NCHRP Web Document 45 (Project 10-50A): Contractor's Final Report

A Process for Selecting Strategies for Rehabilitation of Rigid Pavements

Prepared for:

National Cooperative Highway Research Program
Transportation Research Board
National Research Council

Submitted by:

Stuart D. Anderson
Gerald L. Ullman
Byron C. Blaschke
Texas Transportation Institute
Texas A&M University
College Station, Texas

June 2002

ACKNOWLEDGMENT

This work was sponsored by the American Association of State Highway and Transportation Officials (AASHTO), in cooperation with the Federal Highway Administration, and was conducted in the National Cooperative Highway Research Program (NCHRP), which is administered by the Transportation Research Board (TRB) of the National Research Council.

CONTENTS

ACKNOWLEDGMENTS

This report was developed under NCHRP Project 10-50A by the Texas Transportation Institute (TTI). Dr. Stuart D. Anderson was the Principal Investigator. Dr. Anderson would especially like to thank his co-authors, Dr. Jerry Ullman and Mr. Byron Blaschke for their time, expertise, and dedication to completing this effort.

This work could not have been accomplished without the dedication and persistence of several graduate research assistants associated with TTI. The authors would like to thank Mr. Marc Valls, Mr. Edgar Herrera, and Mr. Cuneyt Erbatur for their efforts.

The authors wish to express their appreciation to all those who participated in telephone or on-site interviews. We specifically would like to thank Mr. Mike Ryan and Mr. Dan Dawood, Pennsylvania DOT, Mr. Paul Mack, Mr. Joe Rutnik, and Mr. Mike Brinkman, New York DOT, Bryant Poole, Georgia DOT, Mr. Doug Failing and Mr. Mario Gutierrez, California DOT, and Mr. John LaVoy and Mr. Curtis Bleech, Michigan DOT. These individuals spent many hours answering questions and providing project information in support of this research.

The authors would like to thank the NCHRP Panel and our Senior Program Officer, Dr. Amir Hanna, for their input, critical comments, and helpful suggestions as this research developed.

SUMMARY

Many highway facilities are experiencing rapid deterioration due to high traffic volumes and a service life that has been extended beyond facility design life. As a result, many pavements are in poor condition. State highway agencies (SHAs) are under pressure to mitigate such pavement conditions through maintenance, rehabilitation, and reconstruction (MRR) work while accelerating construction, minimizing traffic disruption, reducing accident risk, and improving public acceptance. Much of this work is performed with limited funds.

State highway agencies have a range of engineering processes for pavement analysis and design. These *pavement-related* processes focus on pavement condition and causes of pavement distresses to identify appropriate pavement treatments. *Pavement-related* processes determine "what is done." Traffic and construction management processes, *nonpavement-related*, are also commonly considered to identify "how the pavement treatment is accomplished." Little information is available on how to integrate these *nonpavement-related* processes into the MRR strategy selection process for rigid pavements. These *nonpavement-related* aspects of an MRR strategy have, perhaps, the greatest impact on road users and local businesses and may actually have the major influence on strategy selection for high traffic volume pavements.

An integrated selection process that considers a number of potential alternatives to both the *pavement-* and *nonpavement-related* aspects of an MRR strategy is needed. This process will aid decision makers in selecting the most appropriate strategy for MRR of rigid pavement *subjected to high-traffic volumes*. National Cooperative Highway Research Program (NCHRP) Project 10-50A was conducted to develop this selection process.

The research was conducted in two phases. The first phase determined the elements that comprised an MRR strategy and proposed a preliminary process. The second phase of the research fully developed the preliminary process. This development effort created the detailed information required to implement the steps of the process as well as the structure and format for describing the process. The proposed selection process was then demonstrated through project specific applications provided by SHAs and documented as case studies.

The process was developed to help SHA decision-makers identify MRR strategies, screen feasible strategies, and then select the most appropriate strategy from a limited set of project specific feasible strategies. This selection process includes pavement condition analysis, pavement treatment identification, impact of traffic and construction as relevant to the implementation of pavement treatments, contracting, and life cycle cost analysis.

The process is based on the following fundamentals:

- A probable MRR strategy should be identified early in project development, and preferably prior to the establishment of project funding. The strategy ideally will dictate funding, rather than the funding dictating strategy.
- The early and continuing involvement of many agency professionals in the selection process is desirable. Materials, design, traffic, construction, maintenance, and

contract organizations should have input to support the pavement design effort.

- The probable cause of pavement distress should be determined and the MRR strategy selected should correct the cause, not just treat the symptoms.
- After selecting potential MRR strategies for further study, it is desirable to screen the strategies to eliminate those that are not practical or economically feasible. The remaining strategies would then be studied in greater detail.
- In high volume traffic conditions, the disruption of traffic, even for short time periods, can result in extensive road user costs. Hence, selecting pavement treatments, materials, traffic management approaches, and contracting methods that will accelerate the work and minimize traffic disruption becomes a critical consideration. Nonetheless, the process emphasizes that these considerations should not, where possible, be allowed to dictate strategy selections that do not correctly address the actual causes of the pavement distress.
- In high volume traffic conditions, selecting MRR strategies requires construction knowledge and experience to insure that each strategy is constructable, cost effective, minimizes traffic delays, and provides a safe environment for workers and the traveling public.

The following factors and constraints play a major role in decision-making when selecting MRR strategies. A key attraction of the proposed process is that most of the time these factors can be modified to fit the project objectives, if addressed in the early stages of design.

- Availability of Funds - increments on allocated funds for the project may be required to select appropriate and cost-effective strategies.
- Safety (motorist and workers) - development of traffic and construction management approaches that maximize a safe environment during MRR activities.
- Traffic congestion - development of traffic and construction management approaches that minimize the amount of congestion created, the duration of the congestion, and the degree of driver dissatisfaction with the SHA about how traffic is accommodated.
- Public opinion - information campaigns to obtain public involvement in the early stages of the project. This may help avoid conflicts and delays due to public opposition. This may also create public acceptance for delays if the project is completed in a timely way.
- SHA policies - assessment of policies and formal procedures. Possible modifications to written and unwritten policies may have to be submitted for approval.

The approach that many SHAs currently follow to select an MRR strategy is often divided into independent processes carried out by different functional groups within the agency. As a result, traffic and construction issues are often assessed late in the design phase, making it difficult to modify designs without substantial cost and time implications. This approach can obligate the SHA into following a strategy that may not, in fact, be the most appropriate MRR strategy. The lack of sufficient traffic and construction analysis is especially problematic with projects where high traffic volumes are a major concern. Further, current SHA processes do not always differentiate between high traffic volume projects and other projects. These issues can be addressed through the process described in this report. This process can aid state highway agencies select the most appropriate strategies for MRR of rigid pavements *subjected to high traffic volumes*.

The process was developed to support MRR strategy selection decisions in the programming phase and/or the early design phase of projects. It could supplement existing SHA selection processes. SHA senior management is encouraged to integrate information described in this report into their MRR strategy selection process for high traffic volume projects.

CHAPTER 1
INTRODUCTION

RESEARCH PROBLEM

Many highway facilities are experiencing rapid deterioration due to high traffic volumes and a service life that has been extended beyond facility design life. As a result, many pavements are in poor condition. State highway agencies (SHAs) are under pressure to mitigate such pavement conditions through maintenance, rehabilitation, and reconstruction (MRR) work while accelerating construction, minimizing traffic disruption, reducing accident risk, and improving public acceptance. Much of this work is performed with limited funds. Efforts have been made to develop, and in some cases to improve, the MRR strategy selection process that addresses these critical factors for high-volume roadways.

State highway agencies have a range of engineering processes for pavement analysis and design. These *pavement-related* processes focus on pavement condition and causes of pavement distresses to identify appropriate pavement treatments. *Pavement-related* processes determine "what is done." Traffic and construction management processes, *nonpavement-related*, are also commonly considered to identify "how the pavement treatment is accomplished." Little information is available on how to integrate these *nonpavement-related* processes into the MRR strategy selection process for rigid pavements.

Pavement-related aspects of MRR strategy selection are generally well developed, however, the *nonpavement-related* aspects of strategy selection are not. These *nonpavement-related* aspects of an MRR strategy have, perhaps, the greatest impact on road users and local businesses and may actually have the major influence on strategy selection for high traffic volume pavements.

An integrated selection process that considers a number of potential alternatives to both the *pavement-* and *nonpavement-related* aspects of an MRR strategy is needed. This process will aid decision makers in selecting the most appropriate strategy for MRR of rigid pavement *subjected to high-traffic volumes*. National Cooperative Highway Research Program (NCHRP) Project 10-50A was conducted to develop this decision process.

RESEARCH OBJECTIVE

The main objective of Project 10-50A is to develop information that can be used by state highway agencies to help select appropriate strategies for maintenance, rehabilitation, and reconstruction of rigid pavements *subjected to high traffic volumes*. This information is presented as a process that considers factors that influence the selection of MRR strategies. These factors include pavement treatment and material selection, safety (to workers and users), constructibility, quality, construction and traffic control cost, risk assessment, public perception impact, and road user delay. The recommended process guides the user through a series of steps that address both *pavement-related* and *nonpavement-related* issues relevant to high-traffic volume MRR projects.

FRAMEWORK FOR RESEARCH APPROACH

In order to accomplish the research objective, a process has been designed that identifies functions and information used to select the most appropriate strategy for MRR of rigid pavements. A framework, comprised of key definitions and a matrix that schematically portrays relevant key elements, was created to assist in designing the selection process.

Key Definitions

Different definitions are given in the literature and often used by state highway agencies to describe maintenance, rehabilitation, and reconstruction, including types of pavement treatments and other related evaluation considerations. For example, the National Highway Institute (NHI) course for pavement rehabilitation incorporates restoration, recycling, and resurfacing (3R category) as rehabilitation categories (*1*). The American Association of State and Highway Transportation Officials (AASHTO) Guide for Design of Pavement Structures uses four categories (4R) of restoration, rehabilitation, resurfacing, and reconstruction (*2*). The American Concrete Pavement Association (ACPA) describes rehabilitation as restoration, resurfacing, and reconstruction (*3*).

The selection process framework presented herein is structured to cover treatments ranging from maintenance at one extreme to reconstruction at the other extreme; rehabilitation treatments are between the two extremes. Rehabilitation is further categorized as resurfacing, restoration, and recycling. A number of different pavement treatments can be related to each MRR approach. Pavement treatment types are based on earlier NCHRP research and those identified by the ACPA and other literature. Other key definitions include high traffic volumes, project scope, and an MRR strategy. A summary of all key definitions is presented in Table 1.

Traditionally, SHAs themselves have defined what constitutes "high" traffic volumes on roadways under their jurisdiction (see Table 1) (note: figures and tables appear at the end of this report). These values are generally correlated to the level of delays and congestion that the agency is willing to accept as part of work activity on a facility. Many factors, such as normal traffic congestion within the region as well as public/political pressures, may influence an agency's perception of the amount of delay that is "acceptable."

User delays at an MRR activity are caused when traffic demands exceed the reduced roadway capacity through the work zone. This reduced capacity is a function of the number of lanes left open after passing through the work zone. If at least one MRR strategy out of those being considered involves traffic control that would reduce the available capacity below normal traffic demands (and thus create traffic delays and queues), then that roadway section would be a candidate for the analyses being developed and presented in this report.

The process developed is intended to support decision-making at the project level. Thus, a strategy is based on a defined project scope that includes pavement type, total length, number of sections within the project boundary, length of each section, and number of lanes. Finally, a strategy for maintenance, and/or rehabilitation, and/or reconstruction would be project specific and may include one or more pavement treatments as determined by pavement distresses and the impact of such factors as traffic management and control, construction methods and techniques, and life cycle costs.

Matrix of Elements

The process developed for selecting strategies for MRR of rigid pavements is based on two key sets of elements. The first set of elements pertains to pavement treatment types. These pavement treatment types can be loosely categorized within a range from maintenance to reconstruction. Pavement treatments define "what is done." The second set of elements is factors that should be considered when evaluating "how a pavement treatment(s) is accomplished." The factors are summarized according to attributes and criteria. These two sets of elements of the matrix form the framework for developing the selection process and are illustrated schematically in Figure 1.

As shown in Figure 1, the horizontal axis of the matrix is a continuum of pavement treatments covering maintenance, rehabilitation, and reconstruction treatments. A strategy is then described as one or a combination of individual treatments that are relevant to a given pavement type, pavement condition, and behavior characteristic. Table 2 summarizes some possible treatment types under the categories of maintenance, rehabilitation, and reconstruction.

The vertical axis of the matrix, as depicted in Figure 1, lists evaluation considerations that must be assessed in conjunction with each selected pavement treatment type. Evaluation considerations are described in terms of attributes, criteria, and factors. Each attribute has a number of criteria that describe the attribute. Each criterion has a number of factors that must be evaluated when considering each pavement treatment type and making decisions on MRR approaches. A list of key attributes, criteria, and factors is provided in Table 3.

RESEARCH APPROACH

The process for selecting MRR strategies for rigid pavements subjected to high traffic volumes requires a multidisciplinary approach. Information is required in the areas of pavement condition analysis, pavement treatments, traffic, construction, and life cycle cost analysis. Further, the process must have input from key management personnel, as management will ultimately approve MRR strategies for design and construction. In order to insure this variety of input was reflected in the process, SHA personnel were involved in reviewing and validating the process and its details.

The research was conducted in two phases. The first phase determined the elements that comprised an MRR strategy and proposed a preliminary process. The second phase of the research fully developed the preliminary process. This development effort created the detailed information required to implement the steps of the process as well as the structure and format for describing the process. The proposed selection process was then demonstrated through project specific applications provided by SHAs and documented as case studies.

Elements of MRR Strategies for Rigid Pavements

An assessment of the elements of MRR strategies for rigid pavements was performed primarily through a literature review. The literature review focused on four main areas:

- Rigid pavements – condition and treatment types;
- Traffic management – traffic management planning, traffic control plans, road user costs, and other factors;
- Construction management – constructibility reviews, contract time determination, contracting methods, and other factors; and
- Life cycle cost analysis – components and existing programs.

This assessment began with a detailed review of an earlier relevant NCHRP research. Other literature relevant to the four areas was then examined guided by the conceptual framework shown in Figure 1 and elaborated in Tables 2 and 3. The literature revealed that common sets of MRR strategies that include each of the four areas were not readily available. This was, typically, due to the project specific nature of the problems being addressed. The selection of a comprehensive MRR strategy, as defined in Table 1, was found to be highly dependent on the project scope and situation. Multiple MRR alternatives could be identified for each project depending on the project scope and how various factors are evaluated and influenced by SHA policy, funds available, time, and public perceptions. Thus, a common set of MRR strategies could not be adequately defined that addressed the broad range of issues considered.

A Framework for Evaluating and Selecting a Strategy

A process modeling technique was used to formalize and structure the MRR strategy selection process. This modeling technique helped to identify the main steps and sub-steps of the process and the information needed to perform each step. A preliminary model of the process was first developed based on the information contained in publications by AASHTO (*2*), ACPA (*3*), Wisconsin Department of Transportation (*4*) and the interim findings of an earlier NCHRP related study.

The process was developed to help SHA decision-makers identify MRR strategies, screen feasible strategies, and then select the most appropriate strategy from a limited set of project specific feasible strategies. This selection process includes pavement condition analysis, pavement treatment identification, impact of traffic and construction as relevant to the implementation of pavement treatments, and life cycle cost analysis.

MRR Selection Process Development

After developing the preliminary process, an effort was made to confirm that the primary steps of this process were consistent with and would fit into actual SHA practice. Five SHAs were identified and asked to participate in the first phase of data collection. A limited number of SHAs were selected with the intent on focusing data collection on depth rather than breadth. Depth of data collection was essential to better understand how individual SHAs evaluated and selected MRR strategies for high traffic volume projects. Initial contact with the five SHAs involved interviews either conducted on-site or through telephone conference calls. A structured questionnaire guided the interview process. In addition, several SHA personnel were involved in the interviews representing the pavement, traffic, construction, and management areas. The information collected from these interviews was analyzed and then compared to the preliminary selection process. The process steps were modified to reflect comments from these SHAs. The content of each step was elaborated with further detail.

The next phase of developing the selection process required on-site interviews over several hours. This approach was essential to examine specific details of the selection process. Two SHAs participated in this phase of data collection. These interviews followed a structured and detailed presentation of the proposed process and included SHA management, pavement, traffic, and construction personnel. Analysis of the information collected confirmed the steps and sub-steps of the process were suitable for selecting MRR strategies for high traffic volume projects. Some minor modifications were made to the process.

In the final phase of data collection, actual projects were identified to aid in demonstrating the applicability of the process. This was accomplished through direct contact with three SHAs that provided project specific information. A protocol was developed and used for gathering data on-site in a consistent and structured format. The project data was analyzed and then organized to fit within the steps and sub-steps of the proposed process. Four projects were analyzed. Based on this approach, the proposed process was considered consistent with sound SHA practice. The process could be used for different types of projects with different project conditions.

After data collection was completed, the contents of the process were formalized. Some steps of the process reflect standard SHA practice, because their performance is not influenced to a great extent by high traffic volumes. SHAs already have procedures in-place to perform these steps. Description of these steps is generic and reflects standard practice. Other steps in the process focus on non-standard approaches because high traffic volumes have a significant impact on the analysis required for MRR strategy selection. Special emphasis is placed on the description of these steps, especially in the areas of traffic, construction, contracting, and life cycle cost analysis. In these areas, critical issues that a decision-maker must consider when performing a step are identified. Specific resources are also suggested that will help decision-makers perform these steps.

RECOMMENDATIONS

In Chapter 4, conclusions are presented with respect to the assessment and implementation of the proposed MRR selection process. With respect to *high traffic volume projects*, the main conclusions are:

1. Assessing pavement condition and causes of pavement distresses remains critical to selecting the most appropriate strategy, even for pavements subjected to high traffic volumes;

2. For any particular distress problem, a number of effective pavement treatments may exist. However, these treatments must be evaluated in the context of *non-pavement related* aspects, such as traffic management, construction, and life cycle cost, to provide for selection of the most appropriate strategy;

3. No one MRR strategy is best for every project situation and many possible combinations of pavement treatments, traffic management approaches, construction approaches, and life cycle cost impacts exist. The key is to determine the most appropriate combination or strategy for a given project situation and SHA policy constraints;

4. The selection process should involve a multidisciplinary team, including traffic and construction engineering expertise, beginning from the early stages of project development;

5. When possible, project funding should be based on the MRR strategy, that is, the design should determine the funding rather than the funding determining the design for this type of project.

IMPLEMENTATION

The approach that many SHAs currently follow to select an MRR strategy is often divided into independent processes carried out by different functional groups within the agency. As a result, traffic and construction issues are often assessed late in the design phase, making it difficult to modify designs without substantial cost and time implications. This approach can obligate the SHA into following a strategy that may not, in fact, be the most appropriate MRR strategy. The lack of sufficient traffic and construction analysis is especially problematic with projects where high traffic volumes are a major concern. Further, current SHA processes do not always differentiate between high traffic volume projects and other projects. These issues can be addressed through the process described in this report. This process can aid state highway agencies select the most appropriate strategies for MRR of rigid pavements *subjected to high traffic volumes*.

The process was developed to support MRR strategy selection decisions in the programming phase and/or the early design phase of projects. It could supplement existing SHA selection processes. SHA senior management is encouraged to integrate information described in this report into their MRR strategy selection process for high traffic volume projects.

CHAPTER 2
DEVELOPMENT OF SELECTION PROCESS

EXISTING SELECTION PROCESSES FOR MRR SELECTION

The following sections summarize the most relevant MRR strategy selection processes found in the literature. The processes follow different approaches to select a preferred strategy for MRR of rigid pavements.

ACPA Selection Process

The ACPA publication "Pavement Rehabilitation Strategy Selection" provides guidance for selecting cost-effective rehabilitation strategies and contains a systematic process based on cost for decision-making. This process has been reproduced in Figure 2.

In the first step, detailed project information is collected, including information on design, construction, traffic, environmental, and distress condition. Then, the information is evaluated to determine the cause of the pavement distress. An engineering evaluation is made to determine the functional and structural condition of the pavement, the materials condition, the existing drainage, and the difference in pavement condition between lanes.

After the distress mechanisms have been identified, an adequate treatment solution is found. Treatments are described under three categories: 1) restoration, which restores the structural condition and rideability to an acceptable level; 2) resurfacing, which provides a new wearing course; and 3) reconstruction, which includes inlays and recycling. Once the feasible treatment(s) is selected, some preliminary design is then performed to provide information for the final selection.

The preferred alternative is selected by comparing the life-cycle costs of the possible alternatives. All cost items must be considered, and especially costs not related to pavement treatments such as right-of-way, user delay, traffic control, or utility considerations. These non–pavement-related costs can be substantial. The preferred alternative then undergoes detailed design, estimating, and construction.

AASHTO Guide Selection Process

Part III of the AASHTO pavement design guide (*2*) also provides guidance for major rehabilitation activities. The fundamental aspects of rehabilitation analysis are described using a three-phase approach shown in Figure 3.

The first phase of the process consists of establishing the actual condition of the pavement. Substantial data collection is necessary to determine pavement, traffic, and environmental characteristics. This can be accomplished through field surveys and office data collection. The information obtained is then evaluated and additional data needs identified (feedback loop). The constraints placed on the project are also identified at this stage as they frequently affect the choice of the rehabilitation alternative.

In the second phase, the feasible rehabilitation solutions are identified. Based on the problem evaluation made in Phase 1, the treatments that are effective in addressing the existing distress(es) are selected. They are then weighted against project constraints to determine which of them are really feasible. Preliminary designs are then developed for the remaining solutions.

The last phase of the process deals with the selection of the preferred strategy. A life cycle cost analysis is usually the most important criteria used when choosing the preferred solution. User costs must be included to achieve a consistent result. Nonmonetary factors, such as service life, constructibility, or traffic control are also considered. The preferred solution is then determined using primarily a cost evaluation. Weighted nonmonetary factors can differentiate solutions when the cost analysis does not indicate a clear winner. This is the key difference between the cost-based ACPA process discussed in the previous section.

