes during construction was highly desirable.

Ultimately, NCDOT officials opted to go with the 3-lane open option. Traffic control plans obtained from the project indicate that lanes are being narrowed to 11 foot, and shoulders reduced down to as narrow as 2 foot depending on location within the project. Figure E-3 illustrates a typical cross-section through the project. [65]

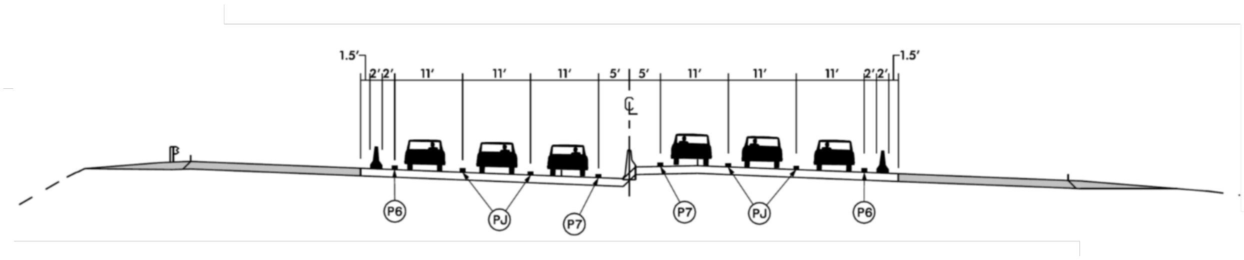


Figure E-3. Diagram. Typical cross-section of project. [65]

From the TMP perspective, officials implemented a significant public information outreach effort as well as improvements to public transit service in the region in the hope of encouraging motorists to utilize buses and carpools during construction, for example. A project website was established to help keep the public up-to-date and encourage use of alternative travel modes during construction. Figure E-4 illustrates the website and other public information initiatives that were implemented.

