Proposal for a Systems Approach to Urban Freeway Work Zone Performance Measures and Mesoscopic Comparison of Work Zone Performance

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INTRODUCTION

The Dwight D. Eisenhower Interstate Highway System was one of the most important civil engineering projects in American history. The creation of the highway system after World War II ushered in an unprecedented era of mobility for the public, and in some ways enabled the United States to rise to its current superpower status. By facilitating fast, safe, and reliable travel, the national economy was allowed to grow exponentially. This growth has also led to the Interstates becoming the backbone of the communities they pass through, with high development density along the right of way and high traffic volumes on the freeways. In order to maintain the conditions that nurtured this economic growth, the condition of the roadways on the Interstate system must be maintained at an acceptable level. This maintenance is becoming more and more prevalent on existing roads because the Interstates built in the 1950’s and 1960’s are at the end of their design life or need to be reconstructed for a second time. The increasing amount of rehabilitation and expansion needed on these already busy roadways is exposing many more motorists to work zones.

Work zones are one of the most challenging conditions facing drivers. The changes in the roadway environment due to a work zone, such as narrowed lanes, shifting lanes, closed lanes, and/or eliminated shoulders negatively impact drivers’ ability to navigate the roadway in a safe and efficient manner. The narrower roadways also leave drivers less room to maneuver, and, in cases where the shoulder is closed or of inadequate width, no room to make emergency movements. In addition to speed drops caused by changing geometry, posted speeds are occasionally lowered in an attempt to protect both drivers and workers in the work zone. The lowered speeds through the work zone (compared to the upstream section) can create dangerous speed differentials, which are a major factor in crash rate and severity. Work zones also present drivers with additional visual clutter, such as barrels, signs, workers, and equipment, which they must process in addition to all of the standard information drivers must process while driving which may also be compromised in a work zone. The potential increase in reaction times caused by the additional visual stimuli adds to the challenges facing drivers in work zones. Safety is also a concern for workers in the work zone. Work zones on busy freeways force workers into close proximity with many vehicles traveling at high speeds. Mobility through work zones is
another priority. The geometric changes and speed drops in the work zone reduce capacity through the area. Work zones can decrease throughput, cause travel time delays, increase queuing in the area, and decrease operating speeds in the work zone, all of which affect mobility. Because agencies have a responsibility to provide safe and efficient roadway, even during times of construction, it is necessary to measure the safety and mobility impacts of work zones, and to use these performance measures to make decisions that will mitigate the potential negative impacts of the work zones.

The current process used for making decisions pertaining to the implementation of work zones, while effective, is not comprehensive. The current process tends to focus primarily on mobility to determine the preferred alternative for implementation. Mobility is often the only explicitly analyzed performance measure used during the design process. The mobility performance measures are typically related to a reduction in capacity on the roadway. Typical performance measures include queuing on the roadway, increased travel times, or increased user delays caused by a reduction in capacity. In value engineering and A+B bidding, other user costs may be calculated and included in the analysis. Safety is accounted for through a social learning process, in which methods that have worked reasonably well in the past are re-used, and assumed to be effective. The mostly linear structure of the process provides little in the way of a feedback loop to improve practices, and there is little formal monitoring of the work zone once it is implemented. A new process is needed that incorporates performance measures throughout the life cycle of the work zone, from design to implementation to completion and review. The performance measures incorporated into this new process should effectively describe the mobility impacts of the work zone as a whole, over the duration of the project. The current performance measures used are adequate to describe the immediate, day-to-day impacts of the implemented work zone, but do little to assess the overall mobility impacts of the work zone. Decisions regarding traffic control plans for work zones should be based on more than one measure of performance, or previously established practices. There needs to be a process for selecting the appropriate performance measures for various types of work zone implementations. Safety and mobility in the work zone need to be monitored throughout the entire process, in order to ensure the current work zone and all future work zones are as safe and efficient as reasonably possible. The process needs to have some type of feedback mechanism whereby
actual conditions in the work zone are compared to the projected conditions, in order to improve the practices followed by most practitioners. This thesis will formulate, describe, and test a new process to use when guiding decisions pertaining to work zones, as well as developing performance measures that will facilitate comparison and assessment of the operational impacts of various work zone treatments.

