Revised Process for Work Zone Decision-Making Based On Quantitative Performance Measures

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Word Count (7293): Abstract (187) + Text (6106) + Tables (2×250) + Figures (2×250)

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Thomas W. Hartmann and H. Gene Hawkins Jr.

ABSTRACT

Work zones create one of the most challenging environments for drivers. Implementing work zones on freeways creates many issues, especially with respect to mobility. Decisions made regarding the work zone should be informed by quantitative data, collected in work zones, to ensure that the mobility impacts of the work zone treatments implemented are mitigated. This paper details the development of a new decision making process, which addresses the shortcomings in the current decision-making processes. The new process incorporates a Performance Measure/Treatment matrix, which recommends multiple performance measures, each of which is chosen to measure the mobility impacts particular to a specific work zone implementation. Most importantly, the revised decision making process incorporates a feedback loop. Quantitative data collected in work zones is analyzed after the work zone is complete, to determine the impacts specific decisions had on mobility in the work zone. The lessons learned in previous work zones are then incorporated into the decision making process, lessening the mobility impacts of future work zones. This paper develops the new decision making process, focusing on mobility measures, and examines the issues with the application of the process.

INTRODUCTION

Work zones create one of the most challenging environments for drivers. Accordingly, it is appropriate to measure the impacts of work zones and to use these performance measures to make decisions that will mitigate the potential negative impacts of the work zones. This paper formulates, describes, and tests a new process for making decisions pertaining to mobility aspects of work zones, which includes mobility performance measures that will facilitate comparisons and assessments of the operational impacts of various work zone treatments.

Problem Statement

There is no standard process currently used to make decisions in work zones. Every agency has a different strategy, many relying solely on engineering judgment to make decisions. While there is no standard process, most processes follow a typical framework. The current, typical process for making work zone-related decisions has been developed through decades of application and refinement. While the process is still viable and applicable, there are deficiencies. A lack of feedback assumes that decisions made in the planning stages will affect mobility in precisely the manner predicted. This assumption leads to traffic control and management strategies that are not adequately monitored to fully quantify the mobility impacts imposed on road users. Currently, some monitoring occurs, mostly utilizing qualitative data to make reactive decisions. Using quantifiable data collected during actual work zone operation, rather than a qualitative assessment of what “worked” and what “didn’t work,” would 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.

The work zone decision-making process can better reflect the complexity of implementing a work zone by focusing on multiple performance measures, considering the whole spectrum of the work zone's impacts, from mobility to construction costs. The appropriate performance measures for different implementation strategies or traffic control treatments needs to be determined. For example, target speeds may be an effective performance measure 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 should to be determined in order to ensure that the most useful data is available to make the most informed decisions possible. These measures should also 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 multiple, 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 of work zones. Developing a comprehensive process that considers all performance measures, including safety and mobility, for all types of facilities would be a daunting process. Therefore, this exercise focused upon developing a process for assessing the mobility impacts.

Objectives

The objectives of this exercise were to propose a process to relate freeway work zone planning decisions and potential work zone mobility performance measures, and to determine a set of performance measures that would enable comparison of the mobility impacts of various work zones. The new process incorporates multiple work zone performance measures throughout the life cycle of the work zone. As part of the framework, a matrix indicating the appropriate performance measures to use for various work zone treatments was developed. The proposed process provides a means for agencies to compare the mobility performance of work zones at both the small-scale and large-scale levels. These measures will enable engineers to compare the impacts of many implemented work zones.

BACKGROUND

Addressing the shortcomings of the current framework required some background information. The following sections describe the current processes for decision making in work zones, as well as some key points considered when developing the new process.

What Are Performance Measures?

For the sake of clarity, it is necessary to define the differences between data, performance measures, and decisions. In this exercise, data is defined as the raw information gathered from a work zone; i.e. vehicle speeds through the work zone. The collected data is then used to create a performance measure, which illustrates some condition of interest in the traffic stream, such as the reduction in overall volumes due to the implementation of the work zone. Based on the calculated performance measures, a decision can be made to improve conditions.

The performance measures can also be evaluated to determine whether the work zone is meeting the agency's goals for the work zone. When formulating performance measures, it is of vital importance to ensure that agency goals drive the development of appropriate measures, not the available data. For performance measures to be effective, they should be able to illuminate deficiencies in current practices. By formulating performance measures with an eye towards the ultimate goals for the agency, any standard practice within the agency that is not meeting these goals can be ferreted out and improved. Conversely, if performance measures are created based on the available data, such as data already collected by the agency, the performance measures may not reveal anything new about the conditions on the facility. Measures tailored to existing data have the potential to only describe the existing conditions, not shed new light on previously unnoticed mobility or safety issues.

Current Decision Making Processes

There is no standard process currently used to make decisions in work zones. Every agency has a different strategy, and many rely solely on engineering judgment to make decisions. A typical work zone decision making strategy is shown in Figure 1.

In the ideal current process, the need for a work zone is realized, and 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. Based on observed conditions, a goal is then set for the facility once 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 the goals set, they are revised until they meet these goals. When an acceptable performance is predicted, the alternative with the least undesirable impacts 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. Without the benefit of an unlimited budget, a work zone with zero impact on the mobility and safety conditions of the facility is infeasible.