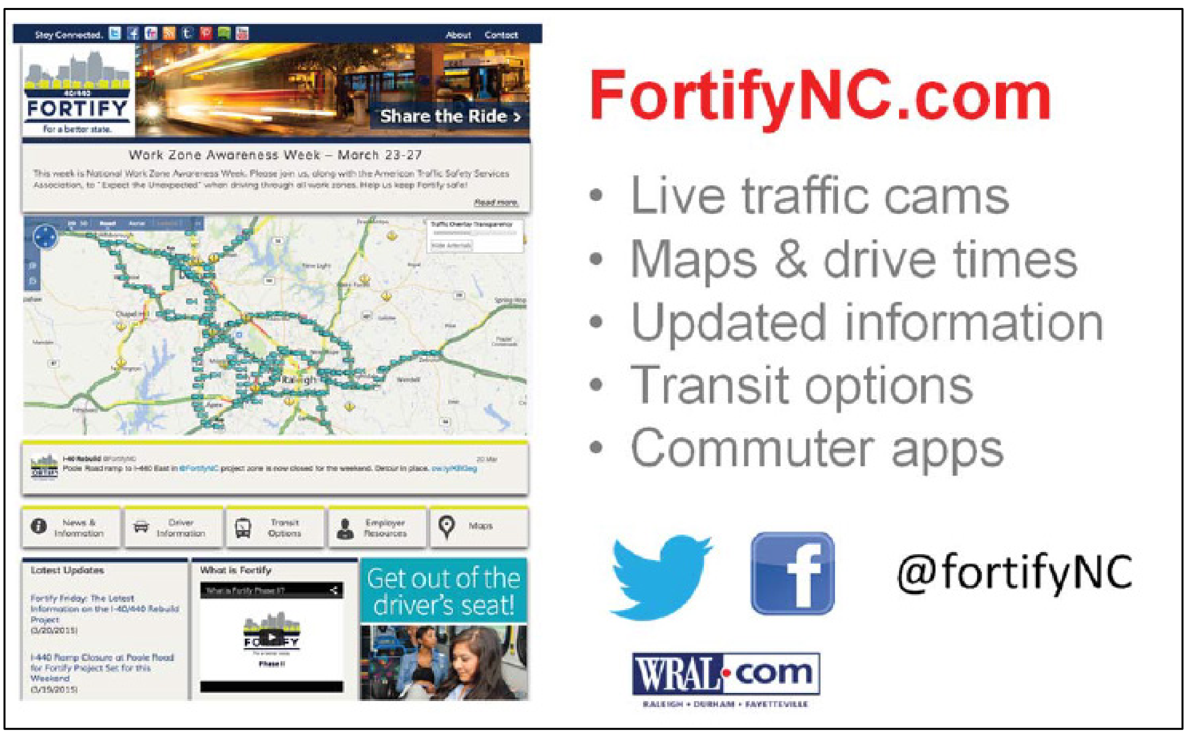


Figure E-4. Screenshot. PowerPoint Slide from a Fortify 40 Project Employer Resource. [66]

A total of $12 million was allocated to the transit improvements. The goal was to remove at least 30,000 cars from the corridor during the peak periods. According to information received from the regional transit agency, 5 bus routes were added/modified as part of the Fortify project. All new service was provided during peak hours only (M-F, 6:00-9:00am, 3:30-6:30pm):

- Additional frequency from once every 60 minutes to once every 30 minutes on existing Route ZWX (Zebulon/Wendell-Raleigh Express). Note: this was implemented Dec 2013 but eliminated Jan 2015 due to low ridership on additional trips (the 60 minute frequency was maintained and is a productive service).
- 30-minute frequency on Route JCX (Johnston County-Raleigh Express). Implemented Dec 2013.
- 30-minute frequency on Route CLX (Clayton-Raleigh Express). Implemented January 2015
- 30-minute frequency on Route CTX (South Cary-Raleigh Express). Implemented January 2015. Eliminated November 2015 due to low ridership.
- 30-minute frequency on Route 300 (Downtown Cary – downtown Raleigh). Implemented January 2015.

In addition, state employees can receive free bus passes if they work in the county where construction is occurring. The agency does not track carpools but is attempting to survey individuals who have contacted them about assistance in finding a carpool to see if they were successful or not.

Somewhat surprisingly, despite the expectation for substantial diversion in the corridor, it does not appear that many TMP strategies related to improvements of alternative routes were pursued in the corridor.

In terms of actual effectiveness of the strategies implemented, ITRE researchers have been monitoring and evaluating the impacts of construction actually occurring during the project. Two types of measures have been tracked:

- Peak period and peak hour volumes on I-40 and I-440 to estimate diversion that was occurring away from the project limits;
- Travel times approaching and passing through the project limits in both eastbound and westbound directions.

In terms of diversions away from the project, ITRE researchers are monitoring four-hour morning and evening peak period volumes at points entering the construction area from the south, east, and west. Figure E-5 illustrates the sensor locations being monitored. Although it is labeled as Area 3, the location to the east of the I-40/I-440 interchange was the first section that underwent construction starting in May 2013.