**PROBLEM STATEMENT**

The current system used as a process for making work zone related decisions has been developed through decades of application and refinement. While the process is still viable and applicable, it has some rather glaring deficiencies. The lack of feedback results in an assumption that decisions made in the planning stages will affect mobility in precisely the manner predicted. This assumption results in decision makers choosing implementation strategies regarding traffic control and management that are not adequately monitored in a way that fully quantifies the mobility impacts imposed on road users by the implemented work zone. For example, a performance measure typically used in work zones is total delay (measured by the queue lengths) caused by the work zone. In this example, the total delay for two different work zones was measured and found to be 30 miles of total queue length over the duration of a project. However, in one work zone this was caused by a 10 mile long queue occurring 3 separate times over the life of the project. In the other work zone, a 1 mile long queue was observed on 30 different days. The total queue length over the duration of the project gives no indication of the very different mobility impacts of the two different work zones. The driver perception of the different mobility impacts must also be considered. New performance measures are needed to more precisely describe the mobility impacts of work zones over the duration of a project so decision makers can assess how well the objectives for the work zone are being met. Traffic engineering, more so than any other engineering discipline, addresses a complex mixture of objectives that may be in conflict with each other. Columns in a structure are not designed to experience failure twice a day, while still supporting the building during the other 22 hours a day. The force of gravity acting on the structure is constant, and the loading can be predicted with relative certainty. In contrast, freeways in most urban freeways experience unacceptable conditions during both morning and afternoon peak times. Other engineering disciplines do not
have the human element inherent to traffic engineering. The human element ensures that no matter how well a facility is designed with respect to mobility or safety, a driver can still do something totally unpredictable and cause a catastrophic event during the peak period. This complexity necessitates that more than one performance measure be considered when designing and implementing a work zone. The performance measures must also enable consideration of the driver perception of the mobility impacts created by the work zone.

The other major deficiency with the current process for decision making in work zones is the lack of feedback once the work zone is implemented. Currently, some monitoring occurs, mostly to make reactive decisions. For example, in Texas, the DOT’s policy is to monitor all crashes that occur within a work zone, and then review them to determine if any changes need to be made. While this is a policy is effective in responding to incidents, it is ill-suited for preventing incidents. Information about what sort of conditions lead to crashes should be input back into the process in order to improve future work zone implementations. Mobility data should also be incorporated into the feedback loop, further improving work zones. Using quantifiable data collected in work zones, rather than a qualitative assessment of what “worked” and what “didn’t work,” will improve the standards and approaches used to make decisions about work zones. Incorporating feedback into the process will also allow agencies to track how well they are meeting their own goals and policies. For example, if an agency’s goal (either explicit or implicit) is to reduce the mobility impacts of implementing work zones, then the mobility impacts of work zones must be measured in a way that the agency can compare the impacts through time, and across various implementations, in order to assess whether they are meeting that goal, or at least improving towards the goal.

The current process needs to be updated to reflect the complexity of implementing a work zone on an urban freeway. Instead of focusing on a single performance measure during the design and implementation of a work zone, multiple performance measures are needed to fully explain conditions in the work zone. The performance measures must reflect considerations across the whole spectrum of the work zone’s impacts, from safety and mobility, to environmental impacts, to the impact on the overall traffic network. These measures need to be monitored throughout the life span of the project, not only during the planning phase. The appropriate performance
measures for different implementations needs to be determined. For example, target speeds may be an effective performance measure, one that is easily employed for a variety of work zone configurations. In some cases, it may not be descriptive enough of the conditions within the work zone to be of use in decision making. The appropriate measures for each treatment need to be determined in order to ensure that the most useful data is available to make the most informed decisions possible. These measures also need to be constructed in such a way that they are easily comparable across a variety of work zone implementations, in order to facilitate a comparison of the various operational effects of work zones. In short, a new process is needed, one in which appropriate performance measures are incorporated before, during, and after a work zone’s implementation. These performance measures would be used to make decisions that would further improve the performance, especially the safety and mobility, in work zones on urban freeways.