Wisconsin DOT Selection Process

In some cases, network and project level selection processes have been integrated into one unified system. For example, the Wisconsin DOT (WisDOT) (4) has developed an expert system, the Pavement Management Decision Support System (PMDSS), which is linked to their Pavement Management System and Geographic Information System. The PMDSS was designed to provide reasonable and reliable solutions to pavement condition problems regardless of the background or experience of the end user (see Figure 4).

The first step of the process involves updating the decision support database. The pavement's main characteristics are stored in Pavement Information Files, wherein each file represents a 1-mile stretch of pavement. The Pavement Serviceability Index (PSI) and Pavement Distress Index (PDI) values are developed based on field measurements while the pavement age and type is obtained from the file. The emphasis level is a subjective rating that characterizes the level of importance of traffic volume. It is usually assigned by the local district. Based on the emphasis level, the program then assigns to the PSI and PDI values a level of performance (satisfactory, questionable or unsatisfactory).

After updating the PMDSS database, the distress(es) for each pavement section is assessed. Based on the extent and severity values obtained, the expert system will determine the level of the distress (minor, moderate or severe). Then, by considering the different types of distresses and their respective levels, the PMDSS will identify the type of problem and its severity.

In the next step, a range of treatments for addressing all of the problems in the pavement section is proposed. This range of treatments is then extended to the project level. Three strategies are selected based on their level of treatment (a high level would mean that only 15% of the total pavement length of the project is under-treated). The determination of the final treatment and project priority depends on the relative importance given to such factors as PSI/PDI improvement, user inconvenience, or life-cycle cost. The project is then placed in either a 3-year maintenance program or 6-year improvement program depending on the type of treatment and budgetary constraints.

Alternate Selection Process

Earlier NCHRP research contained a text description of a MRR strategy selection process entitled, "High Volume Rigid Pavement Strategy Selection (HVRPSS)." However, this tool was not completely formalized. This decision process, as shown in Figure 5, proposes an MRR strategy selection based on either traffic conditions or pavement strategy.

According to the process, traffic conditions are said to dominate when potential user delays costs overwhelm all other factors. In this case, the selection of pavement treatment is focused on reducing traffic delays. The first step is to determine and optimize the temporal and spatial work window available based on traffic demands (e.g. time of day, number of lanes, etc). Then, pavement design and proposed materials are evaluated with the goal of reducing total construction time and maximizing pavement life. Alternate contracting techniques are adapted to expedite construction and minimize traffic lane closure. Finally, a life cycle cost analysis (LCCA) is used to compare alternative strategies and recommend the most appropriate MRR strategy.

When traffic conditions do not pose a serious problem, the treatment selection is based on the pavement condition and type. Long term and short term pavement performance strategies are identified. For each of these, a constructibility and traffic management review is conducted. The objective is to address such issues as lane closure, traffic impact, and work zone size and safety. The final evaluation is again based on a LCCA to select the most appropriate MRR strategy.

Review of Existing MRR Selection Processes

The four selection processes described different approaches to MRR strategy selection. The ACPA and AASHTO processes are similar. Each process focuses on identifying pavement condition and then identifying pavement treatments that remedy poor pavement conditions. Each process recognizes the importance of traffic and construction issues but provides minimal information on how to assess these issues in detail. The ACPA has identified traffic management approaches considered suitable for rigid pavement treatments (*5*). This traffic management handbook focuses on many different types of traffic situations and provides some insights into related issues such as constructibility and contracting. Other publications related to traffic management exist that could supplement the AASHTO process (*6*,*7*). These publications include high traffic volume scenarios but unfortunately do not necessarily focus directly on them and their impact in MRR strategy selection.

The Wisconsin PMDSS also focuses on pavement condition and pavement treatment. However, similar to the ACPA and AASHTO processes, traffic conditions are only assessed qualitatively in terms of high, regular, and low emphasis pavements. High-emphasis pavements are those that have a high level of traffic volumes and, therefore, warrant high pavement quality and particular attention to minimizing user inconvenience. Nevertheless, the impact of very high traffic volumes for a specific project may not be accurately assessed in the PMDSS analysis (e.g., construction cost may be understated).

The earlier NCHRP process takes a different approach. Here, the fundamental question that drives the selection process is the extent to which pavement strategy or traffic conditions (high user delays) drive the MRR selection decision. If pavement strategy is the key factor, possible treatments are identified and then traffic and construction issues are reviewed to determine a suitable approach to implementing each treatment. Conversely, when traffic conditions are key, treatment design features are selected to fit an available work window. This appears to be how many agencies have approached MRR activities on high-volume roadways in recent years. Unfortunately, such an approach can lead to a pavement treatment design and implementation strategy that only addresses the symptoms of the distress, rather than the actual underlying causes. Ultimately, the distress can soon reemerge, leading to increased public dissatisfaction because the roadway must undergo repair again.

The processes reviewed from the literature have common features such as they rely on LCCA to assist the decision maker in selecting the final MRR strategy. These processes also tend to be driven by pavement condition assessment and treatment selection. Traffic and construction issues are considered but the level of analysis is not extensive in selecting a comprehensive MRR strategy.

SHA Practice

Five interviews were conducted with SHAs with the objective of documenting and assessing current practice for selecting MRR strategies. The SHAs interviewed were:

- Pennsylvania Department of Transportation
- New York Department of Transportation
- Texas Department of Transportation
- Minnesota Department of Transportation
- Georgia Department of Transportation

Most of these agencies had formal and documented processes for MRR strategy selection. The extent to which these formal processes were followed varied by SHA. Their processes were similar to ACPA and AASHTO in terms of primarily focusing on pavement condition assessment and pavement treatment selection. All five agencies stated that their agency's selection process did not differentiate high traffic volumes from other traffic situations. However, the Houston District of TxDOT emphasized that all their projects are considered high traffic volume projects. Further, MRR strategy selection is often driven by funds available, that is, the MRR strategy selected must fit within available funds. This approach may sub-optimize the treatment solution especially for those projects in high traffic volume environments.

DESIGN OF AN INTEGRATED SELECTION PROCESS

An integrated process was developed in this research project for selecting MRR strategies for rigid pavements subjected to high traffic volumes. This process identifies pavement treatment type(s) based on current pavement condition and then considers critical factors that influence how the treatment(s) is accomplished. The matrix shown in Figure 6 schematically illustrates this framework of elements used to create the selection process.

The horizontal axis of the matrix in Figure 6 represents a range of pavement treatments covering maintenance through reconstruction. Individual MRR treatments range from resealing joints to full depth repair to an unbonded overlay to complete removal and replacement of the pavement structure (see Table 2). The vertical axis of the matrix represents critical factors that should be evaluated in conjunction with pavement treatment types. These critical factors address (see Table 3):

- Current pavement performance {structural and functional condition};
- Traffic management needs {traffic control costs, road user costs, traffic congestion mitigation strategies, and public perceptions};
- Construction needs {constructibility, contracting, environmental impact, technology, and schedule}; and
- Life cycle costs {construction costs, user costs, future MRR costs, and salvage value}.

A MRR strategy is then composed of one or a combination of individual treatments (relevant to a given pavement type, distress pattern, and behavior characteristic) and those critical factors that affect implementation of each treatment(s). For example, in Figure 7 a MRR strategy identified for a project with two sections might include two pavement treatment types such as diamond grinding on one section and an unbonded overlay on the other section.

Each of these MRR treatments have different limitations and applicability characteristics that encompass different factors and trigger the use of different approaches relevant to pavement performance, traffic management, construction, and life cycle cost. Figure 7 illustrates only some of these factors and approaches associated with MRR strategy selection.

The process was developed guided by the framework in Figure 6 and based on an assessment of literature and current practice in this area. A process modeling technique was used to formalize and structure MRR strategy selection. This modeling technique helped to identify the main steps and sub-steps. The modeling technique was also used to capture the required information needed to perform each step. Figure 8 shows the four main steps of the process and the sub-steps for each of the main steps.

The process shown in Figure 8 was validated in two steps. In the first step, the proposed process was presented to two SHAs:

- Pennsylvania Department of Transportation
- New York Department of Transportation

The objective of this effort was to evaluate the proposed process and confirm that it was comprehensive, logical, and practical. Both SHAs concurred that the process was comprehensive and practical. It would support decision-making for MRR strategy selection of rigid pavements subjected to high traffic volumes. Minor changes were recommended.

In the second step, on-site interviews with SHAs were conducted to obtain information on on-going MRR projects considered by the SHA to be high volume roadways. These projects were developed as case studies that could demonstrate the applicability of the steps and sub-steps and information that described the proposed process to select MRR strategies.

The following SHAs provided information concerning on-going MRR projects:

- Georgia Department of Transportation (I-475 project)
- Michigan Department of Transportation (US 23 and I-496 projects)
- California Department of Transportation (I-710 project)

A pre-interview package was developed and sent to each SHA. The package contained the process (Figure 8) and questions to help guide the interview. Project documents were provided by each SHA and site visits were conducted. A thorough review of all documents and interview notes was performed to identify data that would be used for the case studies. Follow-up interviews were conducted as necessary to clarify information about the projects and the data used to develop the case studies. Finally, each SHA reviewed their respective case study. Final corrections were made.

A second Caltrans project was studied. This project was a Caltrans long life pavement project on the San Bernardino Freeway (I-10) in the city of Pamona, California. A report on this project was published by the Innovative Pavement Research Foundation (*8*). Information was also gathered during an on-site visit while construction was performed. The project focused on completing approximately three miles of pavement replacement over a 55-hour weekend window. Construction and traffic management techniques used to successfully complete this project were analyzed and documented. Many of these techniques could be considered when evaluating MRR strategies for high traffic volume projects.

The case studies demonstrated the applicability of the selection process and its contents. Each case study describes the expected outcomes from performing key activities while considering key factors (traffic and construction). Moreover, the case studies also illustrate the methodology and the main factors SHAs emphasize to select an MRR strategy for each project. Each case study illustrates a slightly different approach. However, the basic steps of the proposed process were followed. Finally, the case studies demonstrated that the proposed process represents a generic approach to selecting strategies for MRR of rigid pavements with an emphasis on high traffic volume situations.

In summary, the process is based on the following fundamentals:

- A probable MRR strategy should be identified early in project development, and preferably prior to the establishment of project funding. The strategy ideally will dictate funding, rather than the funding dictating strategy.
- The early and continuing involvement of many agency professionals in the selection process is desirable. Materials, design, traffic, construction, maintenance, and contract organizations should have input to support the pavement design effort.
- The probable cause of pavement distress should be determined and the MRR strategy selected should correct the cause, not just treat the symptoms.
- After selecting potential MRR strategies for further study, it is desirable to screen the strategies to eliminate those that are not practical or economically feasible. The remaining strategies would then be studied in greater detail.
- In high volume traffic conditions, the disruption of traffic, even for short time periods, can result in extensive road user costs. Hence, selecting pavement treatments, materials, traffic management approaches, and contracting methods that will accelerate the work and minimize traffic disruption becomes a critical consideration. Nonetheless, the process emphasizes that these considerations should not, where possible, be allowed to dictate strategy selections that do not correctly address the actual causes of the pavement distress.
- In high volume traffic conditions, selecting MRR strategies requires construction knowledge and experience to insure that each strategy is constructible, cost effective, minimizes traffic delays, and provides a safe environment for workers and the traveling public.

Although constructibility concerns are present in almost all-major roadway construction projects, the importance of conducting constructibility analyses becomes critical when work is performed on high-volume roadways. Several reasons exist for this:

1. High-volume roadways typically make access to and from the work site more problematic. The construction area typically needs to be designed to allow work vehicles to enter and exit the work area at higher speeds so as to minimize disruptions to moving traffic. In addition, traffic demands may be so high during certain periods of the day that traffic queues are created within and upstream of the work zone, which will delay the speed at which work vehicles and materials can reach the work area.

2. High-volume roadways are often located in areas of significant urban development. Consequently, noise concerns are often a major concern with nearby residents. For

businesses in the area, the maintenance of access points to and from the roadway becomes a key issue. At the same time, the higher degree of development typically implies that the roadway right-of-way will be narrower, and that locations for storing materials and equipment or even a portable batch plant will be more difficult to find.

3. Projects on high-volume roadways are typically more scrutinized by the media, local politicians, and citizen groups. Delays in construction activities are much more likely to be noticed by these constituents, and lead to increased complaints and negative publicity. Consequently, efforts to ensure that work progresses as quickly and on time as possible are of paramount importance.

PROCESS DESCRIPTION

As illustrated in Figure 8, there are four main process steps. Step 1 *identifies candidate sections* for a project. This step determines the project scope. Then, in Step 2, *pavement condition* is assessed for the project through surveys and field-laboratory tests on the pavement section(s) that comprise the project. The objective of this step is to determine current distress characteristics and condition so that the cause of pavement deterioration can be established.

In Step 3, as shown in Figure 8, *potential strategies are screened.* Based on the results of surveys and tests, the cause(s) of pavement distresses is determined and potential treatments are identified. Next, for each treatment(s), general traffic and construction issues are assessed based on project characteristics. This sub-step is a key enhancement to previous selection processes, and introduces the concerns for traffic and construction impacts early enough in the process to allow a wide range of options to be reasonably considered. Preliminary cost estimates are developed to reflect treatments, materials, traffic, and construction approaches. The combination of the treatment type(s) and their associated traffic and construction approaches and costs form the feasible strategies. At this stage, the evaluation of alternative feasible MRR strategies is based on whether the project is worthy of further consideration (or a more detailed analysis). The objective of this last part of Step 3 is to eliminate strategies that are considered inappropriate for the project. The process may lead to feasible strategies where preliminary cost estimates are greater than the allocated funds for the project, but are considered appropriate solutions. If this is the case, one or more of the following actions could be considered:

- request additional funds;
- modify the project scope so that these strategies may be included in the selected feasible strategies (i.e. reduce the length of the project); or
- defer the project to next funding cycle.

In Step 4, *evaluation of feasible strategies,* as shown in Figure 8, key *nonpavement-related* issues are analyzed in greater detail (i.e., how a treatment is to be accomplished). A detailed analysis of traffic and construction issues and a life cycle cost analysis (if the complexity of the project dictates) are performed for each MRR strategy. Based on this analysis, the most appropriate strategy is recommended for detailed design and construction. The most appropriate strategy for a specific project is one that optimizes the relationship between life cycle costs (including user delay costs, community impacts, worker and motorist safety, constructibility, and traffic management capabilities) for a given pavement treatment that solves the distress problems.

In summary, this process includes the following elements of MRR strategy selection for rigid pavements subjected to high traffic volumes:

- Project boundaries
- Pavement distress and causes
- Suitable pavement treatments to correct the cause of distress
- Traffic conditions
- Strategies to effectively address traffic impacts (traffic management and construction options)
- Construction impacts
- Life cycle cost
- Recommendation of most appropriate strategy

IMPLEMENTATION ISSUES

Project Programming versus Project Design

The proposed selection process is a tool that can aid state highway agencies select the most appropriate MRR strategies for rigid pavements *subjected to high traffic volumes*. The process was designed to support the programming phase and/or design phase of projects. By executing Step 1 through Step 3, the process can be used in the programming phase to help identify projects for multiple-year programming, determine funding allocations, and to establish possible project limits. As a design-focused tool Step's 1 through Step 4, should be performed during the early stages of design, after a project has been programmed. Complete development and evaluation of each feasible strategy and the selection of the most appropriate strategy is confirmed. This would occur during the first 10 to 20 percent of the design process. Key design criteria for a project would be established for the preferred MRR strategy as a basis for Plans, Specification, and Estimate (PS&E) development.

MRR strategy solutions are determined based on treatments that properly address the problems being experienced. Traffic and construction issues are investigated, and preliminary costs are estimated. At this point, the cost of each feasible solution is compared with budgeted funds for the project. If sufficient funds are available then the solutions are further evaluated. If not, a decision has to be made to either seek more funds or reduce the scope of the project.

In practice, identification of MRR strategies is often driven by the amount of funds available. In this case, funds available become an input to the process and not a constraint. However, this approach may produce a less than optimal solution to addressing the causes of pavement distress.

Flexibility of the Process

The strategies that are developed through the process cover a continuum of treatments from maintenance to rehabilitation to reconstruction, including the impact of traffic, construction, and cost. The process is comprised of a *pavement-related* component and a *nonpavement-related* component. Figure 9 illustrates schematically the typical level of strategy analysis and development during the four main steps, as outlined in Figure 8.

Step 1, *Identify Candidate Sections*; Step 2, *Identify Pavement Condition*; and the first part of Step 3, *Selection of Possible Treatments*, follow methodical steps with defined objectives and form the p*avement-related* component of the process. These steps focus on project scope and pavement condition assessment and development of appropriate treatment combinations. The remaining part of Step 3 and Step 4 (*Screen Potential Strategies* and *Evaluate Feasible Strategies*, respectively) follow steps focused on the *nonpavement-related* component. These steps primarily assess traffic and construction issues, life cycle cost analysis, and evaluation of strategies including crash risk and public perception.

Development and selection of MRR strategies occurs mainly during Step 3 and Step 4. The extent to which these steps are performed is based on the complexity of the project and the level of analysis the SHA considers necessary. As illustrated in Figure 9, the transition from Step 1 to Step 2 and Step 2 to Step 3 are generally well defined. The transition between Step 3 and Step 4, shaded section of Figure 9, depends more on the level of detail deemed necessary by the SHA to adequately screen potential MRR strategies to determine the feasibility of each strategy. The shaded area suggests that the threshold between when Step 3 is completed, and when Step 4 begins, is not clearly a definite point in time. For example, lightly shaded areas could indicate that the screening of feasible strategies in Step 3 is accomplished without a substantial level of detail required to assess traffic and construction issues and estimate preliminary costs. For example preliminary cost estimates could be based on total construction cost per mile of roadway rehabilitation. When these preliminary cost estimates are compared to available funds, several MRR strategies may be deleted if they are substantially higher than available funds. Detailed analysis of each feasible MRR strategy is than developed in Step 4. Thus, the shaded area in Figure 9 becomes darker to illustrate this point. Alternatively, much more effort may be required to adequately screen feasible strategies in Step 3. In this case, the darker shaded area would indicate increased level of level analysis and development in Step 3. A corresponding decrease in the level of analysis and development would then occur in Step 4, when the focus is only on, perhaps, two feasible strategies. This transition for Step 3 to Step 4 of the process is likely influenced by project complexity and SHA policy for MRR strategy selection.

The approach that many SHAs currently follow to select an MRR strategy is often divided into independent processes carried out by different functional groups within an agency. As a result, traffic and construction issues are often assessed later in the design phase. By assessing traffic and construction issues late in the design phase, many factors and constraints that impact design are difficult to modify without substantial cost and schedule implications. This latter approach may obligate the state highway agency into following one solution or strategy that may not be the most appropriate strategy. Thus, the approach proposed includes an integrated analysis by a multi-disciplinary group participating early in the MRR selection process for high-traffic volume projects.

Process Constraints

The following factors and constraints play a major role in the decision-making process for selecting MRR strategies. A key attraction of the proposed process is that most of the time these factors can be modified to fit the project objectives, if addressed in the early stages of design.

- Availability of Funds - increments on allocated funds for the project may be required to select appropriate and cost-effective strategies.
- Safety (motorist and workers) - development of traffic and construction management approaches that maximize a safe environment during MRR activities.
- Traffic congestion - development of traffic and construction management approaches that minimize the amount of congestion created, the duration of the congestion, and the degree of driver dissatisfaction with the SHA about how traffic is accommodated.
- Public opinion - information campaigns to obtain public involvement in the early stages of the project. This may help avoid conflicts and delays due to public opposition. This may also create public acceptance for delays if the project is completed in a timely way.
- SHA policies - assessment of policies and formal procedures. Possible modifications to written and unwritten policies may have to be submitted for approval.

CHAPTER 3
MRR STRATEGY SELECTION FOR HIGH TRAFFIC VOLUME CONDITIONS

INTRODUCTION

In this chapter, the application of the proposed selection process is presented. The process content describes the steps or sub-steps shown in Figure 8 and follows the hierarchical format in Figure 10. Special emphasis is placed on those steps or sub-steps of the process where high traffic volumes require an increased level of analysis concerning traffic and construction issues. This occurs mainly in Step 3, *Screening Potential Strategies,* and Step 4, *Evaluate Feasible Strategies*. Common areas are used to discuss the application of these two steps and include:

- Objective;
- Key activities;
- Issues to consider;
- Resources; and
- Illustrations.

The key activities that are identified may be performed in any MRR strategy selection process. These activities are emphasized because of their importance when selecting a MRR strategy for rigid pavements subjected to high traffic volumes.

In the process, Step 1, *Identify Candidate Sections*, Step 2, *Identify Pavement Condition*, and Step 3, sub-step *Select Possible Treatments* are described as standard SHA practice. The performance of these steps is not substantially influenced by a project that is considered a high traffic volume roadway. They are included in the description to provide a complete presentation of the proposed process.

Resources are identified that would aid the user in performing the key activities and addressing issues to consider for sub-steps under Step 3 and Step 4. Only those resources that are deemed most useful are identified. A brief description of the resource is provided. Information concerning how to obtain more information about the resource is given in the reference section of the report.

Excerpts from the case studies and the Caltrans I-10 project are used to illustrate how different issues are considered with respect to both traffic and construction approaches when performing Step 3 and Step 4. A brief description of each project is provided in Appendix A. These descriptions present basic information concerning the project location, pavement treatment(s), typical pavement sections, traffic data and project scope and other characteristics.

IDENTIFY CANDIDATE SECTIONS

The main objective of this step is to define in general terms the potential limits of the project under consideration. This step is performed to determine the project scope and boundaries as shown in Figure 11.