Issues with Performance Measures in Transportation Engineering

Transportation engineering addresses a complex combination of frequently conflicting objectives. Citizens are dependent on the transportation system for their very way of life, for everything from their occupations to their leisure activities to their consumer activities. The societal costs of any operational decision (increased traveler costs, lost productivity, increased emissions due to congestion, etc.) should be considered in any performance measures, along with the more obvious consequences (throughput volumes, average speeds, average crash rates, etc.). In some ways, making decisions in a work zone is like squeezing a balloon. Squeezing one side of the balloon (i.e. minimizing total delay by working only at night) causes the other side to inflate more (project durations and costs increasing). This balancing act is difficult, and should be accounted for when planning, implementing, and analyzing a work zone. Consideration should also be given to the fact that work zones, by nature, are temporary conditions on the facility. Complete avoidance of traffic impacts is often not feasible within the constraints of a project (budget, space issues, project timelines, etc.). Engineers must balance the chosen performance measures to be conducive with the public good, within the given constraints. Certain choices could greatly alleviate the impacts of the work zone, such as constructing an alternate route on a new alignment while the existing facility is

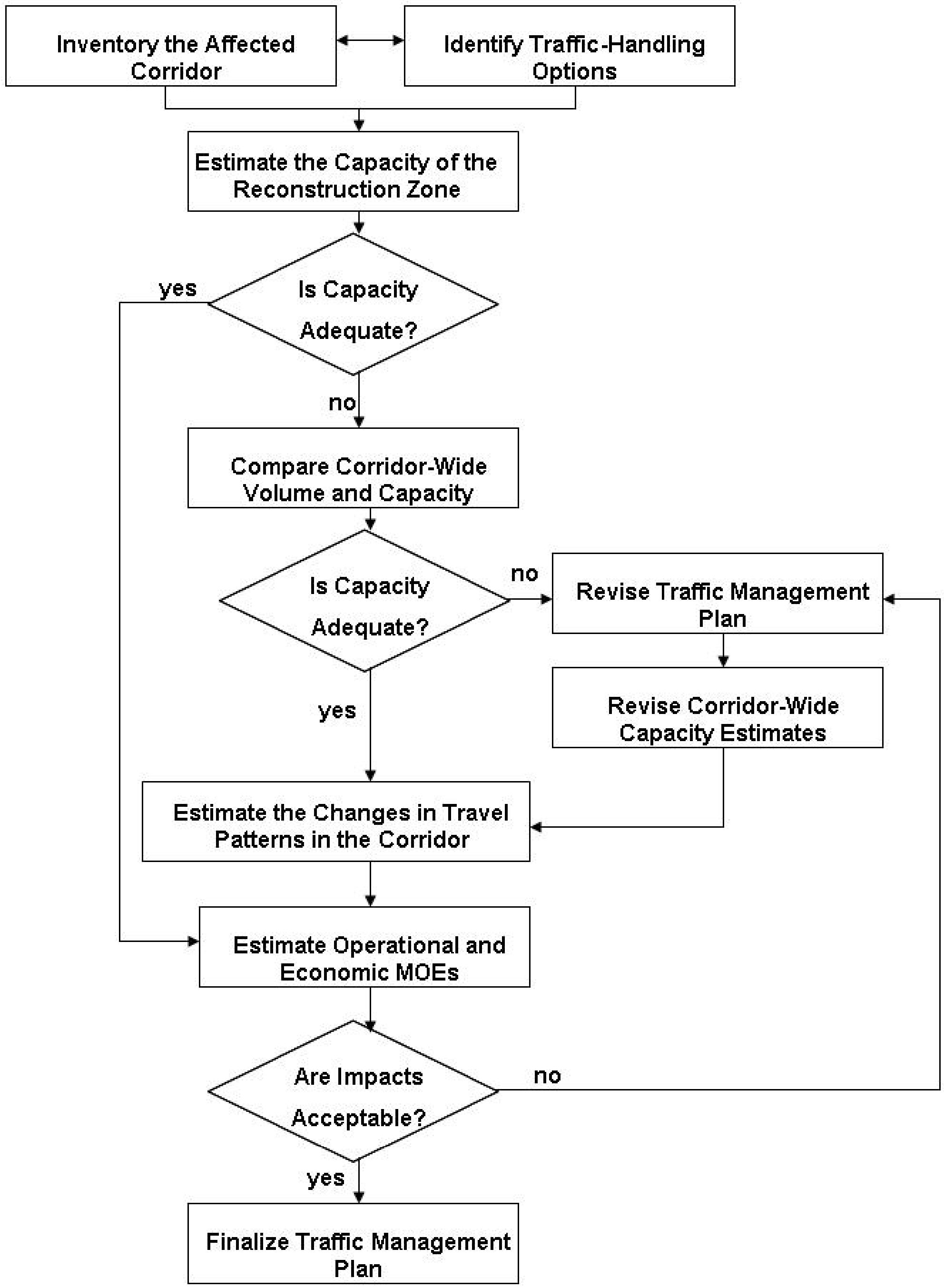

Figure 1: Example of Current Work Zone Monitoring Process (*1*)