BACKGROUND

In order to develop viable improvements to address the shortcomings of the current process, some background information is necessary. The following sections describe the current process for decision making in work zones, as well as some key points to consider when creating a new process.

Current Processes

There is no standard process currently used to make decisions in work zones. Every agency has a different strategy, and many have no formal process for making decisions. Three processes of the typical work zone decision making strategy are shown in Figures 1, 2, and 3.
Figure 1: Example of Current Work Zone Monitoring Process (2)

Step 1: Assemble Data

Step 2: Determine Extent of Roadway Occupancy

Step 3: Identify Feasible Alternatives

Step 4: Analyze Volume/Capacity Relationships

Are There Capacity Deficiencies?

yes  ➔ Step 5: Analyze Capacity Improvement Techniques

no  ➔ Step 6: Define Alternatives

Step 7: Quantify Impacts

Step 8: Modify Procedures

Step 9: Select Preferred Alternatives
Figure 2: Example of Current Work Zone Monitoring Process

Inventory the Affected Corridor -> Identify Traffic-Handling

Estimate the Capacity of the Reconstruction Zone

Is Capacity Adequate?

yes

no

Compare Corridor-Wide Volume and Capacity

Is Capacity Adequate?

yes

Revise Corridor-Wide Capacity Estimates

no

Revise Traffic Management

Estimate the Changes in Travel Patterns in the Corridor

Estimate Operational and Economic MOEs

Are Impacts Acceptable?

yes

Finalize Traffic Management Plan

no

Figure 3: Example of Current Work Zone Monitoring Process

Determine pre-project operating and/or posted speeds, approaching and within construction area

Establish work zone design speed based on target speed. Design work zone

Identify and provide speed management measures needed to attain significant speed reduction

Establish target speed based on constraints

yes

no

Are features related to work zone design speed feasible?

yes

no

Provide speed-related features and signing appropriate for target speed

Implement
Despite the variations in the processes used for decision making, the current processes all have essentially the same structure. Once the need for a work zone is realized, the current conditions on the facility are quantified by collecting data under existing conditions. The data collected depends on the performance measures already specified by the agency. For instance, some agencies define performance in a work zone based on target speeds, while some use volume/capacity ratios. Depending on the conditions already present on the facility, a goal is then set for the conditions on the facility after the work zone is implemented. Alternative work zone configurations and strategies are developed, and then analyzed based on the aforementioned performance measure to determine the operational effects of implementation. If the alternatives all fail to meet acceptable standards, they are revised until they meet these standards. When an acceptable performance is achieved, the alternative with the least undesirable impact is chosen and implemented. Of course, it would be ideal to choose an alternative with the “best” impacts on the traveling public, or the “least” impacts, but when dealing with work zones that almost invariably reduce mobility, it is more realistic to try to minimize that impact than it is to completely eliminate it. It is often infeasible to have a work zone with no impact on the mobility and safety conditions of the facility. As shown in the figures, each of the processes has some superficial differences, but they are all essentially the same. Some of the steps may be in a different order, and different performance measures may be used in different processes, but they all follow the basic procedure outlined above.

The current process has three basic, underlying flaws. For the most part, one performance measure is the focus of the analysis of various alternatives. As previously discussed, traffic engineering, more so than any other engineering discipline, addresses a complex mixture of objectives that may be in conflict with each other. The complex interaction between an assortment of factors, from easily measured engineering considerations such as traffic volumes, to more obtuse factors such as driver satisfaction, is a hallmark of traffic engineering. The human elements inherent in decision making on roadways are a major issue, and may be interpreted differently by different engineers. This complexity necessitates that more than one performance measure be considered when designing and implementing a work zone.
The over reliance on the same performance measures for every situation is another major flaw in
the traditional process. Work zone treatments are as varied as the roadways they are used on, and
each type of treatment impacts the safety and mobility of the roadway in different ways.
Appropriate measures should be used for each type of work zone treatment. In many cases, the
appropriate performance measures for one treatment will be the appropriate measures for other
treatments. But some performance measures that very accurately describe the operation of a
work zone under one treatment may be unsuitable for another treatment. The appropriate
measures need to be utilized for various types of treatments. It is also important for the
performance measures to be compatible with the overall goals of the agency. One main reason
for using performance measures when creating a work zone traffic control plan is to make
decisions that will create conditions conducive to desirable operations on the facility; if the
performance measures used in a work zone are not compatible with performance measures
normally used on the roadway, the proper decisions that would lead to desirable operations may
not be made.