This step is initiated using the following input:

- Pavement Management System and/or Maintenance Management System data
- Field observations
- Crash history
- Network programming considerations (to determine if additional capacity work or other work is planned or programmed)
- Approximate level of funding allocated to the project

Candidate pavement sections are identified through recommendations by local or central SHA offices, field observations, and/or a review of crash history of the road. The identification of sections needing MRR may also be an output of the SHA's pavement management system. The main objective of this step is to produce such items as:

- Pavement sections that are candidates for MRR
- Length of candidate pavement section(s)
- Number of lanes requiring MRR treatments
- Bridges or other structures within the boundaries of the project

Some SHAs are adopting a corridor approach to MRR strategy development and implementation on critical high traffic volume roadways in urban areas. With the corridor approach, the scope of work may incorporate several types of needed improvements, including pavements and bridges, along the extended length of the highway. Traditionally, these different needs have been addressed through individual road work contracts in a non-coordinated fashion. With a corridor approach, the impact of such multiple smaller projects constructed over longer periods of time is reduced. The corridor project is often designed and constructed using techniques that accelerate construction, and reflects the "Get In, Get Out, Stay Out" philosophy some SHAs are implementing (*9*).

IDENTIFY PAVEMENT CONDITION

The main objective of this step is to determine distress characteristics and drainage conditions with the ultimate goal of determining causes of pavement distress. As in Step 1, most SHAs have formal procedures to accomplish this step. The following discussion represents a generic approach to these procedures.

As shown in Figure 12, this step is comprised of the following sub-steps:

1. *Conduct Survey*

   This sub-step consists of performing pavement distress surveys and collecting drainage condition data from representative locations of the pavement sections within the defined scope of the project. Pavement geometry that may affect construction or treatment selection is also assessed along with current traffic levels.

2. *Conduct Field & Laboratory Tests*

   Collection of pavement structure data is undertaken in this step to identify the pavement condition associated with each noted distress and any areas of non-uniform support. Any areas of subbase erosion should also be noted. Both the structural and functional condition of the pavement should be determined. Non-destructive tests (NDT) and destructive tests (DT) may be required to adequately characterized pavement condition.

3. *Identify Distress Mechanisms*

   The next sub-step is analyzing the survey and test information, including NDT and/or DT results, and identifying the mechanisms of distress and factors affecting the pavement condition.

It is worth noting that the objective of this function is to conduct adequate testing to insure that the causes, not just the symptoms of the distress can be determined. Although important for any pavement MRR project, it is especially important for high traffic volume conditions.

SCREEN POTENTIAL STRATEGIES

The main objective of Step 3 is to determine feasible strategies and determine what additional design information, if any, is required to select the preferred strategy for MRR. Each of the sub-steps is discussed in the following sections. This is the point in the proposed process that deviates from existing selection processes. This step is performed based on output data from the previous two steps. Additional information is also required concerning traffic and other project specific location characteristics. Figure 13 illustrates the sub-steps and outputs of Step 3.

Select Possible Treatments

Under this step, the SHA determines potential pavement treatments or combinations of treatments for the project (i.e. the treatment strategies). Treatments are determined based on an assessment of pavement condition. Causes of pavement distress(es) are determined based on the pavement structural and functional condition and other performance information gathered during the previous step (*Identify Pavement Condition*). Climatic and drainage conditions may also be considered when determining the causes of distress. The SHA may also estimate the remaining life of the existing pavement given climate, traffic, and pavement condition. Factors such as traffic volumes, axle loads, type of construction, potential cost, and the desired performance life may be considered. A final set of alternative pavement treatments and material combinations that address the causes of distress is then determined. This set of alternatives would likely include two or more specific treatment types. These treatments could have similar performance periods. They could be classified under the same general category such as rehabilitation. However, it is possible that treatment alternatives could reflect different performance periods and be classified differently. For example, one treatment could be a rehabilitation of the pavement (unbonded overlay) while the other treatment could be total reconstruction.

Most SHAs have standard procedures to select pavement treatments. These procedures typically consider traffic and construction issues at a very summarized level. Two illustrations of these types of procedures are: New York DOT Pavement Rehabilitation Manual (10), and Pennsylvania DOT Treatment Programming Tool (11).

New York DOT Pavement Rehabilitation Manual is comprised of two volumes: The Pavement Evaluation Manual and the Treatment Selection Manual. The Pavement Evaluation manual contains information about the existing procedures and the standard forms used to evaluate distresses for rigid, flexible and flexible/rigid pavements as well as the shoulders. The manual also provides information such as descriptions of various distresses, their causes, and severity levels and how to measure the degree of these distresses. The Treatment Selection manual consists of three main sections: Treatment Guidelines and Typical Sections, Life Cycle Cost Analysis (LCCA), and Model Pavement Evaluation Report.

The treatment matrix is a tool used by Pennsylvania DOT to determine pavement repair costs or to ascertain MRR strategies for their concrete pavements at the programming level. Treatment matrices guide the selection of treatments taking into account distress information, roadway type, and average daily traffic (ADT) ranges.

Published information on pavement treatment selection, such as Concrete Pavement Restoration, Resurfacing and Reconstruction (CPR^3) (*12*) may also be helpful. This document is comprised of technical bulletins published by the American Concrete Pavement Association (ACPA). The compiled technical bulletins contain information about CPR^3 strategy selection, restoration, resurfacing, and reconstruction strategies, and new techniques in CPR^3.

When selecting the pavement treatment(s) for high traffic volume projects, the impact of future traffic volumes on the design performance life must be considered. This information would be essential in estimating remaining life, especially when maintenance and rehabilitation techniques are potential treatment alternatives as this information significantly affects the estimates of when additional MRR work will likely be needed again. Further, the degree of traffic interruption (i.e. added road user costs during MRR) versus the benefit to be gained from the selected treatment(s) should be evaluated when selecting treatments. The public may be more tolerant of major disruptions for treatments that offer a longer service life.

As stated previously, it is desirable that available funds should not influence the determination of MRR treatments, especially those involving pavement rehabilitation and reconstruction. The determination of appropriate treatments should, ideally, be based on the causes of distress of the pavement under consideration.

Identify Traffic and Construction Issues

Objective

This sub-step assesses potential traffic and construction issues for each MRR treatment or combination of treatments. It represents a significant departure from previous MRR selection processes, and emphasizes the importance of considering these issues early in the process. Feasible options for handling traffic and construction are confirmed while those options that are not feasible, based on project specific conditions, are eliminated. The primary objective of this sub-step is to identify traffic and construction limitations that impact the accomplishment of each MRR treatment or combination of treatments.

Key Activities

The objective is achieved through performing the following activities:

- Traffic
  - Assess current traffic characteristics
  - Identify possible options to handle traffic within the work zone
  - Identify access requirements to adjacent properties
  - Identify possible alternate routes for traffic and assess available traffic capacity
  - Explore possibility for diversion to other routes, traffic modes, and times

The primary traffic-related activities that need to be accomplished at this step in the process are to identify those features or characteristics of the site that either:

- constrain if and how a particular MRR treatment can be accomplished; or
- provide an incentive to accomplishing the work in a particular manner with respect to how traffic is handled through and around the project.

In high-volume conditions, these features or characteristics often have the most impact on how a particular pavement treatment can be implemented. For example, a project located near a major shopping mall may have a constraint that requires all lanes and ramps to be open during the Christmas holiday season. Conversely, a roadway with a significant peak-period imbalance in traffic flows offers an opportunity to utilize temporary reversible lane operations or other dynamic lane assignment approaches on part of the roadway within the project limits while work is completed on the other lane.

These primary activities require an accurate assessment of traffic characteristics within the project boundaries (volume patterns over the day, types of vehicles, drivers, typical trip lengths, major nearby traffic generators that rely on the roadway for access, etc.). The availability of, and traffic characteristics along, alternate routes and travel modes in the corridor may be assessed as well if more extensive rehabilitation and reconstruction treatments are being considered. The implications of SHA policies that limit the expected maximum user delay or the closure of travel lanes during peak periods are also assessed here.

- Construction Limitations
  - Identify areas where the work zone area will be highly constrained
  - Identify general site logistic problem areas
  - Identify sensitive areas along roadway due to adjacent properties (e.g., hospitals, schools, etc.)
- Construction Analysis
  - Assess possible work zone area
    - Spatial - width and length
    - Temporal - peak, off-peak, weekend, and seasonal
  - Assess bridge and traffic sign vertical clearances
  - Assess constructibility of general staging approaches including construction methods, techniques, and materials
  - Assess construction time limitations including general staging approaches

The primary construction-related activities for this step have a two-fold focus. The first three activities identify limitations that may have a substantial impact on construction relative to how a treatment is accomplished under traffic. For example, in highly congested traffic areas within the proposed work zone, the logistics of how materials are moved in and out of and around the work zone are identified as an important construction issue to assess. The second set of activities assess how the limitations influence space available, methods used, and sequencing of work to achieve a feasible approach to construction given pavement and traffic approaches and the time available to complete construction.

Traffic Issues to Consider

Several SHAs nationally have policies that restrict maximum user delays during a project or restrict maximum expected traffic volumes per open lane past the work area. Historical traffic volumes at the site are typically used to estimate these delays. However, past experiences from many major projects in large metropolitan areas, suggest that the propensity for traveler diversion away from a project location to other routes, departure times, and so on, can be significant. Such diversion reduces the actual traffic volumes approaching a site, and implies that some strategies often deemed unfeasible due to such policies may in fact be possible.

The key to achieving high levels of diversion is the development and implementation of a high-quality public information campaign or program. The program must adequately keep the public abreast of upcoming events and changes that will impact their travel on that roadway (major phase changes that will alter the travel path through the work zone). Intelligent transportation systems (ITS) might offer opportunities to facilitate this activity.

Construction Issues to Consider

At this point in the analysis, general approaches to construction staging should be identified. This is most important when traffic volumes are extremely high. When identifying staging sequences, attention should be given to the impact on traffic, how materials and equipment are moved into and out the work zone(s) with respect to traffic flow, and then the interface between construction operations and traffic movements through the work zone. The staging approach should be constructible in an efficient manner given the type of treatment and materials required.

If existing materials must be replaced, transportation of these materials from the work zone must be analyzed early on to determine the best available routes to disposal areas and the impact this might have on traffic. Other alternative approaches are to recycle existing materials in place, crack and seat, or rubblization.

When the project includes structures, the interface between structures and pavement construction should be assessed. Vertical clearances may require total reconstruction of the pavement under the structure or jacking of existing structures. Bridge rehabilitation may require careful analysis of bridge versus pavement construction in terms of time and sequencing of pavement construction.

Developing a risk mitigation plan for situations that are particularly time sensitive is advisable. The cost impact associated with risk strategies should be included in preliminary cost estimates. For example, having redundant construction equipment available may be necessary to insure that production is maintained if equipment breaks down.

A construction issue is to determine the major types of construction equipment needed to perform the required pavement treatments. The ability to achieve suitable production rates will depend on the size of the work zone and the type and characteristics of the construction equipment. Paving operations can be enhanced, for example, if larger sections can be paved through work zones. This can improve production and, thereby, reduce paving time. Access into and out of the work zone for construction equipment can influence the staging strategies. Larger size work zones may improve access for construction equipment and better support construction operations, such as supplying concrete to paving machines.

The time allowed for construction is another major issue to consider. Overall project time constraints may require work during the day as well as at night and on weekends. If construction time is critical, then the type of work schedule anticipated must be evaluated. Traffic handling requirements may also dictate the work schedule. Construction operations may be constrained to off-peak hours at night and/or on weekends. This work schedule would likely require multiple crews and equipment to insure adequate production rates can be achieved for main construction operations. Construction time may be further constrained by seasonal windows for construction or critical events that may influence when construction activity must be minimized in work zones.

Material availability may be critical for certain construction operations. If a project is time sensitive, controlling concrete production may necessitate a portable batch plant be located within the work zone or very near the work zone. Space must be available for the batch plant equipment and associated materials required to produce the concrete mix as designed. If a portable batch plant is needed, it should be as centrally located as possible to support paving operations throughout work zone. In extremely large projects, multiple batch plants may be required. The source of materials and the adequacy of supply, such as aggregates or borrowed fill, may require long transportation distances.

If early opening to traffic is a requirement, then the use of materials and techniques that accelerate concrete curing would be appropriate. This requirement would impact the mix design for concrete. Early opening may also apply to general construction staging strategies wherein construction operations may require that new pavement sections be available for use by construction equipment to facilitate timely completion of other pavement sections under construction.

Resources

Estimation of user delays and additional road user costs can be facilitated through the use of work zone analysis tools. Such tools compare traffic demands to available traffic-carrying capacity through the work zone to estimate changes in speeds, anticipated traffic queues, and resulting delays and road user costs. Some tools have the ability to assess the implication of traffic diversion (as discussed previously, such assessments of diversion can have significant implications upon MRR strategy selection). Even so, it is generally the responsibility of the analyst to determine the reasonableness of the diversion estimates and adjust these estimates to reflect local conditions. An example of this type of analysis tool is described in Figure 14.

One tool that can be used to aid in providing construction knowledge and experience in identifying key issues for high-volume traffic conditions is a formal constructibility review process (CPR). Applying such a process will insure that the proper resources are brought to bear on the evaluation of construction issues at this point in MRR strategy selection. Involving professionals with significant construction experience is critical. Figure 15 provides a tool for implementing a constructibility review process. The planning section of the CRP workbook may be most applicable to the level of analysis of construction issues applied during this step. This process can be tailored to fit the requirements of the specific project and culture of the SHA.

Another useful tool is a workshop approach as described in Figure 16. This type of approach requires interaction between a number of disciplines involved in evaluating

MRR strategies and can provide a forum for many innovative ideas related to the construction and traffic interface

Illustration

A Caltrans project I-710, provides an illustration of different applications of the traffic and construction issues in terms of alternate approaches to reconstruction of 15 miles of the I-710 corridor (see Appendix A for a brief description of the project). Traffic volumes range from ADTs of 130,000 to 218,000 with a significant level of truck travel. The main objectives behind the project included minimizing disruption of traffic, minimizing the impact of construction on adjacent communities, accelerating construction in a manner that would reduce lane occupancy during construction, providing a long life pavement (40 years), and striving for a cost effective project. Based on these objectives and the project scope, some of the main traffic and construction issues that were considered include:

- Alternate routes for traffic diversion away from work zones;
- Concerns over traffic demands during construction;
- Public awareness of construction progress;
- Construction operations that reduce project time; and
- Movement of existing and new materials into and out of the work zone.

Figure 17 depicts two alternative approaches that address the project objectives and these issues (A total of four alternatives were studied). Alternative 1, in Figure 17(a), is based on segmental full closures in one direction over weekends. Three construction stages are identified. Recycling in place is used to reduce material transportation time. Alternate 2, in Figure 17(b) is based on reconstructing all 32 bridges on the I-710 project route. The new bridges would provide a clear span across I-710. Under this alternative, bridge rehabilitation would be completed prior to pavement reconstruction. Such an approach would allow all four lanes in each direction to remain open during the reconstruction of the pavement. Recycling existing material is proposed.

The two different alternatives shown in Figure 17 are based on the same set of project objectives and critical traffic and construction issues. The manner in which these issues are assessed and applied to the specific project conditions varied. This simply points out that there could be several potential feasible solutions that are identified during the screening step.

Estimate Preliminary Cost

Objective

Based on the pavement treatment alternatives as well as the proposed traffic handling and construction approaches for each alternative, a preliminary cost estimate is developed for each alternative MRR strategy in this sub-step of the process. Proposed traffic management and construction approaches are based on the analysis of project specific traffic and construction issues. The objective is to determine a realistic preliminary cost estimate for construction for each feasible MRR alternate strategy.

Key Activities

The objective is accomplished by focusing on the following key activities for each alternative:

- Develop approximate quantities for major categories of work
- Determine unit costs (e.g., dollars per square yard) for major categories of work including labor, materials, equipment, overheads
- Estimate total cost of alternative MRR approaches including traffic management, construction engineering and management, right-of-way.
- Estimate possible time duration for construction

Issues to Consider

Most state agencies have estimating systems that support the application of these activities. However, a critical issue when developing preliminary estimates is that project costs accurately reflect the impact of non-standard traffic management and control practices as well as any increased costs due to non-standard construction activities. This is particularly important in high traffic volume scenarios where public awareness plans or information campaigns are often recommended to inform drivers of real-time traffic conditions or to help divert them from the work zone. Cost information regarding specific traffic management actions to be taken is not usually fully determined at this step in the process. Even so, analysts can make a reasonable assessment as to whether traffic management costs will be higher than normal for this situation, and incorporate a larger traffic management cost estimate into the evaluation. Diverting traffic may require improvements to alternate routes and/or other modes of travel. If traffic control requires a number of work zones over different periods of construction, the impact of moving work zones should be reflected in construction costs.

Additional costs may be incurred if right-of-way is impacted both to support the design of the roadway and during construction if construction easements are necessary to support equipment access and construction methods. Timely construction may be influenced by utility relocation and drainage modifications. The extent to which these modifications could influence construction costs depends on the pavement treatment selected and the general sequence of construction within the work zone.

Depending on the traffic management and control approach, construction at night and/or weekends will increase labor costs and other support costs (lighting, noise control, etc.). Availability and source of materials may be a critical issue. Source of aggregates, transportation to the site, and their location on the site, for example, could substantially increase cost. Both cost and time are influenced by where batch plants are located, especially if portable batch plants are required and located near or within work zones.

Construction start dates, seasonal considerations, and overall construction durations will influence costs. If construction is accelerated to complete in one construction season, the contractor will often utilize extended work schedules. These types of approaches will increase the cost of labor while reducing, perhaps, reducing staff and other overhead costs. Accelerating construction might necessitate the use of rapid setting concrete. This requirement can increase the cost of materials substantially and influence the cost related to construction methods for placement and curing.

The cost estimates for each MRR strategy used should include documentation of key assumptions that explain how the high traffic volume condition affects the construction costs estimate. Also, estimate exclusions need to be clearly identified. Finally, the basis for cost estimates for each alternative should be consistently applied so that differentials in costs between alternatives reflect true differences due to project scope, materials, construction methods, time durations and major sequencing of construction operations, and traffic handling approaches for each MRR alternative.

Resources

Most state agencies have processes and programs to aid in developing preliminary cost estimates.

Illustration

An example of how Caltrans estimated the preliminary cost of two MRR strategies for the I-710 project is illustrated in Figures 18. Notice that Section 5, Traffic Items, in the Alternate 1 estimate accounts for approximately 15 percent of Total Roadway Items less contingencies. This cost can be much higher for traffic management and control in extremely high volume situations. In Alternate 1, a large portion of Section 5, Traffic Items, is required for street improvements and media notification (approximately 55 percent of the Section 5 cost). These efforts are required to support the segmental full closure of one direction of the I-710 on weekends when traffic would be diverted to local surface streets. In addition, the estimated cost of the Structural Section (Section 2) reflects recycled pavement and the impact of weekend work on labor and material costs. In Alternate 2, Section 5, Traffic Items, accounts for about 10.5 percent of the roadway costs less contingencies. However, substantial costs ($65.2 million) are required for structure items, that is, reconstruction of all the bridges. A trade off for this approach is that traffic disruption is minimized during pavement construction, as all four lanes are always open to traffic in each direction.

Identify Feasible Strategies

Objective

The main objective of this step is to screen all strategies and eliminate those that are not reasonable for further analysis. This step is accomplished by compiling information developed for the possible strategies and then prioritizing them based on pre-determined evaluation criteria and project objectives. A risk assessment is performed for each possible strategy. The output could be one or more strategies.

Key Activities

The objective is achieved through performing the following activities:

- Compile information collected for each MRR strategy
- Determine if strategies comply with SHA policies
- Assess areas of risk for each strategy
    - Identify location risks
    - Identify critical construction activities that may impact the project schedule
    - Review window of opportunity versus construction work time frame
    - Review possible level of impact to adjacent property access routes
    - Identify level of safety for workers and drivers of each strategy
    - Review assumptions regarding likely impacts with alternate strategies on user delays and mitigation strategies that may be required to minimize those delays
- Reject non-feasible strategies based on traffic, construction and first cost estimate considerations
- Assess first cost estimates
- Consider impact of public perception
- Evaluate remaining strategies to determine best fit with project objectives
- Prioritize remaining feasible strategies
- Select feasible strategies for final evaluation
- Identify additional design information needed for final evaluation and selection of preferred or most appropriate strategy

Issues to Consider

An important issue in this step is to determine the decision criteria that will be used to differentiate between feasible strategies. This criterion will be the basis for identifying the feasible strategies and, therefore, eliminating those that will not be considered for further evaluation. SHAs should clearly identify and prioritize the project objectives and other critical success factors. Based on these objectives and factors, decision criterion can be defined and a weighting system can be developed for purposes of comparing MRR strategies in order to distinguish between feasible alternatives. Typical decision criteria would include project cost, expected life of the MRR treatment, user delay impact, impact to adjacent landowners and local businesses, public perceptions, and time of construction.

At this stage in MRR strategy selection, the expected life of the pavement after the MRR strategy is completed may be considered when comparing feasible MRR strategies. Another important issue to consider during this step is the availability of funds. Obviously, if the estimated preliminary cost of a strategy exceeds the funds available, then that alternative based on its current scope may not be feasible. If this is the case, then one or more of the following options can be considered in the final decision:

- request additional funds;
- modify the project scope so that the strategy may be included with the selected feasible strategies (i.e. reduce the length of the project); or
- defer the project to next funding cycle.

Flexibility of MRR strategies in terms of cost, time, work area required, and traffic may be a critical factor during this step. Flexibility in this context is a relative measure between strategies, identifying to what extent each strategy can be altered without affecting the success of the project. For example, a strategy having a lesser work area requirement would have higher flexibility compared to an alternative that necessitates the utilization of the whole work area allocated for the project.