under construction, but would not be the best use of public money, infrastructure, and resources. The corrections necessary to address the impacts of a work zone may be too permanent to be appropriate, because the conditions caused by the work zone only exist as long as the work zone itself. Restriping lanes, retiming signals in the area, or changing alignments may address the impacts of the work zone, but would be unnecessary once the work is complete. The temporary nature of work zones also influences the choice of performance measures, specifically with regards to data requirements. If too much data is required to calculate a performance measure, the project may be finished by the time a decision is made to correct an observed problem. Ultimately, the decision of which performance measures are needed to assess conditions on a facility is dependent on the goals of the agency responsible for the facility, as well as the constraints of the project.

Current Monitoring Practices

State DOTs use a variety of mobility-related performance measures in the existing work zone to monitor the actual traffic impacts. In late 2005, a survey of state agencies around the country was administered to determine what, if any, performance measures were used to monitor traffic impacts in implemented work zones (*2*).

The survey found that while many states are concerned with the mobility impacts of work zones, most do not specifically monitor those impacts once the work zone is implemented. Most of the performance measures used to mitigate congestion are implemented in the design and planning stages. The performance measures' thresholds are often arbitrary, and may not reflect existing conditions on the roadway.

While decision-makers may not feel that quantitative measures are necessary, they can be useful to either prove or disprove their intuition. If the performance measures verify the assumptions held about the mobility impacts of various decisions, then there is no need to revise the agency's standards. However, if the data contradicts the commonly held assumptions, then the information gleaned can be used to revise the standards and approaches to improve future work zone implementations. In order to learn the correct lessons from an implemented work zone, the appropriate performance measures should be used in the analysis.

DEVELOPMENT OF REVISED PROCESS

There are many treatment strategies currently in use in work zones on freeways; some more significantly impact mobility in the work zone. The first step in developing the revised process was to create a Performance Measure/Treatment Matrix. It was created by determining both the possible work zone treatments and the mobility performance measures associated with each treatment. The anticipated impacts caused by the work zone were used as the basis for deciding which performance measures were most appropriate for the various work zone treatments. Treatments with significant impacts on freeway mobility were categorized in terms of geometric, temporal, and informational implementation strategies.

Geometric Implementation Strategies

The most commonly used geometric treatments affecting mobility are lane shifts, lane constrictions, and lane closures. Lane shifts are commonly utilized when work is necessary on the shoulder, but the shoulder alone does not provide enough space for the work. By introducing a deflection into the normal driving patterns of the freeway, a lane shift changes the mobility of the freeway. This change is most readily apparent, and most measurable, through speeds in the work zone.

Lane constrictions are an option when work is necessary on an edge of the freeway, but the required space does not infringe on the traveled way enough to warrant a lane shift. Constricting the width of lanes on a freeway affects both speed and capacity.

Lane closures have a far more impact on the mobility of a roadway undergoing a significant, long-term work zone project. Closing one or more lanes drastically impacts the capacity of the roadway, in turn affecting the speeds and volumes possible through the closed section. Reducing the number of open lanes causes many conditions which serve to reduce the mobility in a section. The impacts of lane closures are most readily apparent through queuing, slower speeds, and reduced volumes.

Temporal Implementation Strategies

When a treatment is utilized is often as important as *what* treatment is chosen. These decisions are typically only necessary when one or more lanes must be closed in order to complete the project. When scheduling a major work zone project, the practitioner may need to decide between:

- Partial closure vs. full closure;
- Nighttime work vs. daytime work;
- Weekend work vs. weekday work; and/or
- Peak vs. off-peak.

The decision between partial closure and full closure involves many tradeoffs. Fully closing a facility enables work to be done throughout the entire section, with no conflict between workers and motorists. This allows for a very compressed work schedule, but completely removes the capacity of the facility from the traffic network. Closing one or more lanes, while leaving lanes open to serve traffic, greatly extends the timeframe of the project, and exposes both drivers and workers to increased safety risks. However, not closing all lanes allows at least some mobility (however reduced) to be maintained.

The other temporal decisions concern a choice between closing a facility when traffic demand is much lower, such as nights or off-peak, but worker costs and job complexity is higher, or when demand is higher, but costs and complexity are reduced, i.e. days and peak times. Working at night allows for lesser mobility impacts, because the travel demand on the freeway is much less. Restricting lane closures to time periods with reduced demand lessens the impact on mobility, but increases costs (through overtime, extended time necessary to complete the project, illumination costs, etc.). Closing lanes during periods of heavy demand, such as peak hours or weekdays, shortens the time frame of the project and reduces the cost, but impacts mobility more and exposes drivers and workers to more safety hazards. The consequences of these decisions must be weighed.