Operational impacts can be defined in a variety of ways. Operational characteristics, for
purposes of this thesis, are defined as roadway characteristics that can be measured in terms of
the movements, or lack thereof, of vehicles through the work zone. Common operational
characteristics measured by agencies include:

- Speeds;
- Flow Rates;
- Travel Times; and
- Queues.
These operational characteristics can be measured in a myriad of ways. Typical performance measures describing these characteristics are:

- 85th percentile speed;
- Hourly flow rates;
- Average travel times; and
- Queue length.

By collecting these performance measures, agencies can monitor, analyze, critique, and ultimately improve their decision making processes on their facilities. While these performance measures can and are collected on any type of roadway, under any circumstances, they are especially crucial to monitor during work zone implementations. Due to the impact on the driving environment caused by a work zone, it is necessary to monitor traffic conditions in the work zone to ensure that the work zone does not excessively impact the facility.

Another major deficiency in the current decision making process is the lack of feedback once the work zone is implemented. Currently, some data is collected in active work zones, and some qualitative judgments are made about the mobility and safety throughout the work zone. Crashes occurring within the work zone are noted and reviewed, and any problems with the work zone are rectified in response. Traffic conditions throughout the affected area are monitored, and actions are taken if the performance measures are not satisfactory. The current process’s reactive stance is effective in responding to problems once they occur, but does not effectively describe the overall mobility impacts of an implemented work zone. A mechanism for incorporating the results of work zone implementation needs to be introduced into the procedure, so that breakdowns in mobility may be observed and corrected. The standards used by agencies to set up work zones could be improved by addressing problems caused by work zones in the design phase, preemptively correcting the issue before it ever occurs. The most practical way to improve the standards would be to use feedback from the field, in work zones that were implemented using the standards. However, the performance measures used in this reactive approach are not readily comparable across disparate work zones. A need exists for performance measures that can readily describe the overall mobility impacts of a work zone, and that can
easily be compared across work zones. By comparing various work zones, and tracking the mobility trends observed, an agency could assess their standard procedures, and take steps to improve their approach if necessary.

**Systems**

The deficiencies in the current process (a narrow focus on few performance measures, a lack of feedback once the project is implemented) could be rectified through a new process. In order to craft a viable process, some background in systems engineering is needed. The applicable definition of systems engineering is “the application of scientific and engineering efforts to transform an operational need into a description of system performance parameters and a system configuration through the use of an iterative process of definition, synthesis, analysis, design, test, and evaluation (1).” A system is defined as a “group of components that work together for a specified purpose (1).” In this case, the specified purpose is to use data and performance measures gathered in work zones to make informed decisions about the implementation of treatments that may affect safety and mobility. The system itself is dependent on the perspective of the user, as well as the parameters defined. For example, a single access ramp could be viewed a system, or an entire city’s road network. All systems are associated with life cycles. The major events included in any system are:

- Definition,
- Development, and
- Deployment.

In the current process, the definition is the selection of a target performance measure, such as target speed or a volume/capacity that needs to be maintained. The design and refinement of work zone alternatives can be considered the development. The deployment stage of the process is the final implementation of the work zone. The current, mostly linear process is deficient in one key systems engineering aspect. The systems point of view “recognizes that a problem and its solution have many elements and components, with many different relations among them (1).” The major advantage of using a systems point of view for the new process is that it will
incorporate more of the disparate factors that need to be considered when implementing a work zone. As previously mentioned, the complexity involved in the work zone system demands that multiple performance measures be used, in order to fully inform the decisions that must be made.

Each of the three major events consists of three fundamental steps. Definition, development, and deployment each consist of:

- Issue formulation,
- Issue analysis, and
- Issue interpretation.