Under high traffic volume conditions, potential public perceptions about how a particular MRR strategy will impact traffic and the quality of life in the vicinity of the project will be a major consideration in assessing that strategy's feasibility. On the one hand, the public will expect a transportation agency to implement strategies in a manner that indicates that due consideration has been given to minimizing the impact of roadway work upon travelers and nearby residences and businesses. On the other hand, the public expects that once roadway work is completed, additional work will not be required again at some point in the near future (i.e., a "get in, get out, stay out" mentality). Agencies should strive to include both perspectives when selecting feasible strategies that are carried forward for more detailed analyses (Step 4, Evaluate Feasible Strategies).

Resources

The Construction Industry Institute (CII) has developed a tool that can be used as a decision support tool. Figure 19 provides more information about this tool with an example of how it might be used. Although qualitative in nature, the decision matrix shown in Figure 19 can provide a mechanism for screening alternative strategies to identify the more feasible strategies. For example, using the technique illustrated in Figure 19 a total of 500 points is possible for each alternative (100 times a score of 5). In this illustration, Alternates 1 and 3 have scored 370 and 410 points, respectively, based on the category factors, their weights, and the evaluation score. Alternate 2 scored only 295 points. This would indicate that Alternate 1 and 3 are more favorable MRR strategies for achieving the project objectives. Thus, in this case, Alternate 2 might be eliminated.

When using the decision matrix approach, results could indicate that one alternative is clearly superior to the others. Thus, only one alternative would be carried forward into design. Conversely, the scores could be so close that all the alternatives are considered feasible MRR strategies. Other factors may influence the final decision, such as the preliminary estimated cost versus the available funds for the project. If all alternatives cost more than the available funds other actions might be necessary before proceeding to the next step.

Illustration

A Georgia DOT project, I-475, consists of widening and rehabilitation or reconstruction of the existing concrete pavement (see Appendix A for more information about the project). After analyzing the pavement condition survey information and mechanisms causing the distresses, six different pavement treatment combinations were proposed as follows:

1. Six inch asphaltic concrete overlay
2. Ten inch jointed concrete overlay with a one inch AC separation layer
3. Nine inch continuous reinforced concrete overlay
4. Rubblizing existing PCC and then placing a ten inch AC overlay
5. Crack and seat existing PCC and then placing a eight inch AC overlay
6. Removal of existing PCC and base and reconstruct pavement with ten to twelve inches GAB (recycled concrete), five inch lean concrete and ten to twelve inches of jointed PCC

After analyzing traffic and construction issues, developing preliminary cost estimates, reviewing existing pavement conditions, those strategies that were not considered feasible were deleted as shown in Figure 20. Two feasible strategies remained. These two strategies also met the project objectives (see Appendix A).

In the Caltrans I-710 project, four feasible strategies were compared. However, each one surpassed the allocated budget for the project. Some discussion of subsequent actions taken on MRR strategy analysis for the I-710 project is summarized in Appendix B.

EVALUATE FEASIBLE STRATEGIES

The objective of Step 4 is to recommend the preferred strategy for the project. The main focus of this step is integrating the appropriate level of traffic and construction planning into the preferred strategy. This is accomplished by first determining the level of detail required for developing a project specific traffic management approach and construction management approach for each feasible strategy. Based on this information and the treatment approach, a life cycle cost analysis may be appropriate to help assess the most cost effective MRR strategy. Figure 21 shows Step 4 of the process and its six sub-steps.

Determine Level of Traffic and Construction Analysis

Objective

The objective of this sub-step is to determine the level of effort required to analyze traffic and construction issues in combination with the proposed feasible treatments and project conditions.

Key Activities

The objective is accomplished by focusing on the following key activities:

- Determine if a strategy can be undertaken by utilizing:
  - SHA standard traffic and construction approaches; or
  - SHA standard traffic and construction approaches but with some enhanced techniques to address special traffic and construction needs; or
  - A corridor wide project-oriented traffic and construction approach.

Issues to Consider

When deciding on the appropriate level of analysis the following questions should be asked:

- Does the feasible strategy necessitate only the use of SHA standards: traffic manuals, traffic control plan sheets, construction staging, and so on? If so, follow standard SHA practices.
- Does the feasible strategy require the use of additional traffic control and construction approaches upstream and within the work zone not normally included in SHA standard practice (i.e., law enforcement personnel, supplemental advance signing, innovative construction methods, materials, and staging approaches)? If so, enhancing standard practice may be necessary to achieve the project objectives.
- Does the feasible strategy require significant diversion of traffic to other routes, departure times, or travel modes in the corridor and require a substantial level of construction analysis to assess innovative construction methods, materials, phasing/staging, and contract time? If so, developing a corridor plan will require much greater planning and different approaches to achieve the project objectives.

SHA policy would significantly influence the level of analysis of each feasible strategy. Further, the level of analysis may not necessarily be the same for each feasible strategy. One strategy may require only standard practice (maintenance strategy such as a thin asphalt overlay) while another strategy may require that standard practice be enhanced to successfully implement the strategy (rehabilitation strategy such as an unbonded concrete overlay).

The level of analysis is influenced by project complexity, size, and traffic volumes carried by the roadway. For example, moderate traffic volumes will likely require less effort and less depth of analysis concerning traffic and construction issues, while large volume roadways may require more effort and greater depth in the analysis. The level of analysis and number of issues would likely increase for a 15 mile project with a reconstructed pavement and many structures requiring rehabilitation as compared to a five mile unbonded overlay with one or two structures involved. However, if the unbonded overlay project involves very high traffic volumes the level of analysis may be similar, at least to some extent. Thus, the impact of project complexity, size, and traffic volumes is interrelated and must be considered in an integrated manner when determining the level of analysis.

Analyzing traffic and performing constructibility reviews should be an iterative process and should include a collaborative effort between disciplines. The disciplines involved should include traffic engineers, construction engineers, constructibility experts, project engineers, pavement engineers and, as necessary, public information staff.

Analyze Traffic Alternatives

Objective

High-volume traffic conditions will commonly require work zone traffic control and management approaches that go above and beyond the minimum standards required by federal and state regulations and the normal practices of a SHA. In this step, the objective is to identify in greater detail those traffic management and control enhancements that will be employed for a MRR project, how they will be implemented (where, when, how long, etc.), and the costs and impacts (operational, environmental, and road user costs) of these enhancements.

For MRR treatment options that involve significant disruptions to traffic for a significant period of time (such as for reconstruction work on very high-volume urban roadways), it may be necessary to extend the area of consideration beyond the physical limits of the project to other roadways and travel options within the travel corridor. In some cases, the SHA may work with other agencies and even private-sector parties to develop an overall corridor approach to accommodate traffic demand

Key Activities

The objective is achieved through performing the following activities:

- Specify traffic management and control enhancements that can be implemented to reduce traffic impacts of the project or to maintain safety (i.e., those needed for night work, those required for long-term traffic-splitting approaches, etc.)
- Conduct analysis of possible travel pattern changes, delays, road user costs, fuel consumption, and vehicle emissions expected under each enhancement or combination of enhancements
- Compute costs for the enhancements, including set-up and removal

The identification of appropriate enhancements to standard traffic control practices for a given MRR treatment implementation depends heavily on the characteristics of the site itself and often of the other enhancements being considered for application as well. For example, the choice to limit work activities to nighttime hours may lead to a decision to employ off-duty police officers upstream of the work zone to attract additional attention to the work zone and to decrease approaching travel speeds. Similarly, innovative traffic management approaches, such as splitting traffic around work in the middle lanes of a high-volume urban freeway, generally requires significant supplemental advance signing and delineation deployed upstream of the work area (see Figure 22).

MRR treatments that require long-term capacity reductions on a high-volume roadway mean that significant changes in travel patterns will likely occur in the corridor. Although SHAs usually strive to avoid roadway capacity reductions (especially during peak periods) during MRR work, there are times when reductions must be endured. When this happens, improvements to alternative routes (new traffic signal timings, lighting and signing improvements, improved channelization at intersections) and improvements to modes (new park-and-ride lots, more transit vehicles operating in the corridor) can help accommodate any traffic that diverts to these other routes and modes.

In recent years, some SHAs have begun to look more closely at the possibility of completely closing a roadway to allow contractors to work on the entire roadway at one time and complete the work must faster than would be required if performed with traffic traveling through the work zone (Interstate 45 – Pierce Elevated Freeway in Houston, Texas and Interstate 496 in Lansing, Michigan are recent examples). The costs of impact mitigation strategies and the resulting impacts of this approach throughout the corridor must be fully and accurately captured in order to accurately compare them to the reduced work time as part of a life cycle cost or similar analysis of the alternative (as discussed later in this step).

Issues To Consider

Work zones on high-volume roadways can become quite complex from a traffic management and control perspective. Extra attention must be given to positive guidance principles when designing and implementing the traffic control plan to avoid the presentation of misleading information to the driver. The full removal of old pavement markings, use of high-visibility channelizing devices, additional signing for any nontypical traffic control or management items in the work zone, and maintaining agreement between the work zone and normal traffic signing information present at the site become essential when working on high-volume roadways.

Prior experiences with enhancements to standard traffic control practice (i.e., how effective was this enhancement last time it was used?) are useful in estimating the possible effects for the project under consideration. Even so, it is important to recognize that estimates of impacts and to some extent costs are highly dependent upon assumptions made in the analysis. Sensitivity analyses of the effect of changes to these assumptions are important to establish a level of confidence with the analysis.

Certain enhancements require significant advance time to implement, and are less flexible to remove or change (changes to overhead guide signing as compared to the deployment of off-duty officers during a nighttime work activity, for example). Other examples include changes in traffic signal timings or restriping of travel lanes versus intersection widening and channelization improvements on the alternative routes. The addition of new transit vehicles and new park-and-ride lots to encourage mode shifts in the corridor are also possible. These are qualitative factors to be considered when assessing the costs and impacts of an enhancement.

In addition, the extra time required to analyze and implement any techniques or strategies on other roadways must also be built into the project planning process. Analysts must also consider whether any of the strategies implemented on other routes and modes will have any salvage value remaining at the end of the project, and how to treat that value in the economic analysis of the alternative.

Resources

A number of resources are available to obtain information on different types of possible enhancements to an SHAs standard traffic control practice. Information contained in the *National Work Zone Safety Information Clearinghouse,* ACPA *Traffic Management Handbook for Concrete Pavement Reconstruction and Rehabilitation, and* FHWA *Work Zone Best Practices Guidebook* are all excellent sources of information when considering an overall corridor plan for implementing a MRR treatment on a high-volume roadway. Descriptions of these resources are presented in Figures 23, 24, and 25.

Major shifts in traffic patterns within the corridor that can occur because of significant rehabilitation or reconstruction activities are fairly difficult to predict and analyze. SHAs who have these types of projects in the past have often relied on network or regional transportation planning models to help determine how traffic patterns may change during roadwork. The results of these models help to guide the SHA and other agencies in identifying where improvements within the corridor will be needed, and the types of improvements that will be required. One recently-developed planning model is briefly described in Figure 26.

Illustration

The Michigan I-496 project through downtown Lansing consists of three phases (see Appendix A for a description of this project). One phase is reconstruction of the existing concrete pavement and reconstruction and rehabilitation of four bridges. Another phase focuses on replacement/improvement of structures at the interchange between I-496 and US 127. The final phase includes rehabilitation, using concrete pavement restoration techniques, of I-496 west of Phase I.

The primary focus of this illustration is the reconstruction effort of I-496 between Cedar Street and US 127. When Screening Potential Strategies, Step 3, MDOT determined that a full closure of this phase of the project was necessary to complete the project in one construction season. Two pavement treatments were proposed and found feasible for reconstruction. They were a flexible bituminous pavement and a jointed reinforced concrete pavement. In Step 4, Evaluate Feasible Strategies a detailed analysis of the traffic issues was performed to determine how traffic would be handled during the full closure of I-496. Figure 27 provides the results from assessing the issues previously discussed. Figure 28 shows the results of this assessment in graphical form.

Two additional illustrations are provided in Appendix B. One illustration provides an overview of the traffic management issues considered and the traffic approaches proposed for the Georgia I-475 project. In this project, two construction staging options were proposed for the concrete unbonded overlay while only one construction staging option was proposed for the asphalt overlay. The second illustration shows a methodology for documenting a comprehensive traffic management plan for an extremely high volume project, the Caltrans I-10 55-hour weekend project (*19*). The contents of this plan are summarized.

Perform Constructibility Analysis

Objective

The objective of this step is to insure that cost effective and efficient construction sequences, methods and techniques, materials handling, and construction durations are congruent with traffic control approaches for each feasible alternative. The level of constructibility analysis should be consistent with project complexity, size, and traffic conditions.

Key Activities

The objective is achieved through performing the following activities:

Site Limitations

- Identify utility and drainage maintenance points
- Identify right of way restrictions (e.g. private property)
- Identify potential points of access into and out of proposed work zones

Construction Analysis

- Determine construction work scope and identify critical construction tasks for each feasible MRR treatment
- Determine innovative construction methods that may improve efficiency, quality, and safety
- Determine possible production rates for major activities based on materials required and work schedule (weekday, nights and/or weekends)
- Determine the possibility of needing special construction equipment on site
- Determine possible routes to transport material
- Determine if hauling is compatible with existing traffic patterns
- Determine possible construction site logistics based on traffic control approach and location characteristics (storage of materials, haul requirements for disposable materials, access for construction equipment)
- Identify project schedule milestones and determine if project should be constructed in phases

- Determine possible construction schedule based on traffic control analysis and construction methods including use of night and/or weekend work
- Develop basis for a construction staging plan for each feasible strategy

Revision and Modification of Input Data

- Revise proposed preliminary design and traffic control approach for each feasible strategy
- Determine if design elements can be standardized to ease construction
- Determine if design modifications are necessary to improve ease of construction
- Determine if proposed work zone areas are sufficient in size to perform construction operations (e.g., insure worker safety)
- Determine if modifications to traffic control approach are necessary to insure consistency with construction staging

Impacts

- Determine environmental impacts (e.g. noise, dust, night light, etc.)
- Determine possible modifications or removal of landscaping elements, structures, etc.
- Determine input required for public information plan due to construction activities

Site limitations, the first set of activities, identify potential constraints that would influence construction operations. For example, right-of-way may impact access for construction equipment and require construction easements. Utility work may influence where construction staging begins within the work zone. These limitations should be understood prior to performing the construction analysis. The activities under construction analysis are performed to insure that each feasible MRR strategy can be constructed efficiently, cost effectively, and in a timely manner. Project complexity and the level of traffic disruption anticipated during construction would dictate the extent to which each activity is performed. Based on the construction analysis, revisions or modifications to designs and traffic control approaches may be necessary. Finally, the impact of construction approaches on structures, the environment (e.g., noise, dust, night lighting, etc.), and the public must be assessed. Plans may be required to mitigate adverse affects that result from these impacts.

Issues To Consider

The scope and general details of each feasible MRR strategy are developed when screening all potential MRR strategies (Step 3). The scope for each feasible MRR strategy is further developed so that the most appropriate MRR strategy can be selected. The issues to consider would be evaluated in more detail under the *Perform Constructibility Analysis* substep. These issues are similar to those previously discussed under Step 3, *Identify Traffic and Construction Issues*. They are summarized below:

- Alternate construction staging plan(s) that support proposed traffic handling approaches
- Relationship between work space, construction equipment and production

- Haul routes for both incoming materials and removal of existing materials
- Disposal site(s) for existing materials
- Use and location of portable batch plant on-site or near the site, as required
- Availability of materials and their location with respect to the site
- Recycling of existing materials in-place
- Time constraints for completing construction – seasonal, major events, key milestones
- Construction schedule including night work and weekend work
- Need for temporary construction – temporary lanes and/or shoulder widening
- Impact of construction at entrance and exit ramps
- Interface between bridge construction and pavement construction
- Impact of materials to accelerate construction
- Risks involved with traffic and construction approach

In extremely high volume roadways where project complexity is significant, the right expertise on the constructibility team is extremely important. Personnel are needed that can assess construction methods, estimate production rates, assess material and equipment logistics, develop general staging plans consistent with traffic management and control approaches. The team should include a number of disciplines so that the impact of construction approaches on traffic plans can be readily evaluated. Alternatively, changes in traffic management approaches can also be accessed from a construction perspective.

Resources

A number of tools that may be used during the constructibility analysis are presented in the following figures. A *Constructibility Review Process* (NCHRP 391) as previously illustrated in Figure 15 and *Reducing and Mitigating Impacts of Lane Occupancy During Construction and Maintenance* as illustrated in Figure 29 can be useful for SHA personnel while performing constructibility analysis.

Further, the Kentucky DOT and the New Mexico DOT have both developed a contract time determination method that aids their agency in developing conceptual time estimates for projects. These types of tools may be useful in confirming differences in construction durations for different MRR strategies. Brief discussions of the KDOT program and the NM DOT method are provided in Figure 30 and Figure 31, respectively.

Illustration

The Michigan US 23 project consists of major rehabilitation work on a 8.37 km pavement section between M-59 to Faussett Road (see Appendix A for brief description of this project). This four lane interstate will have other improvements including restoration of guardrails, reconstruction of pavement sections under bridges to meet vertical clearance requirements, complete replacement of one bridge, and rehabilitation of ramps (see Figure 32 for the Construction Staging Plan for US 23 project).

When Screening Potential Strategies, Step 3, MDOT determined that total reconstruction was not feasible in the time period required to complete this project (approximately 45 calendar days). As a result, rehabilitation of the pavement sections was considered the best treatment approach. Two treatments were considered feasible: rubblize and bituminous overlay; and unbonded concrete overlay. Both treatments met the estimated time for construction, minimized traffic impacts, and costs were within available funds.

One issue that was important for this project to achieve a 45-calendar day construction schedule was the timely supply of concrete to support paving operations. Based on the location of existing batch plants and a tight schedule, a portable batch plant could be located on or near the project. By analyzing the space available within the limits of the project, a potential location for the batch plant was determined within the right-of-way at Clyde Road as shown in Figure 33. This location, within the project limits, was ideal because concrete production and supply could easily reach any point within the work zone in time to support paving operations.

Several time-related issues were considered in the constructibility analysis. The 45-day schedule was necessary, because this would insure construction was completed prior to Memorial Day. US 23 is a major north/south highway for Michigan residents who vacation in the north so traffic can not be disrupted between Memorial Day and Labor Day. Further, because of the short time requirement it was likely that weekends and night work would be required to achieve acceptable production rates.

One approach considered important on US 23 was to develop a safer work zone for both construction personnel and motor vehicles. Part-width construction staging was proposed. Based on previous experience with this type of construction, a design change was proposed to extend the inside shoulder width. This would help alleviate traffic interference with construction and minimize the probabilities of incidents. In addition, it would allow the contractor to use a larger paver for the outside lane and shoulder (12-foot lane and 10 foot shoulder). Production would likely be enhanced. This approach addressed the issue of the relationship between workspace, construction equipment, and production.

In the case of concrete paving, the construction sequencing started with paving the outside lanes first. One possible point of beginning (POB), as shown on Figure 33, was identified as just south of Clyde Bridge. Under this scenario, paving operations would proceed toward M-59 (south). The next segment of paving would be from M-59 to Faussett Road (north). The last segment would be from Faussett Road to the POB (south). This same sequence would be repeated for the inside lane.

Two additional illustrations are provided in Appendix B. One illustration shows the details of the three construction staging options for the Georgia DOT I-475 project. The second illustration identifies how a mobile movable barrier can be used to quickly establish a work zone or change the limits of an existing work zone. This type of barrier also provides a safe working environment for construction personnel and promotes traveler safety.

Determine Contract Approach

Objective

The objective of this step is to select the most appropriate contracting method that is congruent with the traffic and construction approach required for implementing each feasible MRR treatment. SHAs should choose a contracting method that encourages quality, safety, and timeliness and minimizes impact on road users. The contracting method may be selected from a number of contracting techniques such as traditional bidding practices, incentives and disincentives, cost-plus-time bidding, and lane rental.

Key Activities

The objective is achieved through performing the following activities:

- Review primary focus of project (objectives)
  - Time
  - Cost
  - Quality and facility performance
  - Minimize road user impact
  - Or any combination of the four
- Identify specific schedule constraints that need to be considered in evaluating contracting approach
- Assess impact of unique project characteristics and type of construction work
- Consider desired risk allocation
  - Evaluate available alternative contracting methods
- Traditional contracting approach
- Job ordering contract (JOC) approach
- Night and/or weekend work
- Incentives / Disincentives
- Cost-plus-time (A + B)
- Lane Rental
- Best Value
- Warranties
- Determine cost and time impact of potential contracting methods for each feasible strategy

Issues to Consider

A basic risk management principle is to assign risk to the party in the best position to manage and control the risk. SHAs are confronted with two primary risks in the

construction of projects: 1) selection of the appropriate delivery method; and 2) award of the contract to a contracting party. It is incumbent upon the SHA to match desirable project attributes and features with the delivery and contract method. Shifting risks to contractors has the potential to increase project cost.
Many projects with high traffic volumes are considered time sensitive. Using alternate contracting methods that focus primarily on accelerating time, such as A+B and lane rental, may be required. Incentives and disincentives are also used to encourage a contractor to complete on time or early. Research has demonstrated that clearing utilities and ROW, prior to construction, is often necessary to insure successful use of contract methods that accelerate construction time. The extent to which clearing ROW and utilities can be accomplished before construction for each feasible strategy should be considered. This issue may have cost impacts and other implications on design features.

Key dates, events, and seasonal issues have to be identified at this stage to ensure that the impact on the construction schedule and traveling public, due to these issues, remains minimal. Some examples for occurrences that may have an impact on the construction schedule and/or public are holidays, home sporting events, and weather.

Resources

Most SHAs have used one or more of the methods described. Prior experience may help determine which potential contract methods are best suited for the project. Guidebooks for highway contracting are available to assist SHA personnel, such as those described in Figures 34 and 35.

Illustration

On the Michigan DOT US 23 project, the contract method selected was critical to insure that the 45-calendar day time duration was achieved. Figure 36 provides a brief discussion of the proposed contract method and the implications of this method. Additional funds would be required to pay for any incentives the contractor would receive if the contractor finishes early.