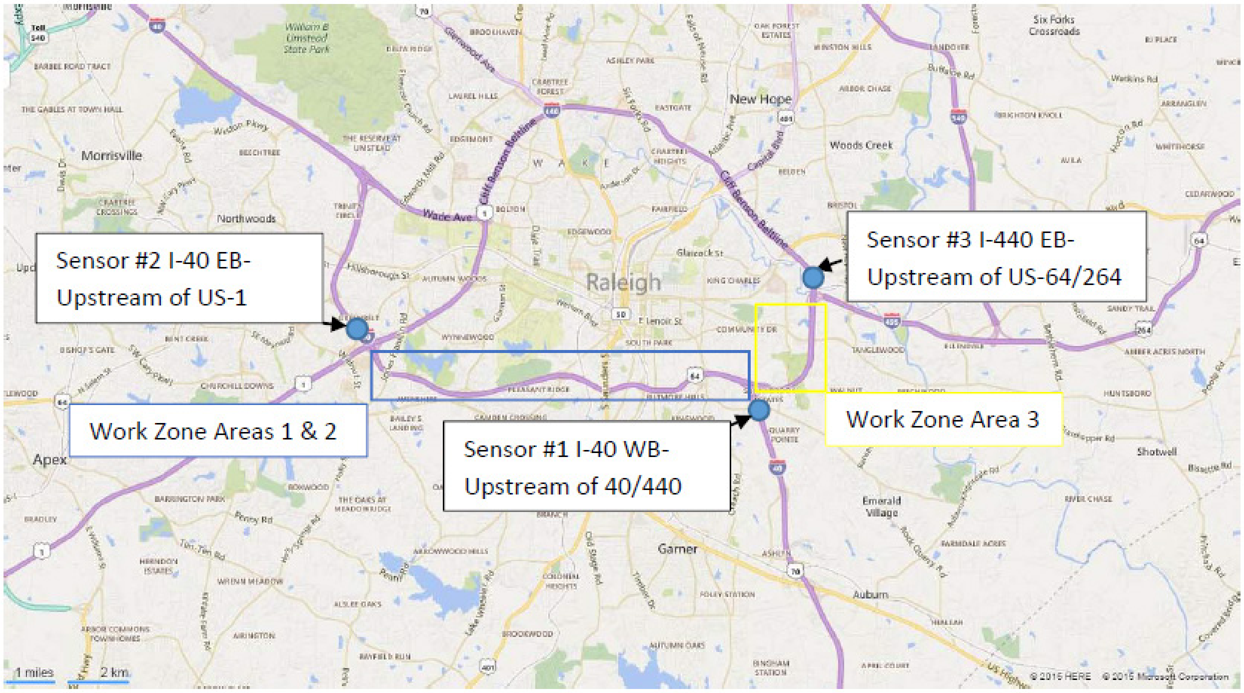
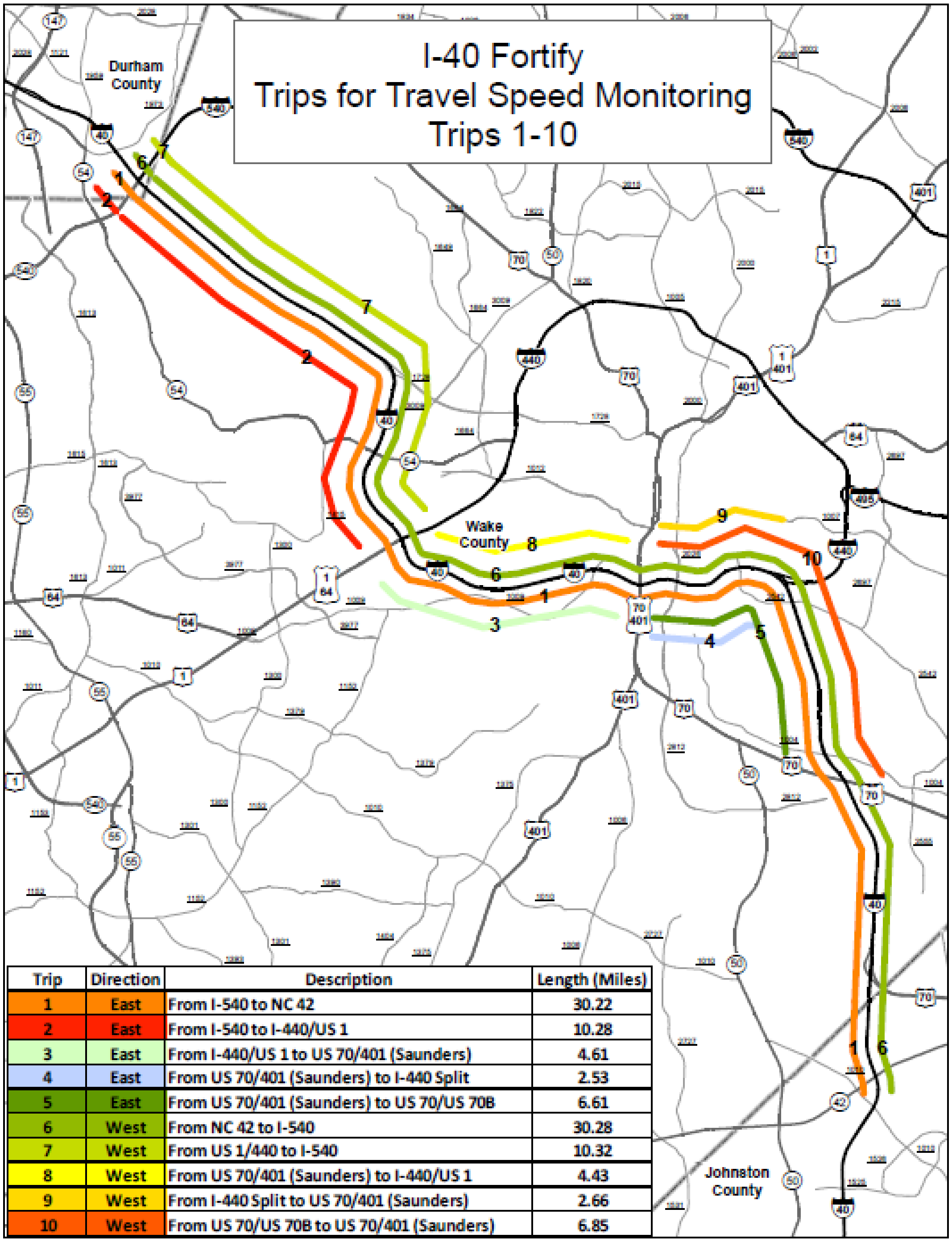