Informational Implementation Strategies

Informational implementation strategies, including static signs, dynamic message signs (DMS), websites, and Highway Advisory Radio (HAR), can be valuable tools for increasing drivers' awareness of the impacts of work zones. Informational strategies can serve two main purposes: they can inform drivers of treatments (i.e. lane closure, diverting traffic), or indicate traffic conditions (when linked to real-time data). Informing motorists can reduce turbulence in the traffic stream caused by driver uncertainty, and reduce demand by diverting traffic before it enters the congested area.

Performance Measures

Assessing the mobility impacts of different implementation strategies requires performance measures that can describe the various aspects of mobility. At the macroscopic level, the performance of the traffic stream as a unit is measured through averages or aggregated measures. This level of measurement is appropriate for large-scale, long term level analysis. The large-scale perspective is vital in obtaining a comprehensive overview of traffic conditions for large geographic areas, such as corridor. Microscopic performance measures describe mobility as a function of the subject vehicle's interactions with the vehicles leading, following, and flanking it. These performance measures are appropriate for short-term, small scale analysis.

In some cases, neither large-scale nor small-scale measures may be appropriate to describe the conditions an engineer is trying to ascertain. Work zones present such a situation. Work zones do not fit neatly into either large-scale or small-scale measures. By nature, work zones are temporary, unlike the permanent network described by large-scale categories. Large-scale measures, such as the travel time index, are often too broad to specifically address the impacts of only the work zone. These measures illustrate the overall performance of a corridor, or network, over long periods of time. However, work zones are typically a small portion of a corridor, or a facility, with much shorter life spans than the facilities they are implemented on.

Small-scale measures are useful when describing the day-to-day operation of work zones. The work zone likely has many different geometric, temporal, and signing configurations throughout the project, so such small-scale measures may inaccurately portray the nature of the work zone's impact on mobility. More performance measures are needed to completely describe the impacts of the work zone than are needed under normal conditions on the same freeway, due to the complex and unavoidable impacts the work zone has on the freeway. Amalgamated measures combine aspects of both large-scale and small-scale measures to describe the unique conditions within a work zone. By combining these point measurements over the length of the work zone, but not the entire roadway, the intermediate impacts of the work zone implementation can be determined and mitigated, if necessary. Using multiple, amalgamated measures is necessary to supplement the existing small-scale measures, and to develop a clearer vision of the impacts a work zone has on a facility.

When formulating performance measures, special care should be taken to ensure that goals drive the performance measures. When performance measures drive goals, the goals have a propensity to reflect the current conditions in order to make the existing performance measures look good, which rather than improving conditions, rewards sub-par performance. There is also an issue with creating absolute thresholds for performance measures. For example, a performance measure would be absolute in the sense that 1500 vph is the cut-off for acceptable service. Once the volume observed on the freeway reaches 1501 vph, the mobility does not instantaneously fall off to an unacceptable level. This fuzziness and uncertainty in the making decisions based on performance measures formulated from the relatively limited data available in a work zone should be taken into account.

Amalgamated measures are needed to supplement the small-scale and large-scale measures currently used for:

- Speeds;
- Travel Times;
- Delays;
- Volumes;
- Capacities;
- Densities; and
- Queues.

Each of these operational characteristics can be measured and described in a multitude of ways, at all three levels of measurement (small-scale, large-scale, and amalgamated.) There are no absolutely correct performance measures that are applicable to every situation. Every work zone implementation is different, as is the facility and network where the work zone is implemented. The nature of the system surrounding the work zone influences the appropriate performance measures. The type of analysis to be conducted, as well as the decisions to be made using the measures, greatly influences which performance measures are appropriate. All of the performance measures are interrelated, and are often available from the same data set. The difficulty comes in determining which performance measures will impart the information necessary to make the best possible decisions in the work zone. Table 1 summarizes the performance measures utilized in the development of the Performance Measure/Treatment Matrix (Table 2). The measures utilized were chosen for their ability to accurately describe their mobility impacts of various work zone decisions, their applicability to various scenarios, and their practicability. The Matrix matches the previously discussed treatment strategies with performance measures that most accurately describe the major impacts of choosing the different implementation strategies.

Table 1: Summary Table of Performance Measures

Measure	*Small-Scale*	*Amalgamated*	*Large-Scale*
Speed	Individual Speed Point Speeds	Average Speed in Work Zone 85th Percentile Speed in Work Zone Speed Variance in Work Zone Percentage of VMT Experiencing Lowered Speeds (less than 50 mph) Speed Profiles in Work Zone	Average Speed for Corridor 85th Percentile Speed for Corridor Speed Differentials for Corridor
Travel Time	Individual Travel Time Individual Travel Time Reliability Instances of Excessive Travel Time	Average Travel Time Through Work Zone Number of Analysis Periods of Excessive Travel Time (20% increase) Percentage of VMT Experiencing Excessive Travel Time in Work Zone	Average Travel Time for Freeway Travel Time Index Travel Time Reliability
Delay	Delay per vehicle	Total Delay per VMT Number of Analysis Periods of Delay (20% increase in Travel Time) Percentage of VMT Experiencing Delay Length of Consecutive Delay Periods Buffer Index in Work Zone	Total Delay for Corridor Buffer Index for Corridor
Volume	Point Volume Headways	Work Zone Volume Occupancy in Work Zone Volume per Lane per Mile of Exposure Vehicle Miles Traveled	Corridor Volume Occupancy for Corridor Volume per lane per mile Flow Rate
Capacity	N/A	Percent Change in Volume/Capacity Ratio in Work Zone Change in Capacity in Work Zone	Volume/Capacity Ratio for Corridor Capacity
Density	Vehicle headway	Average Density in Work Zone Number of Analysis Periods of Excessive Density (over 35 pvpmpl) Percentage of VMT Experiencing Excessive Density	Average Density for Corridor
Queue	Number of Vehicles in Queue	Average Queue Length in Work Zone Instances of Excessive Queue Length Recurrence of Excessive Queue Length	Average Queue Length for Corridor Queue Length Reliability