In every major step of the system, the issue at hand must be formulated and refined. The issue must be analyzed, to determine how well it addresses the formulated problem. An interpretation, based on the analysis, must be performed to ultimately make a decision about the issue. In the current process, these steps are best implemented during the planning stages. The formulation step is analogous to the determination of a goal for the work zone (target speed, target capacity, etc.), the analysis step occurs when the various alternatives are analyzed to establish how well the goals are met, and the interpretation of the issue results in a work zone alternative being chosen. All work zone decisions follow this basic decision making process. The process can be an informal one, with the formulation, analysis, and interpretation performed without much documentation; or, the process can be a formalized one, based on flowcharts with data informing of the steps. This thesis will focused on a formalized, explicit process utilizing data in each phase of the work zone decision making process.

**GOALS**

The goal of this thesis is to use systems engineering principles to develop critical elements of a comprehensive process which guides decision making throughout the life cycle of the work zone, incorporating both quantifiable and qualitative safety and mobility performance measures. While the new process is applicable to all work zones on all facilities, developing the entire process is beyond the scope of this thesis. This thesis will focus exclusively on significant projects on
urban freeway facilities and quantitative performance measures. The other major goal is to determine the appropriate performance measures for various treatments implemented within a work zone that can be used to compare the traffic impacts of several work zones.

**OBJECTIVES**

1. *Propose a process to relate work zone planning decisions and potential work zone performance measures*

The new process will incorporate multiple work zone performance measures throughout the life cycle of the work zone. Multiple performance measures are needed in work zones, because a single performance measure does not adequately address the innate complexity of a work zone. The complex relationship between work zone implementation strategies and the impacts on safety and mobility necessitates the use of multiple performance measures to make decisions. As part of the process, a matrix indicating the appropriate performance measures to use for various work zone treatments will be developed.

2. *Determine a set of performance measures that would enable comparison of the mobility impacts of various work zones.*

Work zones are currently modeled at the project level and at the agency level. At the project level, performance measures such as queue lengths and travel times through the work zone are collected to assess the traffic impacts of the implemented work zone. The project level can be considered a microscopic assessment of work zone impacts. At the agency level, broad statistics such as total work zone exposure for an area are compiled to give an overview of the agency’s total work zone activity. The aggregated overview can be considered the macroscopic assessment of work zone impacts. What is currently missing is a way for agencies to compare the performance of several work zones, a mesoscopic level of analysis. Performance measures will be proposed that will be applicable at both the microscopic and mesoscopic levels. These measures will enable decision makers to compare the impacts of many implemented work zones.
WORK PLAN

Task 1: Narrow focus to urban freeways

Creating and refining the complete proposed process is beyond the scope of this thesis. The basic process is intended to be applicable to any significant work zone on any type of road. Due to a multitude of reasons, the focus of this thesis will be on urban freeway work zones and the performance measures appropriate for various treatments when the work zone is active. These limited access facilities typically have high traffic volumes, high speeds, an emphasis on mobility in any metropolitan area with more than 50,000 people, and are overall significantly important to the urban road network. The combination of high speeds and high volumes make safety, as well as mobility, a priority on these roadways. Freeways and other principal arterials comprise only 5-10 percent of the total lane miles of the urban functional system, but account for between 40 percent and 65 percent of the total vehicle miles travel volume. Many of these facilities are also nearing the end, or are well past the end, of their design lifespan. This necessitates rehabilitation and reconstruction on active freeways. Many communities are experiencing congestion levels that necessitate the addition of capacity, which requires more work zones on congested freeways, exposing more motorists to work zones and the challenges they present. The importance of urban freeways to the overall urban functional system, along with the difficulties inherent in creating a safe and mobile work zone under the conditions encountered along the facilities, and the increasing levels of work zone activity make them a natural choice for the focus of this thesis.