Figure E-5. Map. Volume sensor locations monitored during construction. [(64)]

Data are being monitored for calendar years 2013, 2014, and 2015. Overall, the data indicate diversion did occur away from the corridor over the years of construction at some locations. [(67)] ITRE researchers estimate that volumes decreased by 15.2 percent during Area 3 work, and by only 2.3 percent during work in Areas 1 and 2. When examined on a sensor-by-sensor basis, volumes at sensor 1 were 18.5 percent lower during work in Area 3, 10.4 percent at sensor 2, and 16.3 percent at sensor 3. In contrast, it was estimated that volumes were only 2.1 percent lower at sensor 1 during work in Areas 1 and 2, unchanged at sensor 2, and 5.3 percent lower at sensor 3. It is hypothesized that the impacts are less severe within Areas 1 and 2, and so motorists have gravitated back towards the corridor during work in these areas.

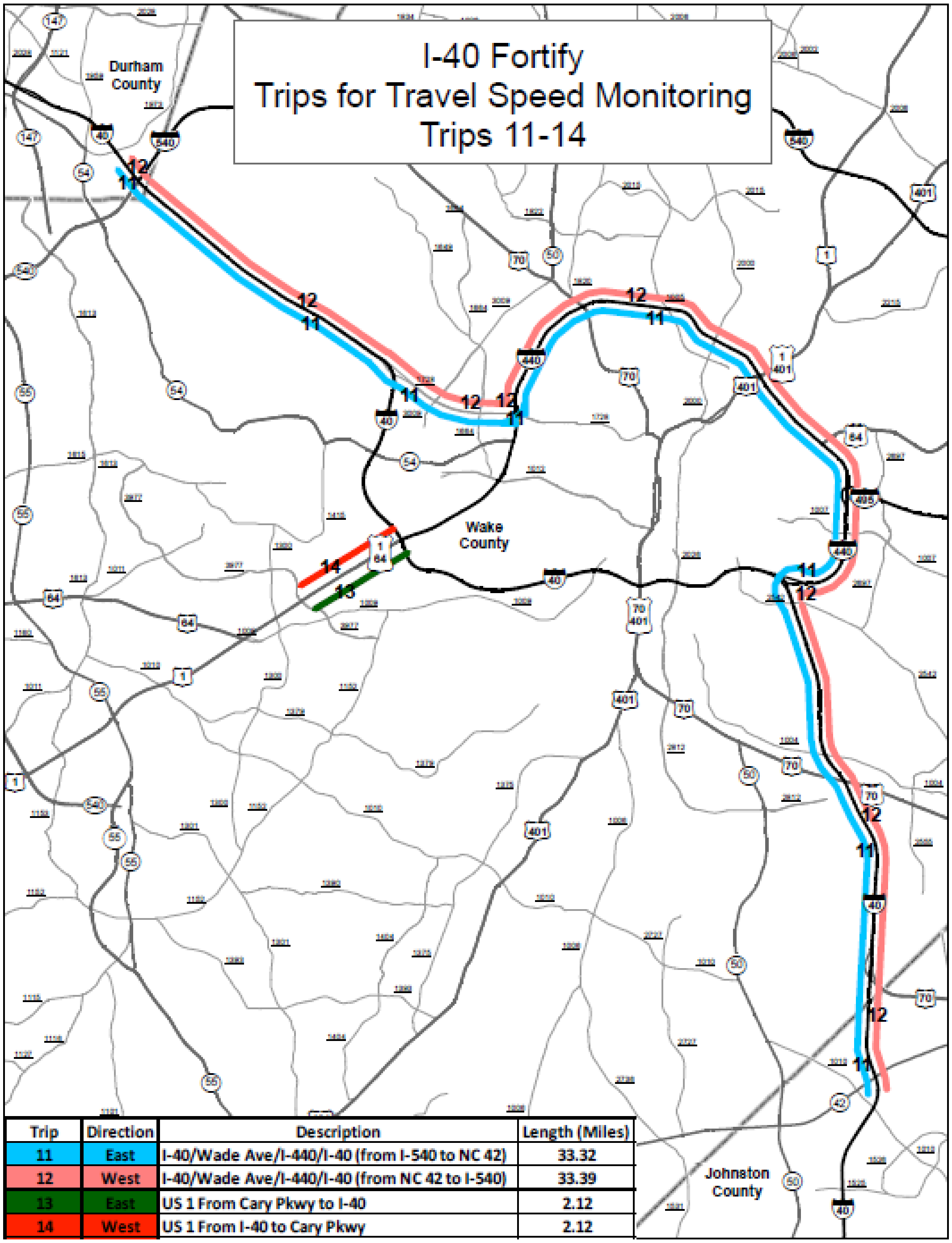
Travel times along I-40 and I-440 are also being monitored during construction and compared to baseline travel times prior to the start of construction [(68)]. A number of route trips are being monitored to reflect the range of trips being made through the project limits. Figure E-6 and Figure E-7 depict those trips. In the morning peak period, travel times for traffic heading north and west through the project were most significantly affected in November 2015. As Figure E-8 illustrates, trips 6 and 10 experienced 13 to 18 additional minutes of travel relative to baseline conditions prior to the start of construction in Areas 1 and 2. In the evening peak period, trips westbound (particularly trip 1, trip 5, and trip 11) experienced the greatest added delays. As shown in Figure E-9, delays during the evening peak period reached 34 minutes for trip 1, 17 minutes for trip 5, and 53 minutes for trip 11.