Perform Life Cycle Cost Analysis (LCCA)

Objective

This step is performed if life cycle costs will help differentiate between alternative strategies. The objective of this step is to rank feasible alternative MRR strategies based on cost effectiveness, and identify the best value MRR strategy, which will also meet the desired level of service for a specified service life. All or part of the user costs and cost impacts to adjoining property owners and affected communities may be included, depending on the policy of the SHA.

Key Activities

The objective is achieved through performing the following activities:

- Select length of analysis period
- Determine all costs that are anticipated over the life of pavement
  - Construction costs
  - Traffic control costs including public impact mitigation measures costs
  - Road user costs during MRR
  - Future required treatment costs
  - Salvage value
  - Others (e.g. user cost and vehicle operating cost)
- Determine discount and inflation rates
- Determine Net Present Value (NPV) or Equivalent Uniform Annual Cost (EUAC)
- Order list of alternatives
- Perform a risk analysis using a predetermined confidence interval to determine the best/worse case scenario LCCA
- Identify the best value MRR strategy
- Analyze results to identify major cost drivers
- Prioritize strategies based on the LCCA
- Reevaluate design strategies, if necessary, to modify the proposed alternatives to develop more cost effective strategies

Issues to Consider

Estimating project costs for each feasible alternative is critical. The SHA must compare this cost with funds available. If estimated costs are higher than available funds, other actions may be required.

In high traffic volume projects, the impact of road user costs should be accounted for in the evaluation. Efforts should be made to include a realistic estimate of road user costs both during construction and also over the life of the facility as future MRR activities are required. The user must identify SHA policies that govern how this step is performed. For example, how the SHA calculates and includes road user costs (RUCs) may affect the results of LCCA.
Recommendations that should be considered when performing LCCA for comparing alternatives are (*25*):

- Use differential cost incurred between competing alternative MRR strategies
- Assess sensitivity of input data to variations
- Make consensus decisions during the LCCA risk analysis (e.g., include key disciplines in this analysis)
- Employ a discount rate that reflects historical trends over long periods of time (i.e., four percent)

- Ensure the level of detail incorporated in an LCCA is consistent with the level of investment decision under consideration.

Resources

Many SHAs have methodologies to calculate LCCA. Some include RUC while others do not. The FHWA has developed a "Life Cycle Cost Analysis in Pavement Design" program to assist SHAs in conducting a more thorough LCCA, which is illustrated in Figure 37.

Illustration

MDOT performed a LCCA for the US 23 project. This LCCA was performed and reviewed by an internal ad hoc committee. The LCCA was based on a construction cost estimate consistent with the pavement treatment and materials of construction. The present value of each alternative was estimated and included the cost for future maintenance work, based on a preservation strategy, and road user costs for each alternative. The results of the LCCA are shown in Figure 38 for each feasible strategy.

Recommend Most Appropriate MRR Strategy

Objective

The objective of this step is to recommend the preferred MRR strategy from the set of feasible MRR strategies. The selection of the preferred strategy is accomplished by identifying pros and cons of alternatives, considering the funds available, the life cycle cost, and analyzing the risks involved with each feasible strategy.

Key Activities

The objective is achieved through performing the following activities:

- If LCCA is not conducted, update preliminary cost estimate, which should include traffic cost, construction cost, etc.
- Compare key characteristics of each strategy that impact the project objectives, such as:
  - Quality and safety
  - Time
  - LCCA results if conducted; otherwise refine cost estimate
  - Traffic and construction issues
  - Impact on traveling public and businesses
- Evaluate key characteristics of each feasible strategy in terms of advantages and disadvantages
- Make a risk evaluation of each feasible strategy addressing key issues, such as:
  - Cost estimates
  - Time estimates

- Other non-monetary issues (e.g., execution, impact on public if not completed as planned)
- Identify possible alternatives to reduce risk
- Select evaluation criteria (consistent with project objectives)
- Select most appropriate strategy

Issues to Consider

An important issue to consider is the funds authorized for the project, for MRR strategies that cost more than the funds available may be discarded at this stage. On the other hand, the SHA has to take into account that a strategy with a higher initial cost may be far more beneficial in the long run based on the LCCA. For a case like this, the SHA can attempt to increase the funds authorized for a specific project.

Evaluation of risks related to the project and possible approaches to mitigate the impact of risk should be carefully considered as part of recommending the preferred MRR strategy and especially when the project is very complex and extremely high traffic volumes are involved. Risk tolerance for an unsuccessful project is very important. The question, "What is the worst that can happen if the project fails to be successful?" should be answered.

Resources

A decision support tool similar to that shown in Figure 19 can be used to aid the decision-maker in making the final decision. Figure 19 provides more information about this tool with an example of how it might be used. If the LCCA approach is used often the feasible strategy with the lowest life cycle cost can be used if based on a tool such as that shown in Figure 37.

Illustrations

Information from four case studies and the Caltrans I-10 55-hour weekend concrete replacement project was used to illustrate various issues and outcomes that are expected from considering these issues in the selection of the most appropriate MRR strategy for rigid pavements subjected to high traffic volumes. The final substep of the process as presented above is to recommend the most appropriate strategy. The following discussions briefly describe the final decisions made for two of the four case studies:

Georgia DOT I-475 Project

Summary of strategies for the Georgia DOT project are:

Alternative 1

- Widening and overlay existing facility with PCCP
- Modification of 12 bridges which includes jacking of some bridges

- Three lanes of traffic during all phases of construction
- Construction can be expected to last approximate 25 months
- Total project cost estimate: $70,976,000

Alternative 2

- Widening and overlay existing facility with PCCP
- Modification of 12 bridges which includes jacking of some bridges
- Four lanes of traffic during all phases of construction
- Construction can be expected to last approximate 27 months
- Total project cost estimate: $72,153,000

Alternative 3

- Widening and overlay existing facility with asphaltic concrete material
- Modification of 12 bridges which includes jacking of some bridges
- Four lanes of traffic during all phases of construction
- Construction can be expected to last approximate 24 months
- Total project cost estimate: $50,190,000

Based on the MRR strategy summaries, Georgia DOT personnel determined that Alternative 3 (asphalt overlay) is the most appropriate alternate for the I-475 project. The factors considered in the decision-making process included: total cost, traffic impact, time required to construct, and impact on road user cost. The asphalt overlay strategy resulted in a lower cost estimate, can be constructed within a shorter construction duration, and can be applied maintaining four lanes of traffic during all phases of construction.

Michigan DOT US 23 Project

Michigan law requires that a rehabilitation and reconstruction strategy with the lowest EUAC be selected as the recommended strategy. Based on the LCCA as delineated in Figure 38, Alternate 2, Unbonded Concrete Overlay, has the lowest EUAC and is, therefore, the recommended strategy for US 23.

Michigan DOT I-496 Project

Michigan law requires that a rehabilitation and reconstruction strategy with the lowest EUAC be selected as the recommended strategy. A LCCA was performed to compare pavement reconstruction using concrete and asphalt materials. Based on this analysis, concrete reconstruction, has the lowest EUAC and is, therefore, the recommended strategy for I-496.

CHAPTER 4
CONCLUSIONS

The main objective of NCHRP Project 10-50A was to develop information that can be used by state highway agencies to select appropriate strategies for maintenance, rehabilitation, and reconstruction of rigid pavements subjected to high traffic volumes. This information was presented as a process to aid decision-makers in selecting the most appropriate MRR strategy for different project situations. This chapter provides conclusions and recommendations for future research.

The research developed a process for selecting strategies for MRR of rigid pavements subjected to high traffic volumes. This process is based on existing MRR selection models. It captures key functions performed to select a strategy for MRR of rigid pavements subjected to high traffic volumes. The process further identifies the information necessary to make decisions regarding the most appropriate strategy for a given project scenario. The selection process serves as a basis for focusing decision-makers attention on key traffic and construction issues that are critical in high traffic volume projects. Thus, the content of the process was developed to be comprehensive and adaptable to specific project conditions and SHA requirements.

Based on the research results, the following conclusions are offered:

- Assessing pavement condition and causes of pavement distresses remains critical to selecting the most appropriate strategy, even for pavements subjected to high traffic volumes;

- Both *pavement-related* and *nonpavement-related* issues relevant to high-traffic volume MRR projects must be considered in the MRR strategy selection process;

- For any particular distress problem, a number of effective pavement treatments may exist. However, these treatments must be evaluated in the context of non-pavement related aspects, such as traffic management, construction, and life cycle cost, to provide for selection of the most appropriate strategy;

- No one MRR strategy is best for every project situation and many possible combinations of pavement treatments, traffic management approaches, construction approaches, and life cycle cost impacts exist. The key is to determine the most appropriate combination or strategy for a given project situation and SHA policy constraints;

- The selection process should involve a multidisciplinary team, including traffic and construction engineering expertise, beginning from the early stages of project development;

- In the process developed for this research, the focus changes as decisions are made and more information is available. The focus shifts from assessing the types and causes of problems, to screening pavement treatment approaches, and finally to selecting the preferred strategy for MRR based on the impact of traffic, construction, and life cycle costs;

- Many SHA MRR strategy selection processes are driven by funds available, that is, the MRR strategy selected fits within the funds available. This approach may sub-optimize the solution. The proposed process determines a MRR strategy based on pavement condition problem(s) and determines the best approach(es) to solving the problem. Funds should be a constraint rather than an input driving the selection process;

- Many SHAs do not differentiate high traffic volumes from other traffic situations in their MRR strategy selection process. The process in this document attempts to provide a greater emphasis on *nonpavement-related* aspects such as traffic, construction, and life cycle cost to enhance cost effectiveness, safety of workers and the traveling public, and public perceptions. Furthermore, the process emphasizes initiating considerations of these nonpavement-related factors earlier rather than later in overall project development;

- The selection process is not a "black box" where the user provides input and the output is an answer. Rather, the process provides the user with steps and information required to identify key inputs, analyze the input in a systematic manner, and provide a realistic output such as a most appropriate strategy for a given project situation and set of SHA policies;

- The process can be used by SHAs in conjunction with their existing process for MRR strategy selection;

- Although the process was developed for pavements under high traffic volumes, it may also be appropriate for lower traffic volume conditions as well.

The following recommendations are made for future research in this area:

- Work directly with two or more SHAs to implement the process in conjunction with their MRR strategy selection approach. Feedback from this process should be integrated into the proposed process to improve its effectiveness for future use. The improved process may facilitate a smoother transition into practice for SHAs or other users; and
- Develop additional tools to provide improved decision support for steps in the process. Communicate with additional SHAs to determine what tools are desired. Improve upon current tools to optimize their use.

Table 1 Key Definitions

TERM	DEFINITION
Maintenance	Periodic activities whose primary purpose is to preserve the existing pavement so that it may achieve its applied loading and anticipated design life or without significantly increasing life (sometimes called normal, routine, and/or preventative maintenance)
Rehabilitation	Includes activities whose primary purpose is to significantly extend the service life of an existing pavement such as through resurfacing and restoration
Restoration	Refers to several techniques which bring the structural condition and rideability of a pavement to an acceptable level
Resurfacing	Provision for a new wearing course, or overlay, to improve rideability, safety, and/or friction; Can provide for correction of cross-section and surface defects; Can increase structural capacity of pavements
Recycling	Involves using old pavement materials as a source of subbase materials for resurfacing or reconstruction
Reconstruction	Involves complete removal of the pavement structure, typically including base layer(s) and replacement with a new pavement or inlay
Pavement Treatment Type	Refers to a specific method or option to accomplish maintenance, rehabilitation, and/or reconstruction
High Traffic Volumes	Refers to volumes that can cause unacceptable user delays as defined by the highway agency
Project Scope	Includes pavement type, total length, number of sections and their length, number of lanes, geometric configuration of pavement and shoulders, etc. describing a project
Strategy for Maintenance, Rehabilitation, and Reconstruction of Rigid Pavements	Comprehensive plan combining pavement treatment(s) and impact of evaluation considerations related to treatment types based on a specific project scope

Table 2 Typical Pavement Treatment Classification Scheme

<table>
<tr><th colspan="3">Framework of MRR Strategies</th></tr>
<tr><th>Classification</th><th>Function</th><th>Treatment Types</th></tr>
<tr><td>Maintenance</td><td>Preventative, Preservative, or Corrective</td><td>▪ Clean drains
▪ Retrofit edge drains
▪ Reseal joints and cracks
▪ Thin asphalt concrete overlay
▪ Slab undersealing</td></tr>
<tr><td rowspan="3">Rehabilitation</td><td>Restoration (CPR)</td><td>▪ Diamond grind
▪ Restore load transfer
▪ Retrofit edge support
▪ Partial depth repair
▪ Full depth repair
▪ Slab jacking</td></tr>
<tr><td>Resurfacing</td><td>▪ Unbonded concrete overlay
▪ Bonded concrete overlay
▪ Asphalt concrete overlay</td></tr>
<tr><td>Recycle In-place (RIP)</td><td>▪ Crack and seat
▪ Rubblize</td></tr>
<tr><td>Reconstruction</td><td>New Construction</td><td>▪ Remove and replace
▪ Remove and recycle</td></tr>
</table>

Table 3 Key Evaluation Attributes, Criteria, and Factors

Attributes	Criteria	Factors
Pavement condition	Functional	Roughness
		Friction
	Structural	Cracking
		Spalling
		Faulting
		Punchouts
Construction	Constructibility	Work zone safety
		Material storage/logistics
		Site access
		Equipment utilization
	Environmental impact	Noise
		Light
		Dust
	Technology	Transportation method
		Transportation time
		Placement method
		Curing method
	Contracting	Construction time sensitive
		Lane occupancy duration
		Coordination requirements
		Overall project time
	Schedule	Construction phasing
		Project duration
		Workday
Traffic management	Traffic control costs	Dollars/set-up
		Number of set-ups required
		Impact mitigation
	Road user impacts	Temporal requirements
		Spatial Requirements
		Traffic Demands
		User delays
	Public perception	Acceptable delays and inconvenience
		Project duration
		Number of future MRR treatments
Life cycle cost	Construction costs	Materials
		Labor
		Traffic control
		Equipment
		Mobilization
		Overhead and Profit
	Road user costs	Dollar value of road user impacts
	Future MRR costs	Type of treatment
		Performance
	Salvage value	Type of pavement

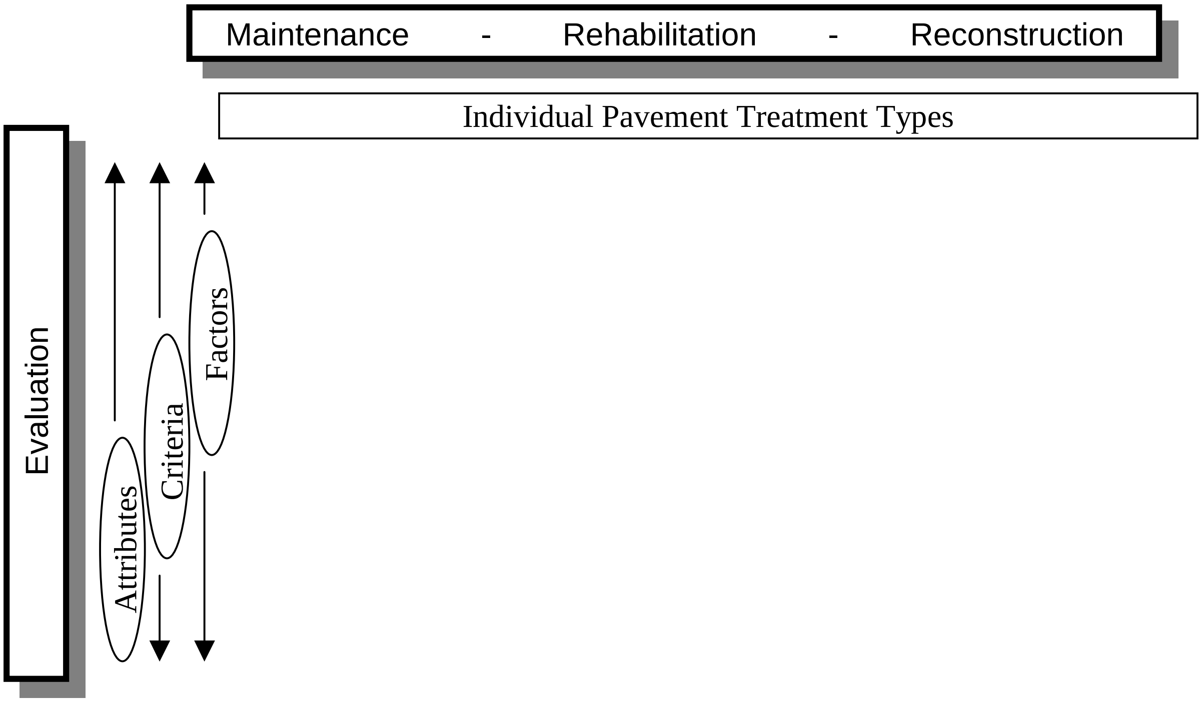

Figure 1 Framework for Selecting Strategies for MRR of Rigid Pavements

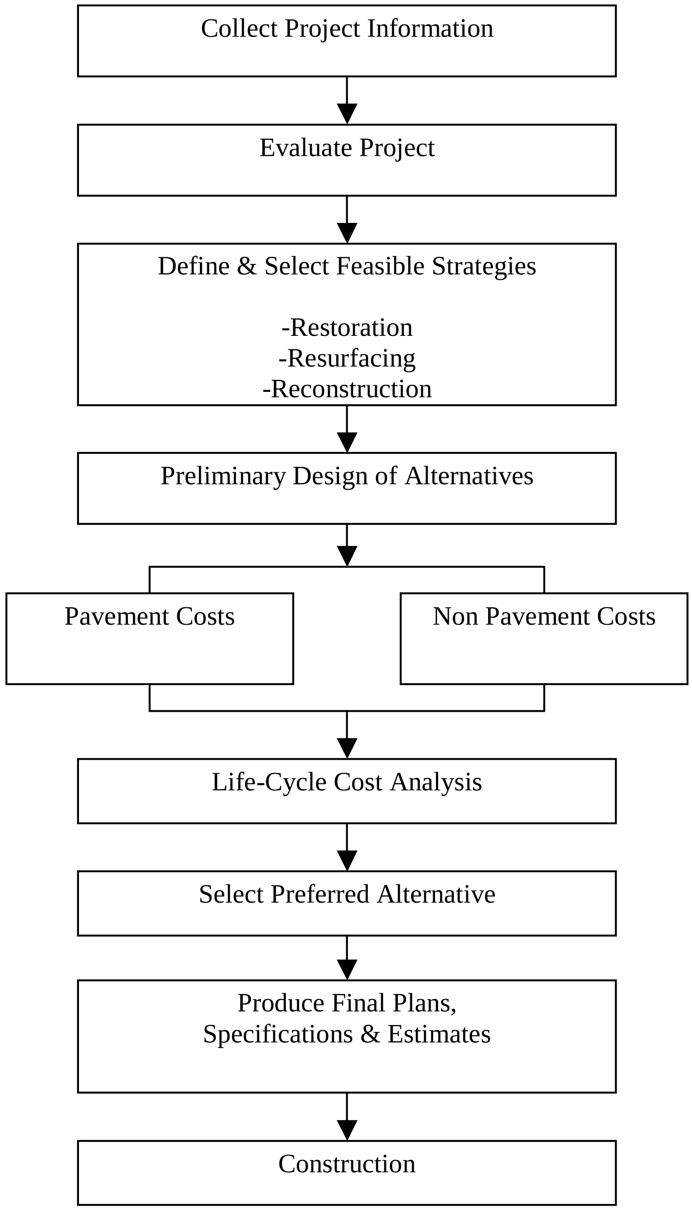

Figure 2 ACPA Selection Process (*3*)

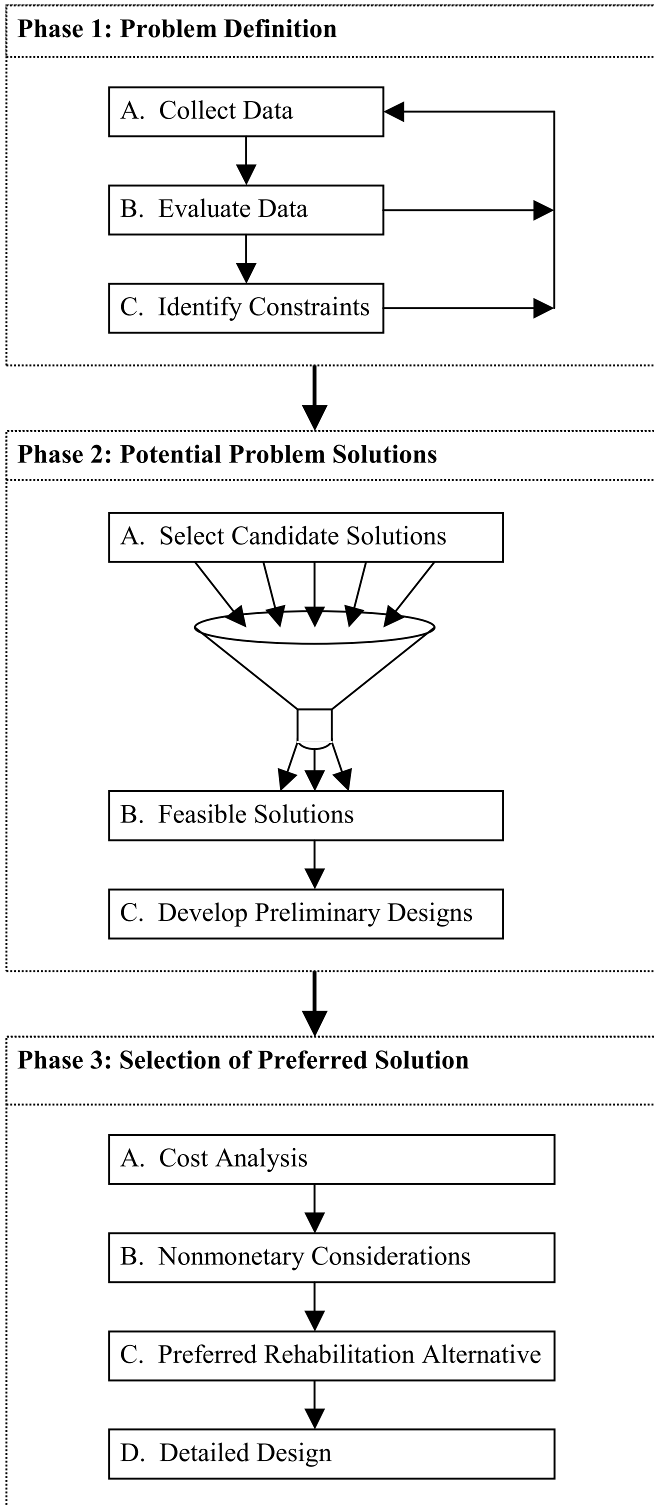

Figure 3 AASHTO Guide Selection Process (*2*)