Task 2: Identify possible treatments, performance measures, and combinations thereof

In order to achieve the stated objective of demonstrating the applicability and appropriateness of the new process, as it applies to urban freeway work zones, lists of common work zone treatments that impact the traffic operations and of possible performance measures to monitor these impacts will be compiled. Once the lists are compiled, appropriate performance measures will be paired with the relevant work zone treatments to create a matrix of performance measures for monitoring mobility in work zones.
Subtask 2.1: Compile list of possible work zone treatments

While each work zone is a unique byproduct of the facility it is placed on, there are certain treatments which are common options for every work zone implemented on an urban freeway. These treatments range from complete facility closures to lane shifts, and can be used singularly or in tandem. A comprehensive list of possible work zone treatments will be compiled from various sources, including state DOTs (specifically TxDOT), and manuals such as the AASHTO Policy on Geometric Design of Highways and Streets and the Manual on Uniform Traffic Control Devices. A small survey of practitioners may also be a part of this task, in order to ensure no possible treatment is overlooked. The list is necessary in order to determine what conditions could possibly be encountered when implementing a work zone on an urban freeway facility. By anticipating the changes that could be made to the roadway, the impacts of these changes, such as reduced capacity, can be predicted. The anticipated impacts caused by the work zone will then be the basis for deciding which performance measures are most appropriate for the various work zone treatments.

Subtask 2.2: Compile list of possible performance measures

A list of possible performance measures for urban freeway work zones will be compiled. This list will include possible performance measures for many different metrics, including safety concerns, operational concerns, environmental impacts, construction concerns, and public concerns. The list of proposed measures will be as broad as possible, but the focus will be on measures relating to mobility. The performance measures will be quantifiable measures, in order to facilitate data collection and decision making. An objective decision pertaining to work zones is easier to make if it is based on quantifiable data, rather than qualitative data. The possible performance measures will also include direct measures, such as traffic volumes as a measure of mobility, and indirect measures, such as speed differentials, which will be used as a predictor for safety within the work zone. The list will be compiled from previous research, current practices by various state DOTs, and any new measures that are thought of throughout the course of the thesis work that could be potentially useful. The data needed to calculate the proposed performance measures will also be determined.
Subtask 2.3: Determine which performance measures are appropriate for which work zone treatment

Once the lists of work zone treatments and performance measures are created, each treatment will be assigned a group of potentially descriptive performance measures. The performance measures assigned to each treatment will be descriptive of the effect the treatment has on safety and mobility on the freeway. For instance, if the treatment will significantly impact roadway capacity (i.e. lane closure), then the performance measures that would naturally describe the treatment’s impact would be change in capacity, and/or the change in volume/capacity ratio. Once the initial list of measures which could potentially be used for each treatment is compiled, the most appropriate measures will be selected for further study. The measures used for various treatments will likely overlap somewhat, because several treatments similarly impact the safety and mobility of the roadway, albeit to different degrees. The applicable measures selected will need to be compatible across a variety of work zones, so that the impacts of the various implementations of work zones can be compared.

Task 3: Propose new decision making process

The current process for creating a traffic control plan for work zones is typically a linear process, concerned with one performance measure, with no feedback. Any monitoring of performance measures in an implemented work zone is somewhat perfunctory and reactionary. For instance, in some agencies, queue lengths in a work zone are measured to ensure they are not excessive. If they reach an arbitrarily excessive length (i.e. 2 miles), the work zone is shut down to allow the queue to dissipate. Little effort is made to determine the reasons that the queue reached an excessive length, and there is no mechanism in the current process for feeding this back into the process to improve future work zones. The proposed process will incorporate performance measures throughout the life cycle of the work zone. Performance measures will be incorporated into the initial planning process in order to determine the appropriate treatment to minimize impact. They will be used while the work zone is active to ensure the actual safety and mobility impacts of the work zone are not radically different from the projected safety and mobility
impacts. And performance measures will be integrated into the review of a work zone after completion, in order to effectively assess the success of the work zone in minimizing safety and mobility impacts. The results of this analysis are then fed back into the process, to help guide the decisions for the next work zone, in order to improve the implementation.

**Task 4: Gather Data**

Data will be needed to perform the analysis necessary for determining the appropriate performance measures for each work zone treatment. When available, existing data will be used for analysis. When not available, data will need to be collected, either from field implementations of the types of work zones under consideration or through simulation data. Data is the basic unit used in a performance measure, the raw materials synthesized into a descriptive performance measure.