Meanwhile, the transit agency has been monitoring bus ridership to assess whether the strategies are achieving the desired goal of reducing automobile trips. In general, the agency believes that ridership in the corridor has been trending up slightly during the project for a few of the routes, but not significantly so. As noted above, some of the additional routes have actually experienced downward trends, and were discontinued. Figure E-10 and Figure E-11 illustrate the trends in ridership observed. Overall, it does not appear that the efforts to improve transit service and achieve increased transit usage is being realized to a significant degree in the corridor, certainly not to the degree that have occurred in freeway volumes approaching and within the project limits.



Trip	Direction	Description	Length (Miles)
1	East	From I-540 to NC 42	30.22
2	East	From I-540 to I-440/US 1	10.28
3	East	From I-440/US 1 to US 70/401 (Saunders)	4.61
4	East	From US 70/401 (Saunders) to I-440 Split	2.53
5	East	From US 70/401 (Saunders) to US 70/US 70B	6.61
6	West	From NC 42 to I-540	30.28
7	West	From US 1/440 to I-540	10.32
8	West	From US 70/401 (Saunders) to I-440/US 1	4.43
9	West	From I-440 Split to US 70/401 (Saunders)	2.66
10	West	From US 70/US 70B to US 70/401 (Saunders)	6.85

Figure E-6. Map. Route trip travel times monitored during construction in areas 1 and 2.
(68)