Table 2: Performance Measure/Treatment Matrix

Performance Measure		Treatment Strategy								
		Geometric Implementation Strategies			*Temporal Implementation Strategies*				*Informational Implementation Strategies*	
Type of Performance Measure	Indicator	Lane Shifts	Lane Constrictions	Lane Closures	Partial vs. Full Closure	Nighttime vs. Daytime	Weekend vs. Weekday	Peak vs. Off-Peak	Informative Messages	Diversionary Messages
Speeds	Average Speed	X	X	X	X					
	85th Percentile Speed	X	X	X	X					
	Speed Variance	X	X	X	X					
	Percentage of VMT Experiencing Lowered Speeds (20 mph drop)	X	X	X	X					
	Speed Profiles	X	X	X	X					
Volumes	Work Zone Volume					X	X	X		X
	Occupancy					X	X	X		X
	Volume per lane per mile of exposure					X	X	X		X
	Vehicle Miles Traveled					X	X	X		X
	Average Density					X	X	X		X
Densities	Average Density			X		X	X	X		
	Number of Analysis Periods of Excessive Density (over 35 pvpmpl)			X		X	X	X		
	Percentage of VMT Experiencing Excessive Density			X		X	X	X		
Travel Times	Average Travel Time Through Work Zone	X	X	X	X	X	X	X	X	X
	Number of Analysis Periods of Excessive Travel Time (20% increase)	X	X	X	X	X	X	X	X	X
	Percentage of VMT Experiencing Excessive Travel Time	X	X	X	X	X	X	X	X	X
	Buffer Index	X	X	X	X	X	X	X	X	X
Delay	Total Delay per VMT	X	X	X	X	X	X	X	X	X
	Number of Analysis Periods of Delay (20% increase in Travel Time)	X	X	X	X	X	X	X	X	X
	Percentage of VMT Experiencing Delay	X	X	X	X	X	X	X	X	X
	Length of Consecutive Delay Periods	X	X	X	X	X	X	X	X	X
Capacities	Percent Change in Volume/Capacity Ratio		X	X	X	X				
	Change in Capacity		X	X	X	X				
Queues	Average Queue Length in Work Zone		X	X	X	X	X	X	X	X
	Instances of Excessive Queue Length		X	X	X	X	X	X	X	X
	Recurrance of Queue Length		X	X	X	X	X	X	X	X
Project Duration	Project Duration				X	X	X	X		

Performance Measure/Treatment Matrix

Initially, the matrix may appear to recommend an excessive number of performance measures for each treatment, with a large amount of data collection needed to calculate all of the measures. In actuality, many of the performance measures can be generated from the same data. For example, the average speed, 85th percentile speed, speed differentials, and speed profiles can all be generated using the same collected speeds. Each of these speed measurements gives different information about the mobility through the work zone; aggregated, they fully depict the speed-related conditions within the work zone. Practitioners have leeway when choosing which performance measures to utilize. They are encouraged to choose the performance measures compatible with the goals set by their agency.

Additionally, the performance measures recommended in the matrix are not meant to be the exclusive measures used for the particular treatment. The matrix matches performance measures to the major impacts of treatments. Just because a particular treatment impacts speeds more than volumes does not mean that only the speed impacts should be measured, excluding volumetric measures. It just means that at the very least the work zone's impact on the speeds observed on the facility should be monitored. Practitioners are free to choose the performance measures they are concerned with; the matrix is a guide for which performance measures should be considered. The use of as many performance measures as reasonable is encouraged, in order to fully understand the complex impacts of a work zone on a freeway. As more performance measures are used, a clearer representation of mobility through the work zone is created. Through the use of these recommended amalgamated performance measures, the mobility in a single work zone can be monitored more effectively, and the mobility of several work zones can be compared. By using consistent measures, work zones utilizing different configurations, project durations, and implementation strategies can be easily compared to improve work zone performance in the future.

Revised Decision Making Process

The Performance Measure/Treatment Matrix can be a valuable tool for determining which performance measure will best describe the mobility impacts of the various work zone implementations, but without context, the matrix does not realize its full potential. The matrix must be incorporated into a systematic decision making process. Agencies typically have processes already formulated, albeit informally, to make work zone related decisions, but these existing processes have three major deficiencies. The typical processes currently used:

- Employ the same performance measures for each work zone implementation, regardless of work zone characteristics;
- Rely on too few performance measures throughout the process; and
- Lack a formal, quantitative feedback mechanism to incorporate the results of implemented work zones on future implementations.