**Subtask 4.1-Determine what field data is available**

The first subtask will be to determine what field data is available concerning work zones on urban freeways. Existing field data could be used from previous TTI research efforts, data sets from DOTs or municipal agencies, or other sources. Previously collected data from the field would be the ideal source of data for this project. It will be used to calibrate the simulation processes to be utilized in the next task. Data that would need to be part of these sets include basic information about the geometry of the roadway (number of lanes, lane widths, etc.), the type of treatments implemented as part of the work zone (lane closures, time of day work zone was active, etc.), and traffic data relevant to the performance measures, collected both before and after the work zone was implemented (volumes, speeds, etc.). Relevant data has already been collected by TxDOT in Waco. Their work zone ITS system installed on IH-35 collects speed, volume, and occupancy data from 6 different stations every minute. DMS displays are also included in the data set. Collected data is further categorized by lanes. The one-minute increments of the data are also summarized in 15 minute blocks. These 15-minute periods of collected data will be more appropriate and usable than the one-minute intervals, and will be the main source of data for testing the proposed process and postulated performance measures.
Subtask 4.2-Determine what simulation data exists

In the event that Waco field data is not available, or is not adequate and needs to be supplemented, existing simulation data will need to be located. This data could be procured from previous TTI research efforts, data sets from DOTs or municipal agencies, or previously calibrated processes. While not quite as desirable as existing field data, simulation data that has already been calibrated could be an acceptable substitute for field data. The simulated data will need to have the same information as the field data. Unlike field data, however, information about a specific work zone scenario would not be necessary. If simulation processes of existing freeway facilities are available, they could be used as templates and modified to create a realistic work zone within the simulation.

Subtask 4.3-Collect needed field data

If no existing field or simulation data is unavailable or unsuitable for analysis, it may become necessary to collect new data in the field. This could be reasonable under the auspices of another TTI project. Data could be collected in College Station from State Highway 6, or from any of the major freeways in Houston or San Antonio. Data collected in College Station could be used as a calibration for the base process of the simulation, because there are no active work zones currently along Highway 6 within the College Station city limits. Data could be collected in the active work zone to the south of College Station on Highway 6, but might not be relevant because it is more of a rural section of highway. Houston and San Antonio both have several active work zones on their urban freeways, and could be a viable candidate for data collection.

Subtask 4.4-Collect needed simulation data

Finally, data could be created with the use of simulation processes. This tactic would not be ideal, but may be a last resort if no other data available. A basic simulation process could be created in any of the various traffic simulation processes available (VISSIM, CORSIM,
TRANSYT-7F, etc.) with generic properties (standard lane widths, typical traffic volumes, etc.). This process could then be used in the next task.

Sub-task 4.5: Create a simulation model

If necessary, a simulation model will be created to test the impacts of the various treatments. The model will be created using VISSIM, and calibrated with the data collected in the previous task. With this base model created, the treatments can be applied to the simulated freeway and the impacts measured using the predetermined performance measures. Three idealized freeway configurations will be used as base models to apply treatments. Treatments will be applied to four-, six-, and eight-lane divided freeway sections, with one on-ramp and one off-ramp. This model will only be necessary if data gathered from the Waco ITS is not sufficient.

Task 5: Analysis

Once sufficient data has been gathered, the assumptions used to create the new process and the performance measures suggested will need to be analyzed to determine their effectiveness in assessing the mobility effects of implementing various work zones.

Sub-task 5.1: Analysis of Existing Data

The postulated performance measures will be applied to the data collected in Waco to assess their applicability and appropriateness for use in a work zone on an urban freeway facility. The performance measures will use the volume, speed, and occupancy data collected in 15 minute intervals on IH-35 in Waco to measure the mobility impacts of the work zones implemented on this urban freeway. In addition to assessing the impacts of the work zones, the analysis will also test the sensitivity, robustness, and applicability of the proposed measures. There should be enough data available from Waco to adequately analyze the performance measures. The precise amount of data reduction and analysis necessary will not be known until the measures are proposed, because different measures will demand different analyses.
**Sub-task 5.2: Simulation Analysis**