Trip	Direction	Description	Length (Miles)
11	East	I-40/Wade Ave/I-440/I-40 (from I-540 to NC 42)	33.32
12	West	I-40/Wade Ave/I-440/I-40 (from NC 42 to I-540)	33.39
13	East	US 1 From Cary Pkwy to I-40	2.12
14	West	US 1 From I-40 to Cary Pkwy	2.12

Figure E-7. Map. Route trip travel times monitored during construction in area 3. [68]

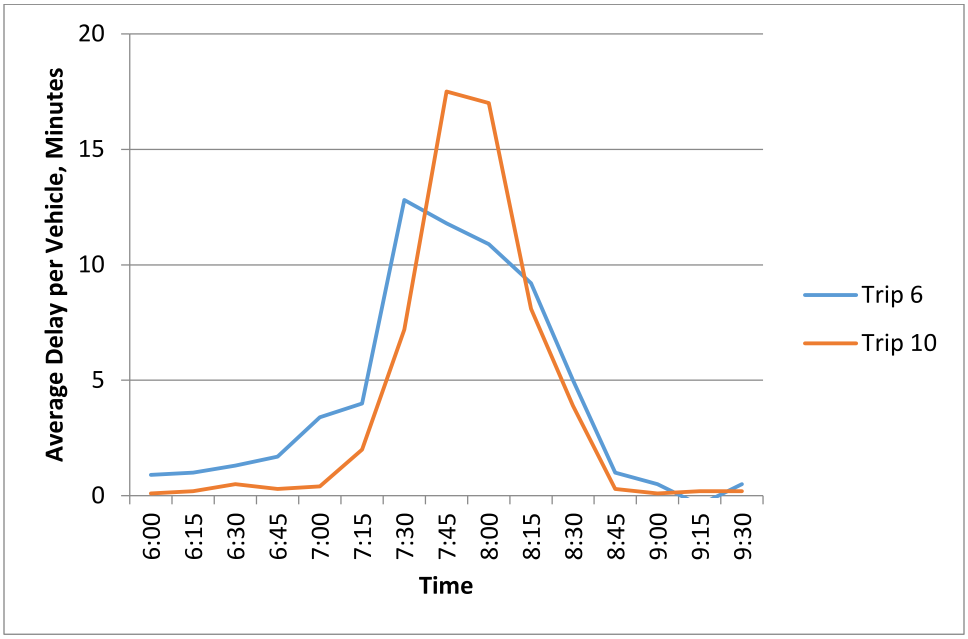


Figure E-8. Chart. Route trip delays during AM peak (adapted from 68).

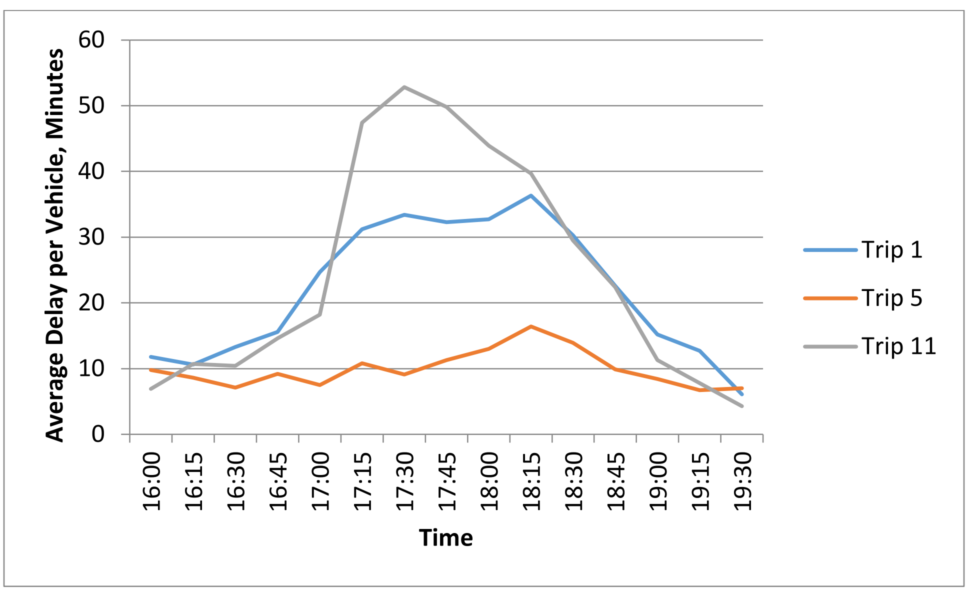


Figure E-9. Chart. Route trip delays during PM peak (adapted from 68).