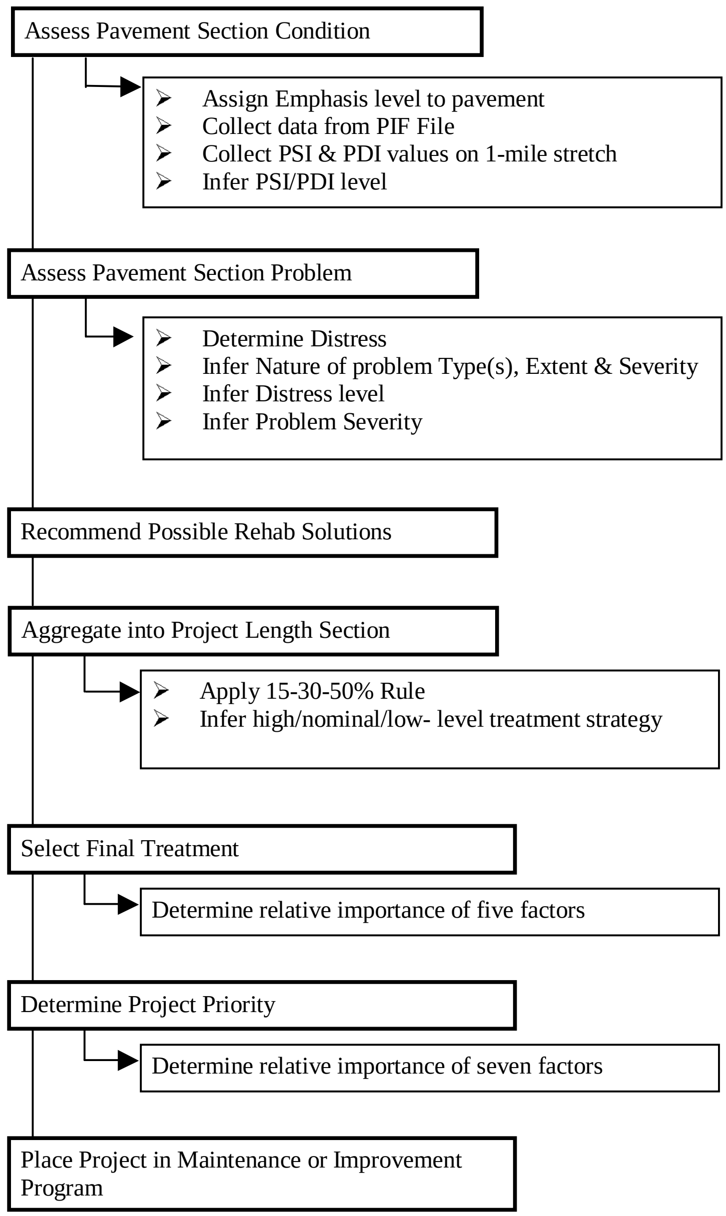

Figure 4 Wisconsin DOT Selection Process (*4*)

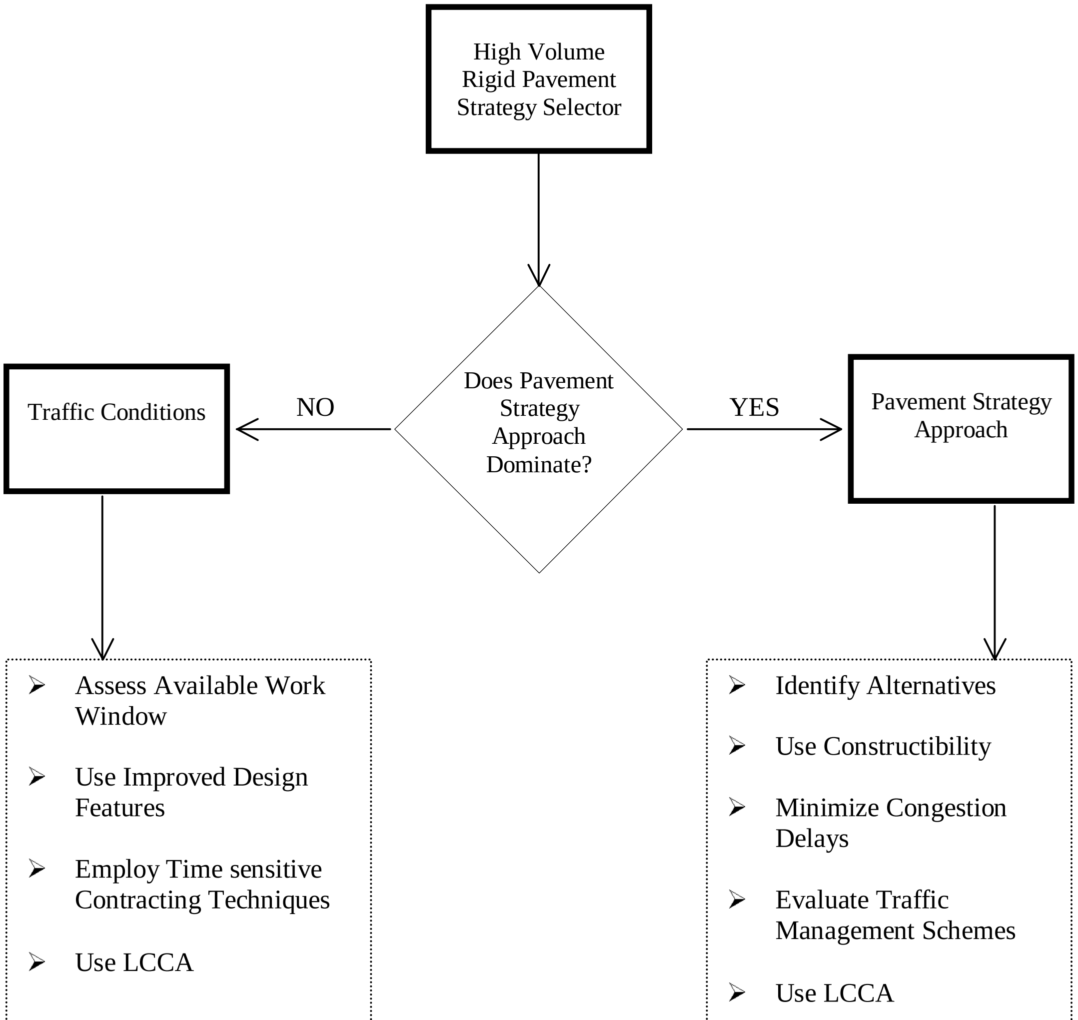

Figure 5 Alternate Selection Process

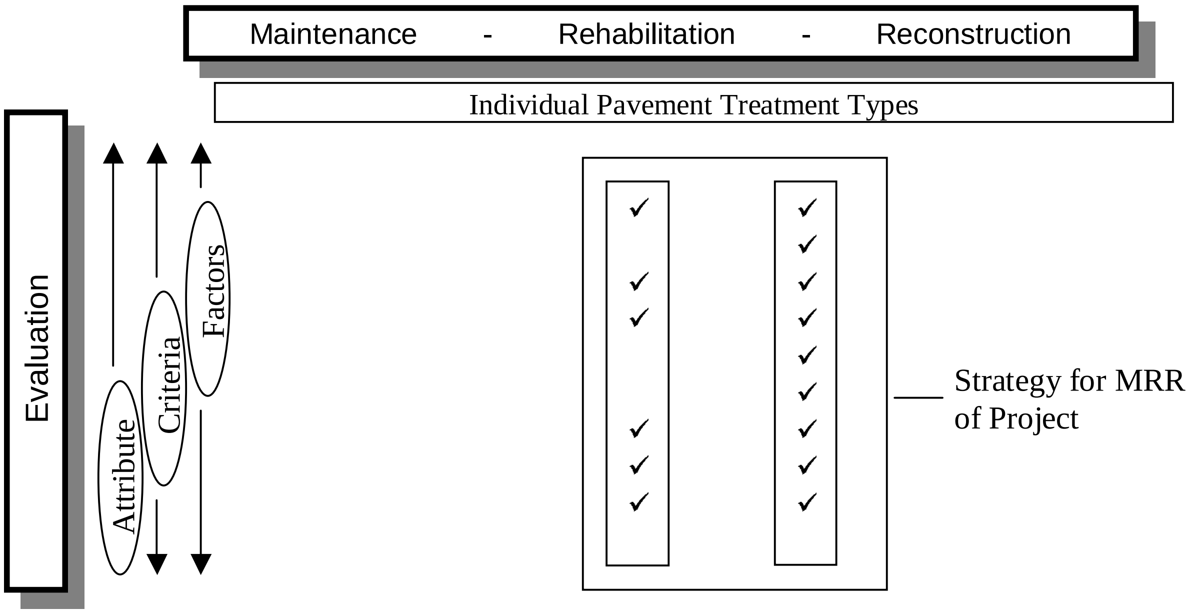

Figure 6 Framework for Selecting Strategies for MRR of Rigid Pavements

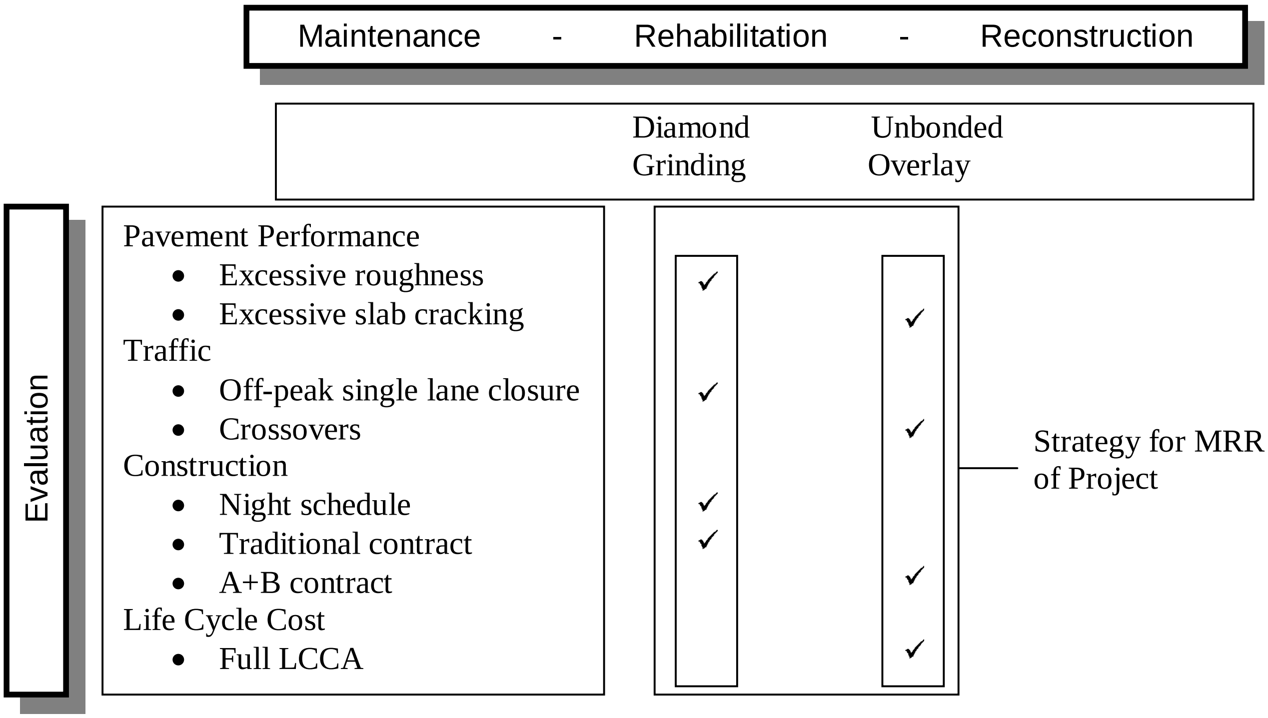

Figure 7 Example MRR Strategy with a Combination of Treatments

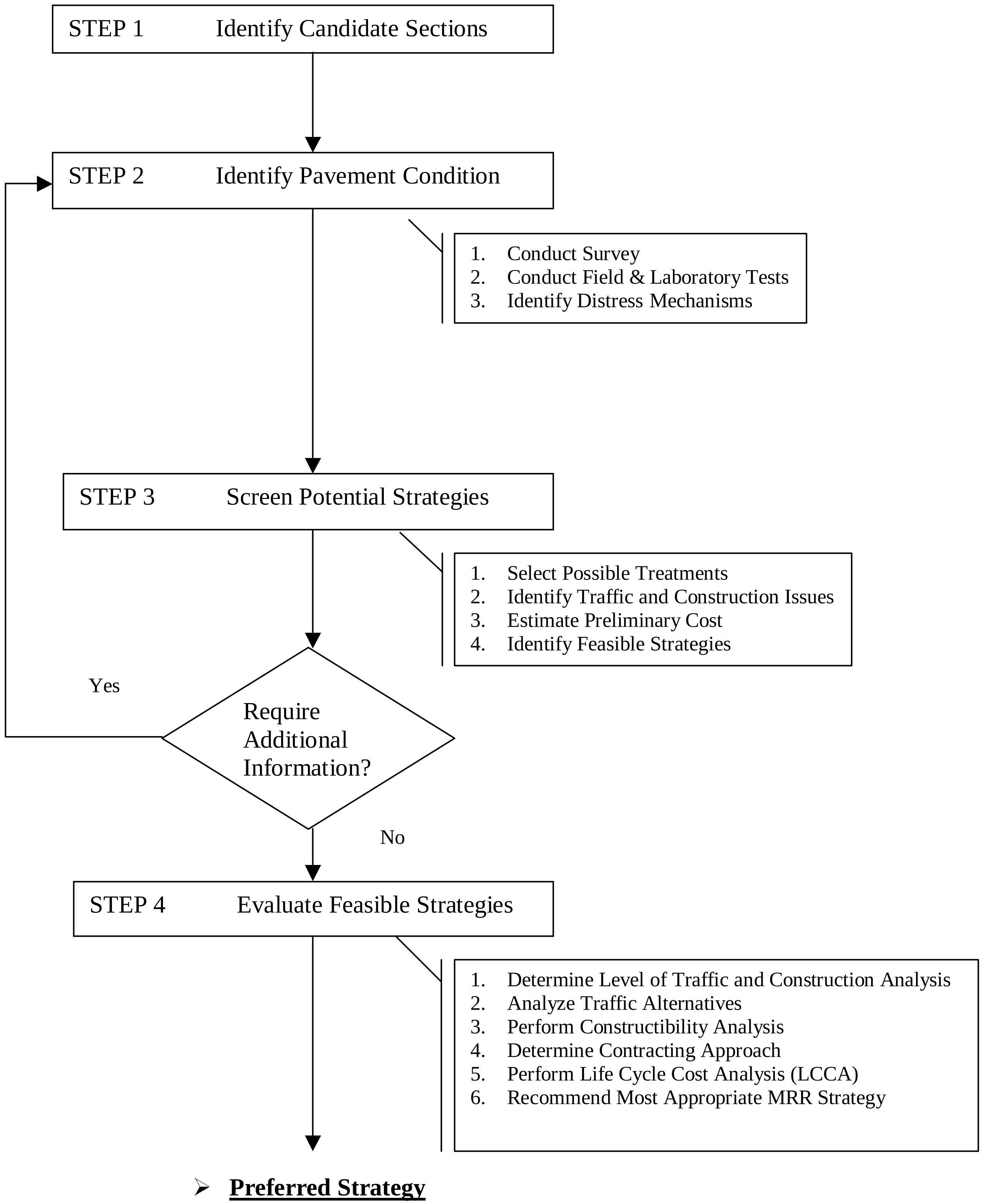

Figure 8 Selection Process for Selecting MRR Strategies

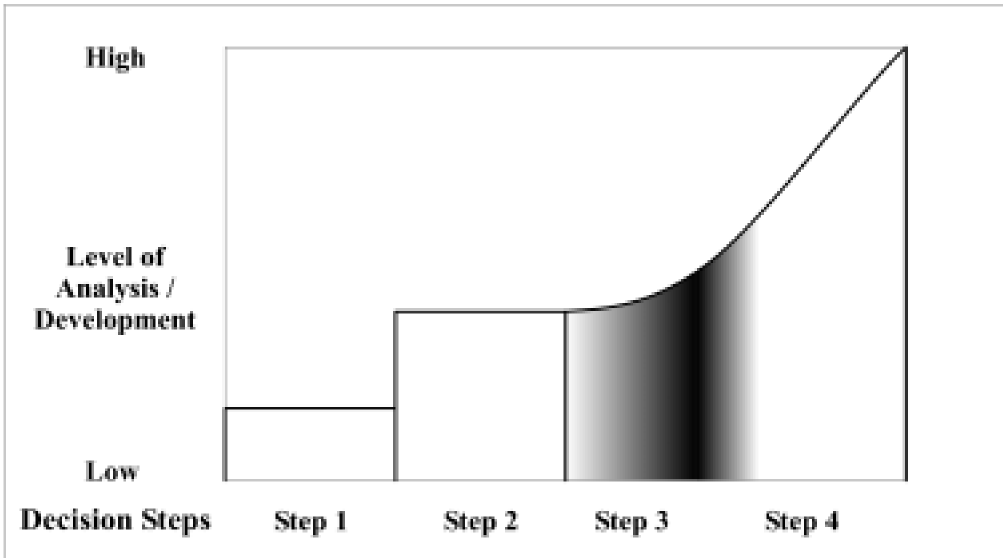

Figure 9 Level of Analysis and Development of Strategies

1 2 3 ←**Hierarchical Levels**

↓ ↓ ↓

- **Select Appropriate Strategy for MRR**
  - **Step 1: Identify Candidate Sections**
  - **Step 2: Identify Pavement Condition**
    - Conduct Surveys
    - Conduct Field & Laboratory Tests
    - Identify Distress Mechanisms
  - **Step 3: Screen Potential Strategies**
    - Select Possible Treatments
    - Identify Traffic and Construction Issues
    - Estimate Preliminary Cost
    - Identify Feasible Strategies
  - **Step 4: Evaluate Feasible Strategies**
    - Determine Level of Traffic and Construction Analysis
    - Analyze Traffic Alternatives
    - Perform Constructibility Analysis
    - Determine Contract Approach
    - Perform Life Cycle Cost Analysis (LCCA)
    - Recommend Most Appropriate MRR Strategy