As discussed in previous chapters, different work zone implementation strategies impact the mobility of a freeway in different ways. If an agency exclusively uses the same measures as the metric of performance for each work zone implementation strategy, some important mobility impacts will be overlooked, and perhaps not considered during the decision making process. Practitioners need to ensure that the performance measures used as a basis for decision making are relevant to the work zone implementation strategies employed. The matrix discussed previously can be used as a tool to find the correct performance measures.

Relying on too few performance measures to determine the mobility impacts of an implemented work zone is another flaw in the commonly used processes currently in use by various agencies. In many agencies, cost, data collection, data handling, and analysis limitations constrain the number of performance measures available to decision makers. Because of the changes to the roadway environment created by a work zone, multiple performance measures are needed to completely comprehend the mobility impacts. The use of multiple performance measures leads to a better understanding of work zone mobility impacts, which in turn leads to better decisions with respect to this mobility.

The lack of a feedback mechanism in the traditional decision making processes prevents work zone implementation strategies from reaching their full potential. By evaluating work zones after the completion of the project, and comparing the work zone to other similar work zones, standards for implementation strategies can be improved to further mitigate the mobility impacts. Agencies may become aware of mobility impacts that were not readily apparent during the project by analyzing the impacts of the work zone. The reasons behind these impacts can then be determined, and the information gleaned from the post-completion analysis can be used to improve future work zone implementations. Once the work zones have been analyzed to determine what impacts were observed, and which impacts were unique to a specific work zone feature, more feedback is returned to the process, further improving implementation techniques and strategies. The measures used to evaluate the performance of the completed work zone should be the same measures used when the work zone was active. The measures should also reflect the goals of the agency; using them for evaluation of the work zone before, during, and after implementation should result in the progress toward meeting the goals. Addressing these three main deficiencies in the current processes was the purpose of creating an improved process, shown in Figure 2.

The process starts with the assumption that a work zone is needed, and the objective of the project is already understood. The level of significance of the work zone project determines how much performance monitoring is necessary. A large scale, long term project, such as reconstructing a freeway, requires careful monitoring of operations to ensure the work zone is impacting the operation of the freeway as little as possible. Different agencies define project significance differently. The simplest definition of a significant project, according to the FHWA (*3*) is one located on an interstate that:

- Is within the boundaries of a designated Transportation Management Area;
- Occupies a location for more than three days; and
- Has intermittent or continuous lane closures.

These significant projects are the focus of the monitoring described by the revised process, using the appropriate performance measures taken from the matrix. These performance measures are then used to inform the decisions made throughout the rest of the process.

Based on existing conditions, such as the surrounding network and the traffic in the area, and the type of activity necessary to meet the objectives of the work zone, various treatment configurations can be formulated. The alternative work zone Transportation Management Plans (TMP) should incorporate variations of several possible decisions to be made. The number of alternatives created depends on the feasibility of creating multiple alternatives and the decisions to be made about the work zone. The alternatives should be formulated using three main influences:

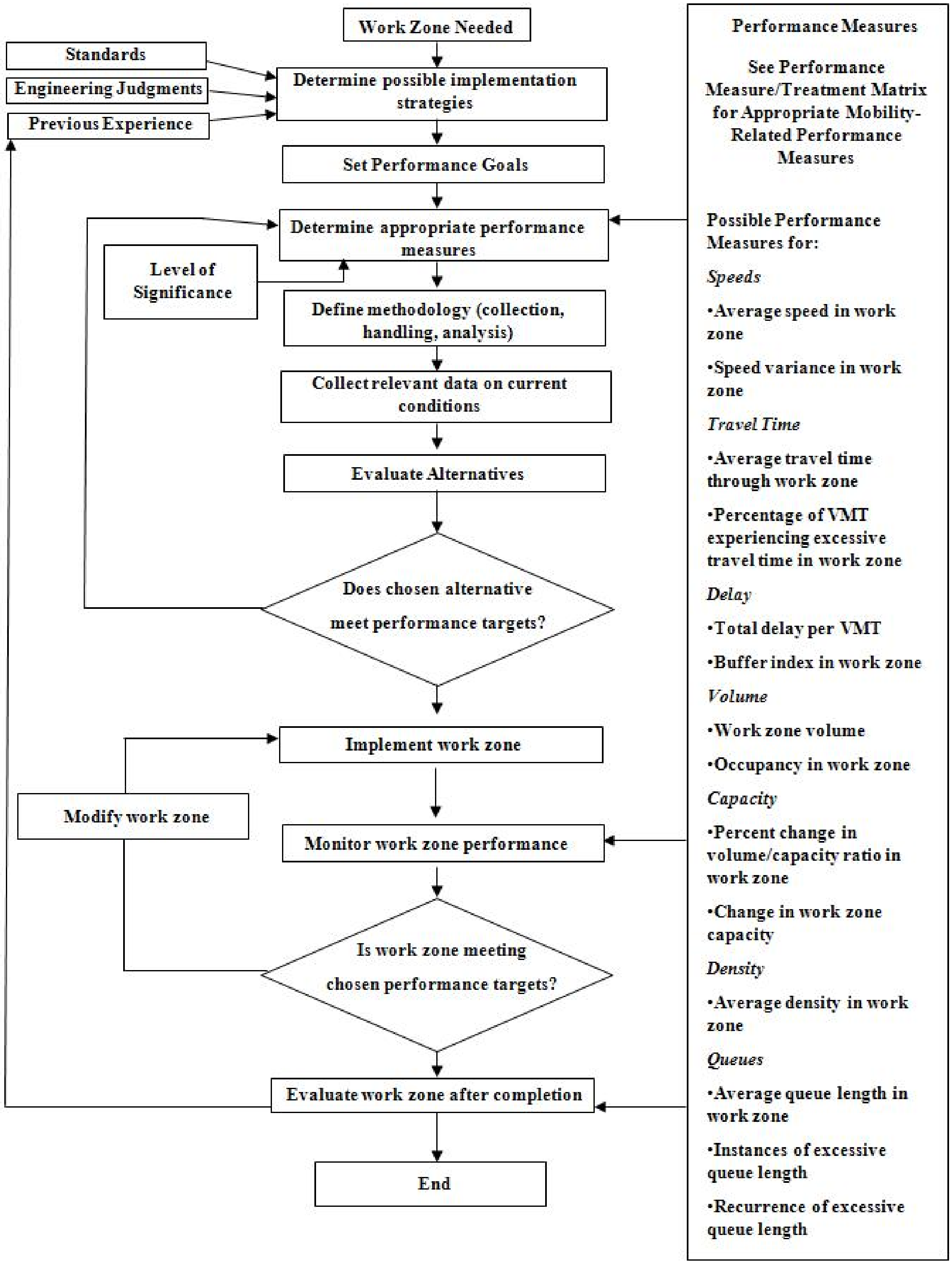

Figure 2: New Decision Making Process
(See Table 2 for Performance Measure/Treatment Matrix)

- Agency standards;
- Engineering judgments; and
- Previous experience.

Most large agencies have standard procedures and plans for creating a work zone. These standards should be followed when creating TMPs to ensure compliance. When the standards do not sufficiently mitigate the mobility impacts anticipated, engineering judgment should be used to modify the plans to improve performance. Previous experience should also be utilized as an adjunct to engineering judgment. The previous experience can be gleaned from both qualitative and quantitative assessments of prior work zones. Qualitative information is commonly a part of the current processes, but the use of quantitative measures as feedback to be incorporated back into the design phase of a work zone implementation is one of the improvements the new process is based on.

Once the appropriate performance measures are chosen, data is needed to determine baseline conditions on the facility. The data collected on the facility prior to the implementation of the work zone are used for comparison to predict the impacts of the work zone.

Once the multiple alternatives have been created, they need to be analyzed using the amalgamated performance measures deemed appropriate earlier in the process. At this stage of the process, the performance measures are only measuring the predicted impacts, so the results of this analysis may not sync perfectly with the impacts observed in the real world after implementation of the work zone. Once the alternatives have been analyzed to predict their mobility impacts, the practitioner must decide whether the alternatives meet the goals described by the performance measures. If at least one of the proposed alternatives meets the goals set forth previously, then the process can move to the next step.

Based on the evaluation, the work zone alternative with the least undesirable impacts should be chosen for implementation. Once the work zone is active and in place, performance measures are used to monitor conditions within the work zone. Depending on the data collection techniques, these performance measures can be used to alert agencies to traffic problems within the work zone in real time.

If possible, data collected in a work zone, should be used to monitor performance to ensure there are no excessive impacts on motorists. When excessive impacts are observed in the performance measures, the agency should take steps to correct the issue and redeploy the work zone with the necessary adjustments. Addressing these issues as they occur can result in a safer work zone with more mobility, leading to benefits including fewer crashes, less delay, a safer environment for workers in the work zone, and less driver frustration.

The data collected in the active work zone should be used to evaluate the work zone after completion. Reevaluating the observed conditions from a distance, looking at the overall project, can lead to valuable insights that can be used to improve future work zone implementations. By examining conditions that led to problems in work zones, what steps were taken to correct these problems, and how well the corrections addressed the problem, work zone implementations can be improved, and the overall goals of the agency can come closer to reality.

The lessons learned in the evaluation phase of the process are then used as feedback into the previous experience used to initially create implementation alternatives. The improvements from each work zone will be incremental, and not immediately apparent, but as feedback becomes more standardized and more data is gathered about various implementation strategies, agencies may be able to improve their work zone strategies dramatically.

This new process was created to address the three main deficiencies observed in the current processes for making decisions in work zones on freeways. The use of the same performance measures for different work zone implementation strategies was addressed through the use of the performance measures matrix, specifically the Operational Performance Measures Matrix presented earlier in this chapter. The reliance on a limited number of performance measures, which may or may not be sufficient to create a complete description of conditions within the work zone, was addressed through the recommendation to use more performance measures. A single performance measure can be misleading; using multiple performance measures describing different aspects of work zone impacts can more completely describe the conditions within the work zone and improve decision making. Feedback based on a post-completion analysis of work zone impacts can also be a tool for improving decisions. By including feedback as an explicit step in the revised process, along with comparisons to other similar work zones, it is expected that trends in work zone impacts will become more readily apparent, and easier to use as a basis for decisions.