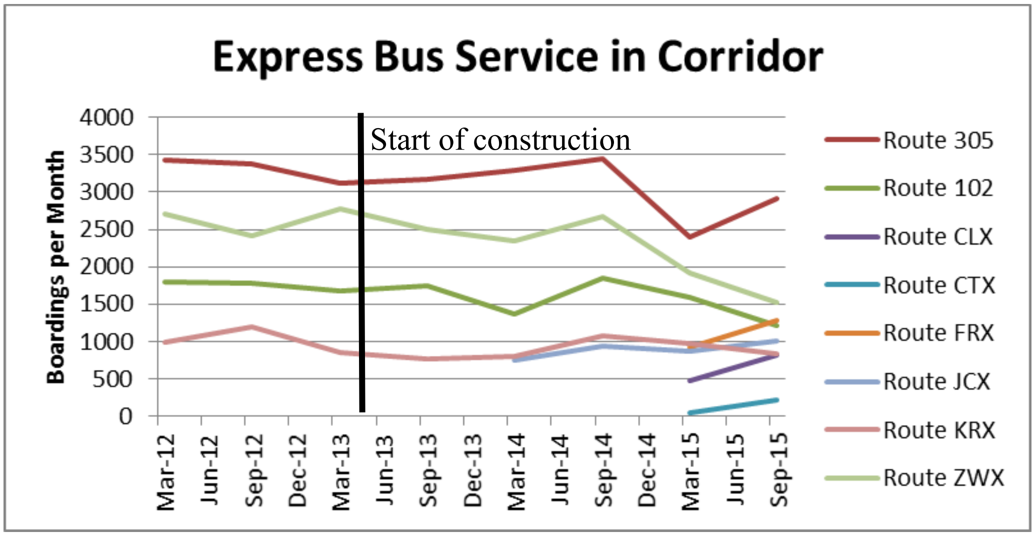


Figure E-10. Chart. Express Bus Transit Usage Trends in Corridor. [(69)]

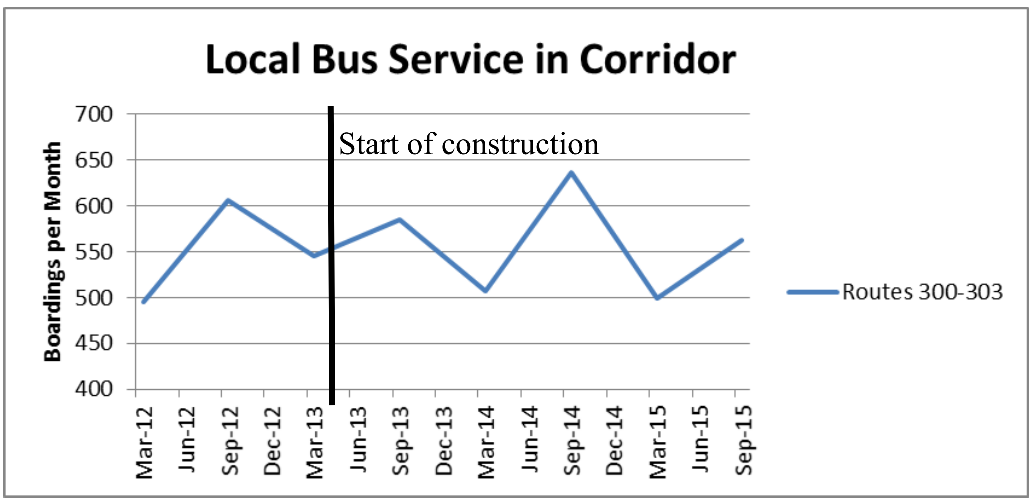


Figure E-11. Chart. Local Bus Transit Usage Trends in Corridor. [(69)]

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