Figure 10 Hierarchical Layout of the Selection Process Steps

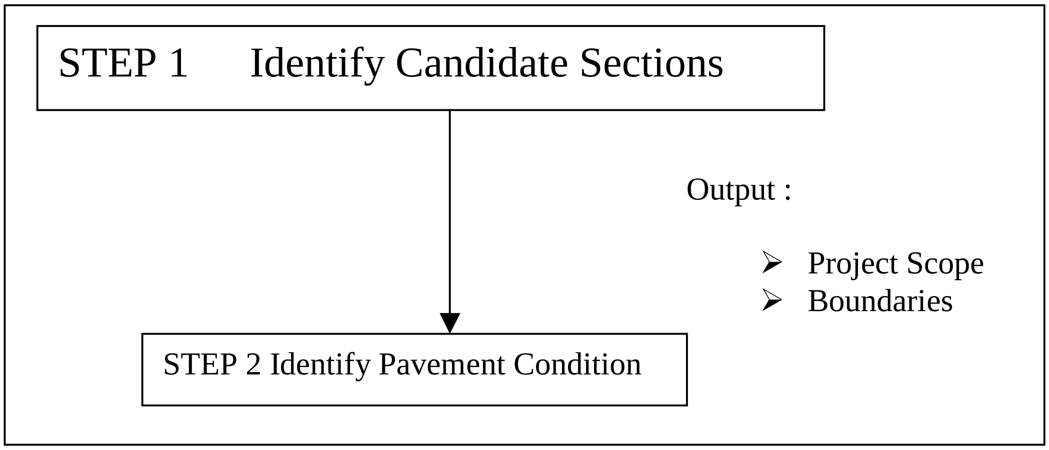

Figure 11 Identify Candidate Sections

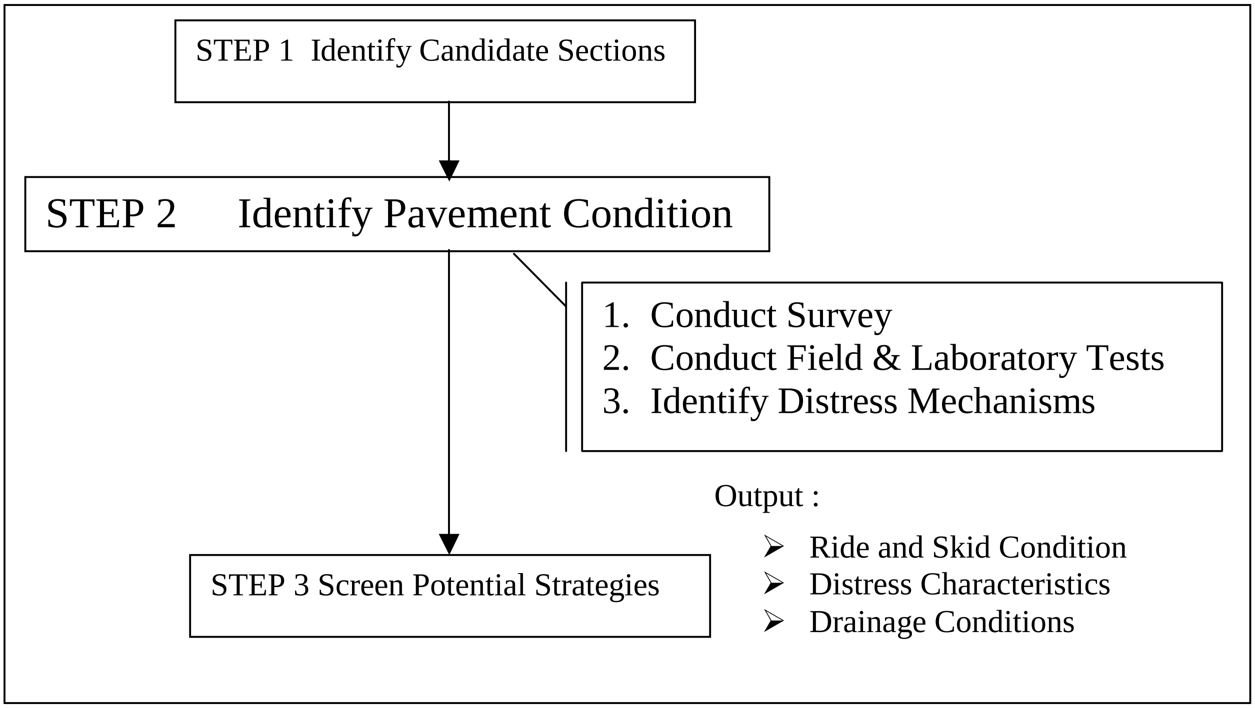

Figure 12 Identify Pavement Condition

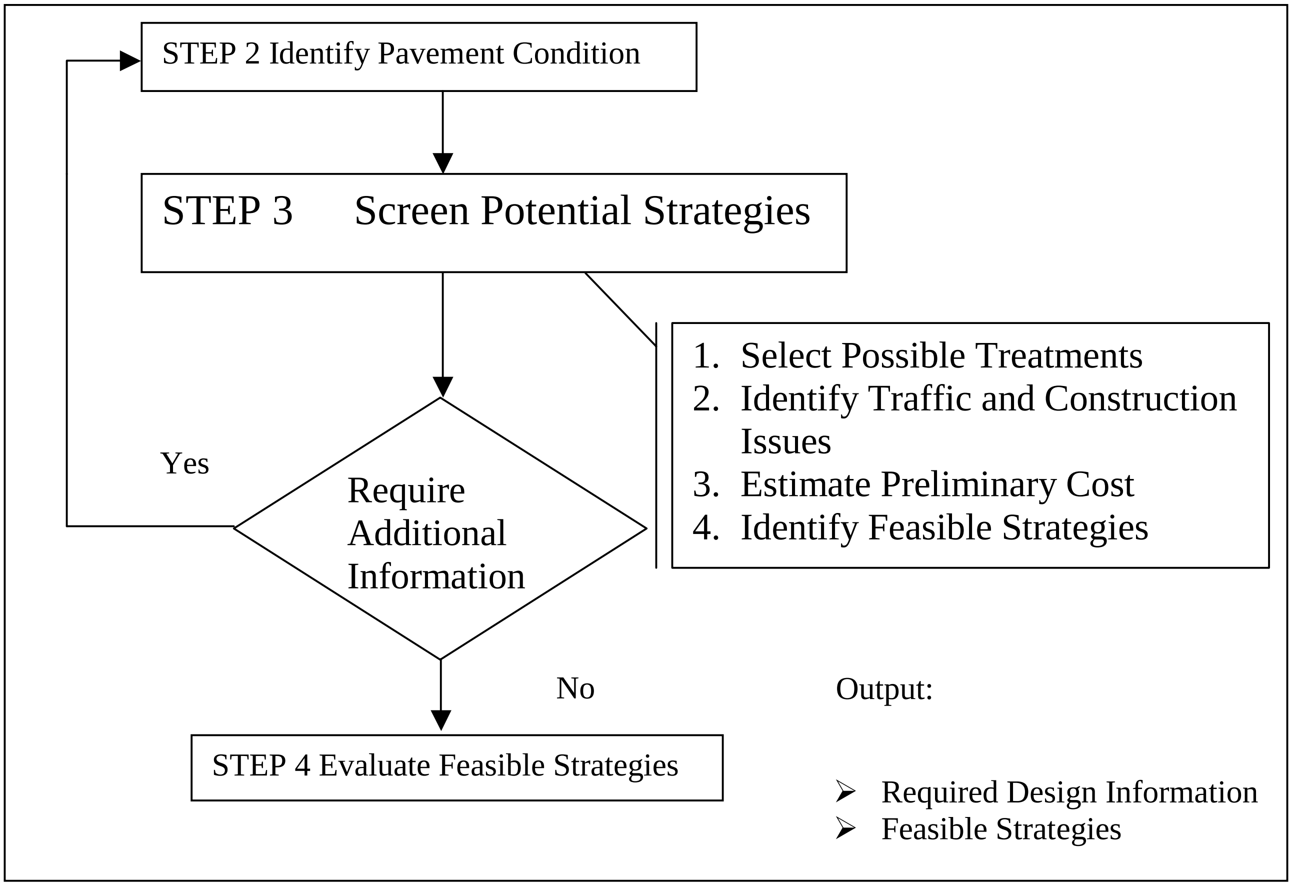

Figure 13 Screen Potential Strategies

QUICKZONE

QuickZone is the first tool being developed under the SWAT (Strategic WorkZone Analysis Tools) Program at the Turner-Fairbanks Highway Research Center at the Federal Highway Administration. QuickZone is a traffic impact analysis spreadsheet-based tool that can be used for work zone delay estimation. Some of its uses include:

- Identifying delay impacts of alternative project phasing plans,
- Conducting tradeoff analyses between construction costs and delay costs,
- Examining impacts of construction staging (location along mainline, time-of-day, season),
- Assessing travel demand measures and other delay mitigation strategies, and
- Supporting the setting of work completion incentives.

Figure 14 Example of a Work Zone Analysis Tool (*13*)

CONSTRUCTIBILITY REVIEW PROCESS WORKBOOK

Constructibility review process (CRP) is a formalized process that integrates construction knowledge and experience into the project development process. The CRP analyzes key information and documents produced by the project development process (PDP) following a formal set of constructibility functions or steps and using appropriate tools for performing those steps. By applying constructibility during the PDP, the user can assess construction issues that impact the planning and design of a facility. This CRP assessment may contribute overall project benefits such as a reduction in costs, an improvement in the quality of the constructed facility, an improvement in safety, a reduction in schedule, an enhancement of management risk, and an improvement in customer satisfaction. This workbook is divided into planning, design and construction guideline sections so constructibility analysis can be performed during each project development process phase. Each guideline section leads the user through a series of steps. These steps contain key information that assists the user in performing the step. The constructibility review process is defined by a generic approach. It was designed to be flexible and to be adaptable to specific project conditions and requirements. Similarly, an agency can modify the CRP to be consistent with its approach to project development, policies, and resources available.

Figure 15 Constructibility Review Process for Transportation Facilities: Workbook (*14*)

WORKSHOP APPROACH

In project situations with extremely high traffic volumes, a decision analysis approach that would identify alternate feasible solutions for specific pavement treatments may be justifiable. This type of decision analysis would be conducted through a short workshop that would allow experts in rehabilitation and reconstruction to brainstorm potential approaches for handling traffic and construction with respect to pavement treatments. The workshop of this nature would be conducted in two one-day working sessions. Steps to plan, conduct and document results could include the following actions: select suitable project within SHA; select facilitator; create local teams to participate in workshop; collect background information on the project; select date for workshop; organize the working sessions; conduct workshop sessions; collect follow-up information; and report the results.

The workshop approach was utilized by the Federal Highway Administration, the California Department of Transportation, and the Transportation Research Board (TRB) to evaluate pavement renewal strategies for urban freeways. Results of the workshop are published in “Get In, Get Out, Stay Out!” by the National Academy Press (*9).* Caltrans has adopted a similar approach, termed Value Analysis Study, in the Los Angeles District.

Figure 16 Workshop Approach

Alternative 1 Traffic and Construction Approach

Treatment Selected

Portland Cement Concrete (PCC) solution utilizing a combination of two concrete techniques:

- New PCC slab over a full depth recycling of existing pavement with some unbonded PCC overlay.

This treatment combination provides forty years of service life with little required maintenance and low life cycle cost

Construction

- Two concrete plants with dual 8.2 cubic meter drums were proposed, which could produce 1377 cubic meters of concrete an hour
- Pavement production rate of 0.833 mi./weekend/2 lanes
- Replace PCC pavement with "forty-year" pavement
- Contractor will have back-up equipment and extra sources of construction material to avoid unforeseen delays and possible shortages
- Recycle on-site existing PCC pavement and cement treated base
- Widen and replace median with full structural section
- Ten hour workshifts
- Construction stages:
    - Stage I
        (a) Removal of existing metal beam guardrail at the median, and recycling of existing material
    - Stage II
        (a) Cement treated base and PCC are constructed
    - Stage III
        (a) Installation of barriers in the median and shoulders will be widened to 3.6m.

Traffic

- Segmental full closures (of 4.8 – 8km in length) of one direction from one major ramp to another off ramp during weekends and late weeknight hours.
- All lanes available to traffic on weekdays
- Install ITS (intelligent traffic systems) with changeable message signs (CMS) to provide real-time information to traffic
- Recommend use of traffic alternate routes (I-110, I-605, Lakewood Blvd. and other local streets)

Public Awareness

- Recommend use of television, radio and newspaper media to inform the public about the project
- Establish 24-hour hotline to inform the motorist

Schedule

16 weekends along with some mid-week night time closures to complete the work

Figure 17(a) Traffic and Construction Approach for I-710 Project Alternate 1 (*9*)

Alternative 2 Traffic and Construction Approach

Treatment Selected

- Twelve-inch doweled pavement constructed of high performance PCC would be placed over a fourteen-inch lean concrete base

Construction

- Existing PCC and hot mix asphalt (HMA) pavements would be recycled on site, thus avoiding disposal problems
- Replace overpass structures with clearspan bridges
- Replace median with a full structural section
- Widen shoulders (both outside and inside)
- Create a conflict resolution team
- Construction stages:
  - Stage I
    - (a) Replace existing overcrossing structures with clear span structures
    - (b) Construct temporary drainage facilities as required
    - (c) Close No. 1 lane on the northbound direction during off-peak hours
  - Stage II
    - (a) Shift traffic and temporarily strengthen pavement with AC on southbound outside shoulder
  - Stage III
    - (a) Shift traffic and construct permanent pavement on nourthbound lanes
  - Stage IV
    - (a) Shift traffic and construct permanent pavement on median
    - (b) Construct temporary AC pavement on northbound lanes as required
    - (c) Shift traffic and construct permanent pavement on northbound lanes
  - Stage V
    - (a) Shift traffic and construct permanent pavement on southbound lanes
    - (b) Construct temporary AC pavement on northbound lanes as required
  - Stage VI
    - (a) Shift traffic and construct permanent pavement on southbound lanes

Traffic

- Maintain four lanes of traffic in each direction during all phases of construction
- Use moveable concrete barriers during construction to route traffic through the different work zones along I-710 route
- Traffic control plan based on established construction phases
- Use ITS technology to monitor traffic condition and advise motorists to seek other routes

Schedule

- Duration of construction can be expected to last for up to five years. Construction schedule would include 35 weeks for bridge work and 5 months for planning for pavement work once contract is awarded

Figure 17(b) Traffic and Construction Approach for I-710 Project Alternate 2 (*9*)

Alternate 1 Preliminary Cost Estimate	
Section 1. Earthwork	$ 815,000
• Roadway Excavation	
Section 2. Structural Section	$35,930,000
• PCC Pavement	
• Recycled Lean Base	
Section 3. Drainage	$ 5,000,000
• Storm Drains	
Section 4. Specialty Items	$ 3,349,000
• Landscaping / Irrigation Facilities	
• Concrete Barrier Type 60W	
Section 5. Traffic Items	$10,515,000
• Traffic Control Systems	
• Pavement Delineation	
• Maintain Traffic (Street improvement and media notification)	
Section 6. Minor Items (10% of Subtotal of sections 1-5)	$ 5,561,000
Section 7. Roadway Mobilization (10% of Subtotal of section 1- 6)	$ 6,117,000
Section 8. Roadway Additions	$20,186,000
• Supplemental (10% of Subtotal of sections 1-6)	
• Contingencies (20% of Subtotal of sections 1-6)	
Total Roadway Items	$ 87,473,000
Structures	$ 100,000
Total Roadway and Structures	$ 87,573,000
USE	**$ 87,580,000**

Figure 18(a) Preliminary Cost Estimate For I-710 Project Alternate 1 (*9*)

Alternate 2 Preliminary Cost Estimate

Section 1. Earthwork	$ 1,281,000
• Roadway Excavation	
Section 2. Structural Section	$ 43,772,000
• PCC Pavement	
• Asphalt Concrete (Type B)	
• Recycled Lean Concrete Base	
• Steel Dowel Tie Bar	
Section 3. Drainage	$ 5,000,000
• Large Drainage Facilities	
Section 4. Specialty Items	$ 17,096,000
• Media Service	
• Landscaping / Irrigation Facilities	
• Erosion Control	
• Movable Concrete Barrier	
• Engineers Office	
• Water Pollution Control	
• Concrete Guard Rail	
Section 5. Traffic Items	$ 10,792,000
• Traffic Striping/Markings	
• Traffic Electrical/Lighting	
• Permanent Signing	
• Traffic Control System	
• Traffic Management Plan	
• ITS/IVHS	
• Temporary Railing	
• COZEEP	
Section 6. Minor Items (10% of Subtotal of sections 1-5)	$ 7,794,000
Section 7. Roadway Mobilization (10% of Subtotal of section 1- 6)	$ 8,573,000
Section 8. Roadway Additions	$ 28,292,000
• Supplemental (10% of Subtotal of sections 1-6)	
• Contingencies (20% of Subtotal of sections 1-6)	
Total Roadway Items	$ 122,600,000
Structures (32 Bridges Reconstructed with full spans)	$ 65,200,000
ROW	$ 3,700,000
Use	**$ 191,500,000**

Figure 18(b) Preliminary Cost Estimate For I-710 Project Alternate 2 (*9*)

DECISION MAKING MATRIX TOOL

This tool uses the information gathered in the earlier steps of a project to form an evaluation basis to select the best alternative among various others. The evaluation of alternatives is performed based on project objectives and criteria that would help differentiate between alternatives.

I Steps:

1) Category factors are determined based on project objectives and other key factors
2) Each factor is assigned a weight according to its importance for a successful project
3) Each factor for each of the alternatives is given an evaluation scored; 1 being the lowest and 5 being the highest performer
4) Weighted score for each factor is determined simply by multiplying it's weight times the evaluation score
5) Total weighted score for each of the alternatives is calculated
6) The alternative(s) with the highest score is the most appropriate

II Matrix:

		Alternative 1		Alternative 2		Alternative 3	
Category Factor	Factor Weight	Evaluation Score	Weighted Score	Evaluation Score	Weighted Score	Evaluation Score	Weighted Score
Performance Life	20	5	100	5	100	3	60
Construction Cost	15	4	60	1	15	5	75
Construction Duration	10	5	50	2	20	4	40
User Cost Impact	25	2	50	3	75	5	125
Public Impact	15	3	45	3	45	4	60
Location Impact	5	5	25	2	10	4	20
Execution Approach	10	4	40	3	30	3	30
Total	**100**		**370**		**295**		**410**

Evaluation Score 500 (MAX)

1 → Indicates that this alternative is the lowest performer for the category factor being considered

5 → Indicates that this alternative is the highest performer for the category factor being considered

Weighted Score = Factor Weight x Evaluation Score
Total of each alternative = Sum of Weighted Scores
Maximum score equals 500

Figure 19 Decision Making Matrix Tool: Evaluating Alternatives (*15*)

Example From I-475 Case Study

Analyzed the six alternatives based on cost, traffic impact, pavement condition, and the required time to construct. The following conclusions were drawn:

- The nine inch continuous reinforced concrete overlay was discarded because of its estimated high preliminary cost estimate for construction.
- The option to rubblize the existing PCC pavement with ten inch AC overlay was ruled out as a feasible MRR strategy due to the condition of the soil. Analysts believed the improved pavement section would not meet the needed quality characteristic.
- It was determined that the crack and seat with eight inch AC overlay alternative would not correct current distresses of the existing pavement. Therefore, this alternative was not considered a viable option.
- The reconstruction treatment was discarded due to the lengthy time of construction and the high preliminary cost estimate.

Two alternatives were determined to be feasible and sound. Therefore, they were considered for further evaluation. These two MRR alternatives are:

- Six inches asphaltic concrete overlay
- Ten inches jointed concrete overlay with one inch AC separation layer

Figure 20 Identifying Feasible Strategies for I-475 Project

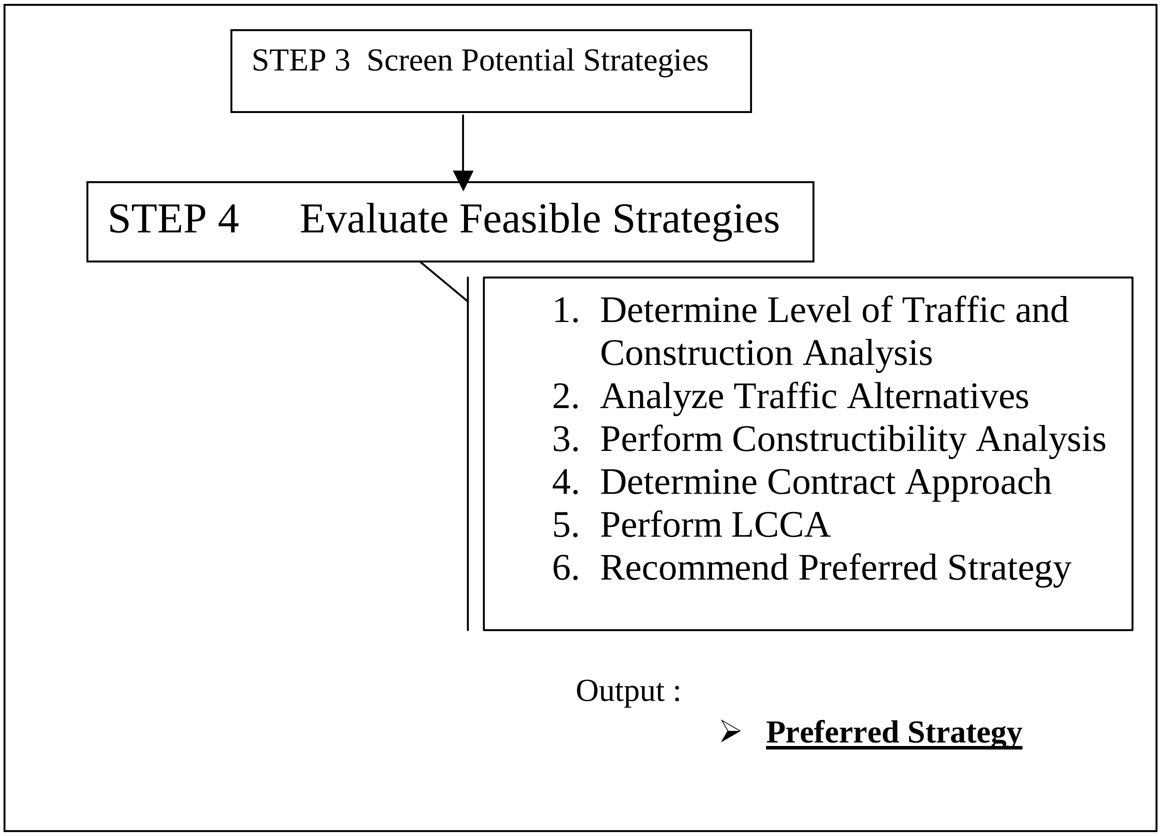

Figure 21 Evaluate Feasible Strategies

Figure 22 Example of Additional Signing and Delineation Needed for a Traffic Split on a High-Volume Roadway

WORK ZONE SAFETY INFORMATION CLEARINGHOUSE

The Work Zone Safety Information Clearinghouse is a resource available to transportation industry practitioners to help obtain current, accurate information about work zone safety practices, experts, equipment and technologies, research activities, reports, and crash statistics that are available nationwide. The Clearinghouse can be used in a variety of ways to facilitate improved traffic management decision-making for pavement rehabilitation and reconstruction activities. Practitioners can visit the Clearinghouse Internet website and access a number of topic databases and electronic reports pertaining to work zone safety. Practitioners can also contact the Clearinghouse directly to request information on a work zone safety-related topic. Examples of the types of ways the Clearinghouse have been used to date include the following:

- Determining if other states have used a particular traffic control device, technique, or technology and if so, what the experiences of those states have been to date;
- Identification of available training resources (courses, videotapes, manuals, etc.) exist in other locations nationwide and how they can be obtained;
- Obtaining electronic copies of recent articles and technical reports about ongoing or recently-completed work zone safety research studies.

The Work Zone Safety Information Clearinghouse has an internet web site that provides users direct access to much of the collated work zone safety-related information that has been identified to date.

Figure 23 Work Zone Safety Information Clearinghouse (*16*)

Traffic Management - Handbook for Concrete Pavement Reconstruction and Rehabilitation

This handbook presents a traffic control strategy selection process that seeks to find a balanced strategy that considers user cost as well as project cost. The process has five steps as follows:
1) Choose Feasible Alternatives, 2) Consider Planning Issues, 3) Compare Alternatives, 4) Choose Recommend Strategy, and 5) Determine Phasing/Key Constraints/Special Provisions.