While using multiple performance measures illustrates the conditions in a work zone more fully than using a single performance measure, they can sometimes give contradictory and misleading results. Using a single performance measure allows for easy decisions – a comparison needs to be made between two measures to determine which is most desirable. A single measure could be just as misleading as a suite of multiple performance measures. In order to make the most informed decisions possible, multiple performance measures should be utilized. When utilizing multiple performance measures, it is necessary to define the ultimate goals of the decisions made. Based on the ultimate goals, the appropriate performance measures can be chosen.

There are other difficulties with using data as a basis for decision making, especially the nature of the data involved. A data set will never be perfect, and this fact should be taken into account when choosing and using performance measures. Also, other factors that impact mobility are not reflected in the measures. For example, inclement weather conditions can adversely affect mobility, but are not reflected in any of the performance measures. Even with the best performance measures, other information should still be taken account when assessing decisions made. Quantitative performance measures are a very important component of the revised decision making process, but engineering judgment and common sense are still necessary.

Using quantitative data does not automatically answer another great debate about mobility impacts – is it better to delay a few vehicles infrequently for a very long time, or is it more desirable to spread that delay among more vehicles over the duration of the work zone. Every decision maker must answer this question individually. The quantitative data can be used to gather unbiased information about the conditions within the work zone, but the decision maker should make the ultimate determination about which impacts are more vital to the operation of the facility, and how to address the observed problems.

CONCLUSIONS AND RECOMMENDATIONS

The concepts explored in this paper, the ideas pursued, and the analysis performed led to several conclusions about the processes and measures used to plan, manage, and assess the impacts of a work zone implemented on a freeway.

Conclusions

One major focus of the exercise was the creation of an improved process for making work zone decisions, based on data, throughout the entire lifespan of a project, from design, to implementation, to post-completion analysis. The revised process presented was created to address the shortcomings in the existing processes. The revised process is paired with a Treatment/Performance Measure Matrix, which recommends the appropriate performance measures, based on the most significant expected impacts of the chosen implementation strategies. The Matrix also recommends a suite of performance measures. By utilizing multiple performance measures, a more complete assessment of the impacts of the work zone can be created, leading to a better understanding of the impacts and their underlying causes. The feedback mechanism incorporated into the new process allows for a post-hoc analysis of a work zone, allowing the lessons learned from a particular implementation to be applied to future implementations, improving strategies and lessening the negative impacts of implementing a work zone on a freeway.

An important component of the new process is the performance measures utilized within. Creating performance measures that would adequately assess the complex impacts of a work zone on a freeway was the other major focus of the exercise. The selection of the appropriate performance measures to monitor the work zone is one of the most critical steps in the monitoring and assessment process. The measures chosen should reflect the goals of the agency, as well as the impacts of the expected impacts of the implementation plan chosen. The Treatment/Performance Measure Matrix lists a multitude of potential performance measures that can be applied to a work zone on a freeway facility to predict, monitor, and assess the mobility impacts. The measures in the Matrix can be applied to a variety of different work zones, with different traffic characteristics, implementation plans, configurations, and decisions.

Decisions made in a work zone affect all of the aspects involved. As previously described, making decisions in a work zone is like squeezing a balloon. Balancing between decreasing one measure (i.e. project duration) at the cost of increasing another (i.e. cost) is difficult, and should be accounted for when planning, implementing, and analyzing a work zone. The unintended consequences of decisions can be more easily quantified when using multiple performance measures, as suggested in the revised process. The data-based feedback loop also aids in determining these consequences, by using the results of previous implementations to improve future decisions.

Recommendations

Based on the conclusions reached through this exercise, several recommendations can be made:

- Engineers should base work zone-related decisions on quantitative data, as well as past experience and engineering judgment;
- Decisions should be made in the context of the new process, with different measures for different implementations, utilizing multiple measures to fully detail the impacts, and using post-hoc analysis to inform future decisions;
- The performance measures chosen should be utilized throughout the process, from planning to monitoring to analysis;
- The performance measures should be chosen with the goals of the agency and the probable impacts of the work zone in mind; and
- Performance measures should be tailored to the decisions made in the work zone.

The results of this paper also point to many future research efforts that could further improve the monitoring of impacts in a work zone. Among the possible areas that could be further explored are:

- Examining the effectiveness of other aspects of the process, including the planning and monitoring aspects;
- Creating and examining safety-based performance measures;
- Creating and examining construction-based performance measures;
- Creating and examining societal impact-based performance measures;
- Creating and examining environmental-based performance measures; and
- Applying the principles set forth in the new process to arterials, to determine whether it is still applicable.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Texas Transportation Institute, especially Dr. Jerry Ullman. Portions of this paper were originally part of Mr. Hartmann’s thesis.

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