If necessary, a simulation analysis will be performed to supplement the results of the analysis of existing work zone data collected in Waco. Once the simulation model is created and calibrated, it can be used to perform a sensitivity analysis on the various performance measures to determine robustness of each measure with respect to each treatment. The inputs that determine each performance measure will be varied from their original values to determine how the change impacts the resultant performance measures, and their impact on the decisions that would be made based on those measures. The sensitivity analysis will be a statistical analysis. The specific tests to be utilized will be determined at a later date. Approximately 6 work zone treatments will be explored for each of the 3 roadway configurations, with multiple simulations performed for each treatment in order to gauge the sensitivity of each measure. Traffic volumes will be simulated for undersaturated, saturated, and oversaturated conditions as well. The duration and approximate time period of the simulations will be dependent on the treatments under consideration. For example, a nighttime lane closure that only occurs overnight will not need to be simulated for all daytime hours as well. The simulations will occur only when the work zone is in place and influencing conditions on the roadway.

**Task 6: Summarize results and revise proposed process**

Once the appropriate and most descriptive performance measures for each treatment are determined through simulation and sensitivity analysis, the results will be summarized. The summary will recommend a revised process for making safety and mobility related decisions about work zone treatments on urban freeways, with multiple performance measures, rather than one or two general performance measures currently used, which will be considered in the design phase, while the work zone is active, and after the work is complete. The main component of the revised process will be a set of matrices describing the proper performance measures for various work zone treatments, based on a number of factors, including base lane configuration, work zone treatment, and saturation levels. These matrices will guide decision making by giving decision makers a more comprehensive process for basing their decisions on relevant performance measures. The appropriate measures for each treatment will be determined based
on the simulation analysis, with appropriateness based on a variety of factors, including robustness of each performance measure, applicability to a given treatment, responsiveness to changing conditions, and the ability of each performance measures to accurately describe the changing conditions caused by the work zone treatment. These performance measures can then be used by practitioners to monitor and, if necessary, improve the mobility throughout a work zone over its entire life cycle. The performance measures will also allow decision makers an overview of the work zone’s mobility impacts over the duration of the project, which will in turn allow them to assess how well the agency’s goals are being met, as well as to track the mobility trends of their work zones.

**Task 7: Recommendations**

Finally, based on the analysis performed, recommendations will be made regarding the proposed process for using performance measures to make work zone related decisions. Recommendations for the appropriate performance measures to be used in work zones with various treatments applied will be made. These performance measures will be related back to the conceptual process previously proposed. These measures can then be used to make decisions regarding mobility in work zones on urban freeway facilities.

**EXPECTED VALUE**

Currently, the decision making model is a linear process. When a work zone is necessary, alternative treatments are proposed, the mobility and safety impacts of the proposed treatments are predicted through simulation or engineering judgment, an alternative with the most acceptable impacts is chosen and implemented, and some qualitative monitoring occurs during the time the work zone is in place. While the process works, and has worked for some time, there is still room for improvement. The current process has limited feedback once the work zone is implemented, with no mechanism for improving the standards in place based on the performance of a work zone in the field. For the most part, the same performance measures are used for all work zone implementations. The other major deficiency in the current process is limited number of performance measures considered during the process. Often, only one explicit
performance measure is considered when creating a traffic control plan. The most common metrics considered when deciding between work zone alternatives are the target speed through a work zone, expected delays, road user costs, and the volume/capacity relationship. The consideration of safety is not usually specific, instead relying on the DOT standards and the traditional methods and assuming they will be safe. Accidents in the work zone are monitored, and any observed problems are corrected, but this reactionary stance is not ideal. Under the new comprehensive process, which incorporates a number of performance measures throughout the lifespan of the project, as well as incorporating feedback, practitioners will have a process that better informs the decisions that must be made regarding the implementation of work zones. Increasing the number of performance measures considered when making implementation decisions will improve the safety and mobility throughout work zones. The feedback loop incorporated into the new process will allow for the standards currently in place to be improved, again improving safety and mobility on the facilities.
REFERENCES