The process ensures that a number of issues are considered to compare feasible alternatives. These issues are divided into the following nine areas: 1) Scoping, 2) Traffic Management, 3) Safety, 4) Concrete Pavement Construction Requirements, 5) Innovative Bidding, 6) Operational Performance, 7) Constructibility, 8) Emergency Planning, and 9) Public Information and Coordination.

Figure 24 Traffic Management - Handbook for Concrete Pavement Reconstruction and Rehabilitation (*17*)

TRAFFIC MANAGEMENT TOOL – FHWA BEST PRACTICES GUIDEBOOK

The Federal Highway Administration (FHWA) has compiled a list of practices from state and local transportation agencies that have been used to address safety and mobility concerns in highway work zones. A description of the practice, how it was used, and pertinent contacts for more information about the practice were also obtained. These practices have been collated and incorporated into a guidebook for practitioner use. The guidebook is useful in identifying practices, techniques, and technologies other practitioners perceive to have been useful in minimizing motorist delay and maximizing motorist and worker safety in past work zone projects. Some of the "practices" represent changes or adoption of new policies and processes within planning and programming phases of a project, whereas others are techniques or tools for consideration during project design or actual construction activities.

Figure 25 Traffic Management Tool – FHWA Best Practices Guidebook (*7*)

TRANSIMS

The Transportation Analysis and Simulation System, or TRANSIMS, is an integrated system of travel forecasting models designed to give transportation planners accurate, complete information on traffic impacts, congestion, and pollution. It is part of the Travel Model Improvement Program sponsored by the U.S. Department of Transportation, the Environmental Protection Agency, and the Department of Energy. TRANSIMS models create a virtual metropolitan region with a complete representation of the region's individuals, their activities, and the transportation infrastructure. Trips are planned to satisfy the individuals' activity patterns. TRANSIMS then simulates the movement of individuals across the transportation network, including their use of vehicles such as cars or buses, on a second-by-second basis. TRANSIMS could be used to assess how traffic management approaches that involve a significant reduction in roadway capacity during reconstruction (such as by completely closing the roadway to allow work activities to be completed faster) might affect travel choices in the region. The model could also help estimate what impact mitigation strategies on alternative routes and modes may help accommodate traffic that would have to divert.

Figure 26 Example of a Regional Transportation Planning Model (*18*)

Michigan I-496 Project Traffic Assessment

Determined the following traffic restrictions that may be applicable to all reconstruction alternatives under consideration:

- This portion of I-496 (between Cedar Street and US 127) will be completely closed to vehicular traffic during the construction of bridges and pavement in this area.
- The closure is necessitated by the replacement of four bridges, two over the Grand River and two over Pennsylvania Avenue, that will take approximately 21 weeks to reconstruct.
- The closure is being implemented so that the construction of these bridges can be completed in one construction season rather than the two construction seasons it would take to build the project part width.
- Traffic will be diverted to several alternate routes (parallel route, trunk line routes, etc.) throughout the Lansing area (i.e., Saginaw Highway, Michigan Avenue, Oakland Avenue, Grand River Avenue, I- 69, US 27, US 127, and I- 96).
- Potential alternate routes were assessed to determine possible impacts.
- Public events will be held to inform the public of the project early in the planning phase of the project.
- Monthly meetings with the public communities will be held to see the impact of the project on the community.
- Funds allocated to public information will be used for radio ads, TV ads, web site, and billboard ads.
- An ITS system will be provided through an outside consultant. The scope of the ITS system includes:
    - Real time information to motorist
    - Incident management system:
        - (i) Detect incidents on I-496 and alternate routes
        - (ii) What to do in case something happens
    - Estimated travel time
    - Provide recommended alternate routes to the public during construction
    - The contractor is responsible for providing people to control the ITS system
  - Public surveys purpose
    - Public reactions and major concerns
    - Satisfaction survey during construction phase
  - To reduce the traffic impact 30000 bus passes will be distributed in the downtown area
- Project start date is set for the week of spring break.

Figure 27 I-496 Project Traffic Assessment

Figure 28 MDOT I-496 Construction Guide and Alternate Routes (photo courtesy of the Michigan Department of Transportation)

Reducing and Mitigating Impacts of Lane Occupancy During Construction and Maintenance

This report describes the current state of the practice for reducing and mitigating the impacts of lane occupancy during construction and maintenance. Information for the synthesis was collected by surveying U.S. and Canadian transportation agencies and by conducting a literature search to gather additional information.

The scope of the synthesis is broad and covers work performed in all phases of the life cycle of the facility. Moreover, an estimation of the relative impact of the techniques, methods, and processes on reducing lane occupancy is presented. The framework for categorizing information and data collection covers the following areas: 1) Programming and planning, 2) Design, 3) Contracting, 4) Construction, and 5) Maintenance. Within each area, specific issues and techniques that would influence lane occupancy are identified. For example, at the design level, information was gathered on project phasing, traffic control, construction sequencing, constructibility, materials, construction equipment, and prefabrification.

Figure 29 Reducing and Mitigating Impacts of Lane Occupancy During Construction and Maintenance (*20*)

KY-CTDS PROGRAM

The KY-CTDS program provides a conceptual estimating tool for predicting construction contract time for the Kentucky Department of Highways. It uses the pre-determined project classifications with only the major activities that control the project duration. Production rates and activity relationships were determined and are included in the program. Final adjustments can be easily made by the responsible engineer. The system utilizes Microsoft Project 98 and Microsoft Excel Version 7.0 software operating on a personal computer. System outputs include a graphical bar chart schedule for estimating contract time for bidding purposes. The program is not suitable for detailed scheduling of construction operations.

Figure 30 Kentucky Contract Time Determination System (*21*)

NM DOT Process

The New Mexico Department of Transportation (DOT) developed a tool that helps estimate the duration of the construction phase during the design phase of a highway construction project. The results of this process, also helps determine if accelerated construction processes and innovative contracting methods are required for a specific highway construction project. The procedure for using this tool relates the project cost estimate to an estimate base value of construction workdays by assuming that a regular construction schedule will be followed. This base value is then modified in the process for specific project conditions.

Figure 31 New Mexico DOT Process To Determine Contract Time for Highway Construction Projects (*22*)

Proposed a construction staging plan based on the traffic control approach. This construction staging plan is applicable for both feasible alternatives:

Stage I Trench and pave median shoulder for both directions. This work may be performed at night under a lane closure. One lane of traffic in each direction and all ramps have to be maintained at night. All lanes and ramps will remain open during daytime.

Stage II Shift traffic to the median lane/shoulder and construct outside lane, shoulder, guardrail in concrete/bridge areas and all ramps for both directions. One lane of traffic in each direction and all ramps (with the exception of Clyde Road) will be maintained. The Clyde Road ramps have to be immediately reopened following this stage.

Stage III Switch traffic to outside lane/shoulder and construct median lane, shoulder, guardrail in concrete/bridge areas. One lane of traffic in each direction and all ramps will remain open to traffic.

Determined that the guardrail (except as required in Stages II and III), Crouse Road bridge work and culvert work may be performed during any stage.

Figure 32 Proposed Construction Staging Plan for US 23 Project

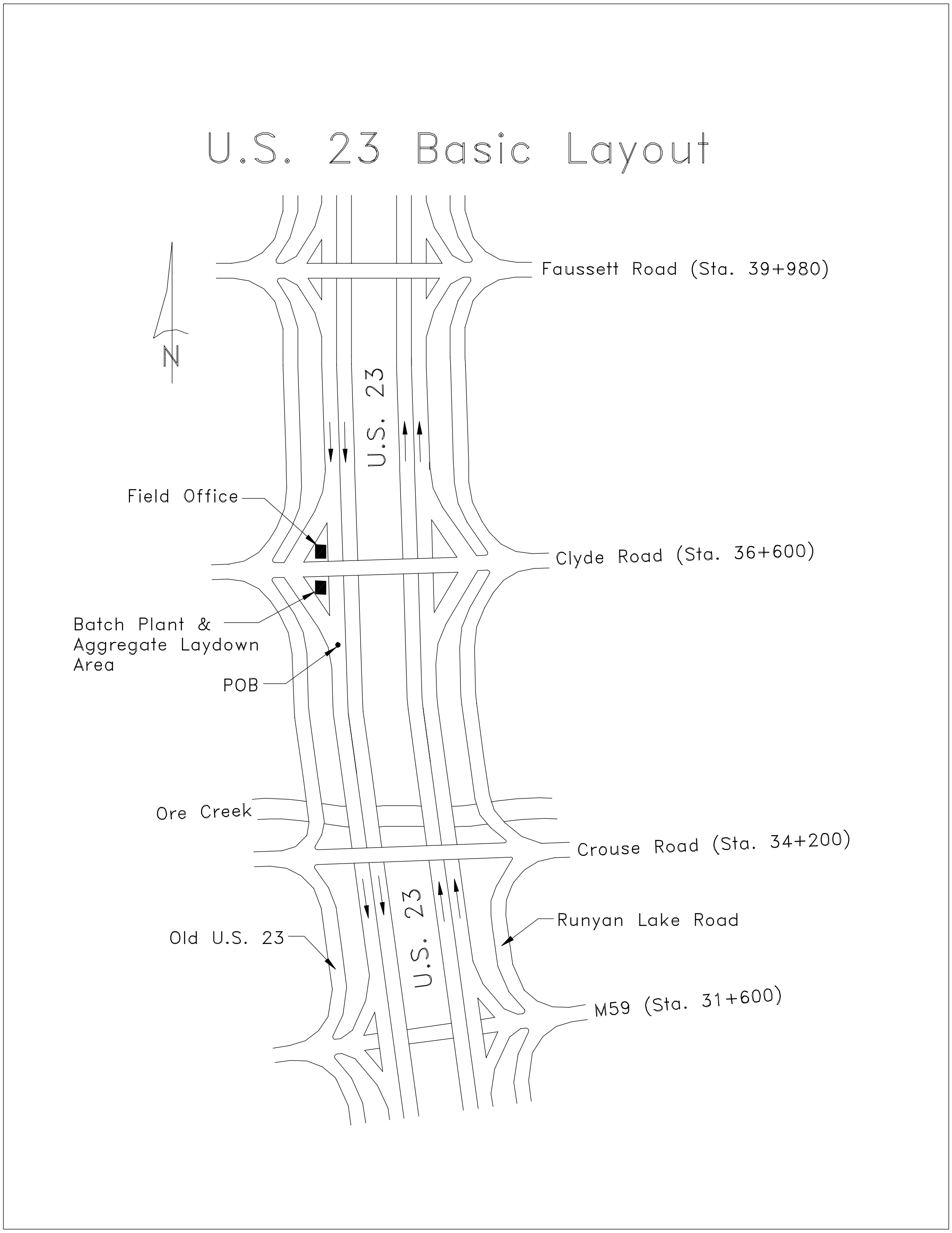

Figure 33 US 23 Project Basic Scope

GUIDEBOOK TO HIGHWAY CONTRACTING FOR INNOVATION

Guidebook to Highway Contracting for Innovation is a report that identifies and evaluates procurement and contracting approaches for the design and construction of highways. The National Cooperative Highway Research Program (NCHRP) has published this report especially for state highway personnel and others involved in the administration of construction contracts. The guidebook introduces organized data that helps the user evaluate and select procurement and contracting methods. Each procurement and contracting approach is presented with information pertaining its applicability to highway construction projects by:

1) illustrating the survey results from SHAs and contractors;
2) describing benefits and positive aspects;
3) addressing potential problems and considerations;
4) exemplifying types of projects that have been found to work well; and
5) recommending contracting approach combinations to enhance the possibility of positive results.

Example of Procurement and Contracting Approach From Guidebook

I-70 PAVEMENT REHABILITATION
Indiana Department of Transportation (INDOT)

This project consisted of removing an existing pavement overlay and placing a new asphalt overlay on a reinforced concrete pavement. INDOT used Multi-Parameter (A+B+C) contracting method to shorten the construction time for the project and include a five-year Construction Warranty for the pavement overlay to emphasize the quality of the finished pavement. The contract also included Incentive/Disincentive clauses.

The Construction Warranty provisions required the contractor to make any repairs, if necessary, to the pavement for five years after project completion. This combination provided the contractor greater flexibility and control of the work and encouraged a higher quality pavement.

Partnering between INDOT and the contractor was also included in the contract as a special provision. This effort played an important role in promoting innovation in two aspects of this project. Partnering between INDOT, FHWA, contractor organizations, and material suppliers assisted in the development of the Construction Warranty provisions.

Figure 34 Guidebook to Highway Contracting for Innovation NCHRP Report 428 (*23*)

Guidelines for Warranty, Multi-Parameter, and Best Value Contracting

The objective of this report is to provide comprehensive guidelines for implementing three alternate contracting methods for highway construction projects (warranty, multi-parameter, and best value). Each contract method is contained in one chapter and each chapter is organized in a similar fashion. The guidelines are designed for first time users of the contract method. However, experienced users can compare their practice with that proposed in the guidelines. For the first step in the process the user is asked to identify their experience level with the contract method (none, moderate, or high). Based on the experience level, the user is directed to different steps in the implementation flowchart. The flowchart steps are presented in terms of the following four general categories, which reflects the implementation process of a new contract method: 1) Conceptual planning; 2) Program planning; 3) Bid, contract award, and construction; and 4) Evaluation of pilot project(s) and program. Case studies are also provided to illustrate the application of each contract method.

Figure 35 Guidelines for Warranty, Multi-Parameter, and Best Value Contracting (*24*)

EXAMPLE FROM US-23 CASE STUDY

Due to the restrictive construction time frame and that construction would likely take all of 45 days, the cost-plus-time (A+B) bidding method was not required. Michigan DOT determined that the traditional contracting approach with the use of incentives and disincentives (I/D) would be the more appropriate contracting method.

Based on the road user costs determined the I/D amounts for the contract:

- An incentive of $30,000 will be awarded for each calendar day (weekday) or $60,000 per weekend day (Saturday or Sunday) if the northbound and southbound US-23 roadways are opened to traffic, prior to the 45 calendar days established for the construction time frame.
- A possible $450,000 maximum incentive was established.
- A disincentive of $30,000 will be assessed for each calendar day (weekday) or $60,000 per weekend day (Saturday or Sunday) if the northbound and southbound US-23 roadways are not opened to traffic within 45 calendar days established for the construction time frame.
- No cap will be established for the total disincentive amount. Therefore, the disincentive will continue to be assessed until all lanes of the US 23 roadway and ramps are opened to traffic.

Additional provisions were determined for the contract document:

- No extensions of time will be granted for labor disputes unless it can be shown that such disputes are industry-wide.
- No extensions of time will be granted for weather conditions. Any extra costs incurred by the contractor due to cold weather protection will not be paid separately.
- Any extra costs incurred by the contractor for night work and overtime utilized to maintain the expedited schedule will not be paid for separately.

Figure 36 Contract Approach for US-23 Case Study

Life Cycle Cost Analysis (LCCA) in Pavement Design

LCCA is an analysis technique used to evaluate the over-all-long-term economic efficiency between competing alternative investment options. In highway construction projects, this economic analysis incorporates initial and future costs and benefits of each alternative analyzed, taking into account inflation and interest rates. While a useful decision support tool, LCCA results are not decisions in and of themselves. In conducting a LCCA it is important to be aware of the uncertainty surrounding the variables used as inputs into the analysis and the *risks* this uncertainty creates in the results. *Risk Analysis* is a technique that exposes areas of uncertainty, typically hidden in the traditional "deterministic," approach to LCCA, and allows the decision maker to weigh the probability of any particular outcome occurring.

The *Life-Cycle Cost Analysis in Pavement Design* corresponds to Report NO FHWA-SA-98-079 of Federal Highway Administration. The FHWA Office of Engineering, Pavement Division in cooperation with the Office of Technology Applications offers a 2-day demonstration on "Probabilistic Life Cycle Cost Analysis (LCCA) in Pavement Design Demonstration Project No. 115 (DP-115)" to any SHA upon request.

Figure 37 Life Cycle Cost Analysis (LCCA) in Pavement Design (*25*)

Alternate 1: Pavement Preservation Strategy

Facility: Freeway / Divided Highway
Fix Type: Rehabilitation – Bituminous Overlay on Rubblized Concrete

Activity	Approx. Age		Cost per Lane-Km		Present Value (Directional km)
Maintenance	5	RUC	$9,500 $64	Agency + User Cost	$16,580
Maintenance	10	RUC	$24,400 $64	Agency + User Cost	$36,762
Rehabilitation or Reconstruction	25				
				Total PV =	**$53,343**

Alternate 2: Pavement Preservation Strategy

Facility: Freeway / Divided Highway
Fix Type: Rehabilitation – Unbonded Concrete Overlay on Repaired Concrete

Activity	Approx. Age		Cost per Lane-Km		Present Value (Directional km)
Maintenance	13	RUC	$20,000 $128	Agency + User Cost	$27,761
Rehabilitation or Reconstruction	23				
				Total PV =	**$27,761**

Present Value (PV) = (Agency Maint. Cost + User Maint. Cost) / (1+I)n
i = Real Discount Rate (2.9%)
n = year of rehabilitation or reconstruction

Figure 38(a) Pavement Preservation Strategies for US 23 Project

Alternate 1: Rubblize and Resurface

Average Road User Cost $30,567/weekday $148,636/weekend-day

Stage 1 = 12.3 days
Stage 2 = 10.9 days

Total days = (12.3 + 10.9) x 2 directions = 46 Days

46 Days Total

34 days @ $30,567/day =$1,039,278
12 days @ $148,636/day =$1,783,632

Total Initial User Cost = $2,822,910/(8.4km x 2dir) = **$168,030/dir-km**

Alternate 2: Unbonded Conc. Overlay

Average Road User Cost $30,567/weekday $148,636/weekend-day

Stage 1 = 12.1 days
Stage 2 = 10.2 days

Total days = (12.1 + 10.2) x 2 directions = 45 Days

45 Days Total

33 days @ $30,567/day =$1,008,711
12 days @ $148,636/day =$1,783,632

Total Initial User Cost = $2,792,343/(8.4km x 2dir) = **$166,211/dir-km**

Figure 38(b) User Costs for US 23 Project

Alternate	PV Initial Constr. Costs	PV Initial User Costs	PV Maint. Costs	n	EUAC
1. Rubblize & Resf.	$262,906	$168,030	$53,343	25	**$27,502**
2. Concrete Overlay	$242,766	$166,211	$27,761	23	**$26,284**

EUAC= NPV*(.029*1.029n/(1.029n-1))

Note: All costs are per directional kilometer
n = Number of years
NPV = Net Present Value
EUAC = Equivalent Uniform Annual Cost

Figure 38(c) Equivalent Uniform Annual Cost Analysis for US 23 Project Alternatives

REFERENCES

1. "Course on Techniques for Pavement Rehabilitation." National Highway Institute, NHI Course Number: 13108, http://www.nhi.fhwa.dot.gov/

2. "Guide for Design of Pavement Structures." American Association of State Highway and Transportation Officials, Washington, D.C., 1994

3. "Pavement Rehabilitation Strategy Selection." *Technical Bulletin TB-015.P*, Concrete Paving Technology, American Concrete Pavement Association, Skokie, Illinois, 1993.

4. DeCabooter, P., Weiss, K., Shober, S., and Duckert, B. "Wisconsin's Pavement Management Decision Support System." *Transportation Research Record,* Transportation Research Board, 1455, 76-81, 1994.

5. "Traffic Management – Handbook for Concrete Pavement Reconstruction and Rehabilitation." *Engineering Bulletin EB213P published by the FHWA*, U.S. Department of Transportation, Washington, D.C., and the American Concrete Pavement Association, Skokie, IL. (2000).

6. "Meeting the Customer's Needs for Mobility and Safety During Construction and Maintenance Operations." Report No. HPQ-98-1, FHWA, U.S. Department of Transportation, Washington, D.C., September 1998.

7. "The Best Practices Guidebook" Federal Highway Administration, Report No FHWA-OP-00-010, U.S. Department of Transportation, Washington, D.C., and American Association of State Highway and Transportation Officials, April 2000 http://ops.fhwa.dot.gov/wz/wzguidbk/Documents/workzoneguidebook.pdf

8. "Case Study of Urban Concrete Pavement and Traffic Management for I-10 (Pamona, CA) Project." Innovative Pavement Research Foundation, Falls Church, VA, 2001

9. "Get In, Get out, Stay out!" *Proc., Workshop on Pavement Renewal for Urban Freeways*, Transportation Research Board, National Research Council, Washington, D.C., 2000.

10. "Pavement Rehabilitation Manual" New York State Department of Transportation, Albany, NY

11. "Treatment Programming Tool" Pennsylvania State Department of Transportation, http://www.dot.state.pa.us/

12. "Concrete Pavement Restoration, Resurfacing, and Reconstruction (CPR^3)" American Concrete Pavement Association, Skokie, IL, http://www.pavement.com/

13. "Quickzone" Information and Technology Exchange Center, Texas Transportation Institute, http://tti.tamu.edu/product/catalog/order.stm

14. Anderson, S.D. and Fisher, D.J. "Constructibility Review Process for Transportation Facilities Workbook." *NCHRP Report 391*, National Cooperative Highway Research Program, Washington, D.C., 1997.

15. “Pre-Project Planning Handbook” Construction Industry Institute (CII), Special Publication 39-2, April 1995

16. “The Work Zone Safety Information Clearinghouse” The American Road and Transportation Builders Association, http://wzsafety.tamu.edu

17. "Traffic Management – Handbook for Concrete Pavement Reconstruction and Rehabilitation." *Engineering Bulletin EB213P published by the FHWA*, U.S. Department of Transportation, Washington, D.C., and the American Concrete Pavement Association, Skokie, IL. (2000).

18. “The Transportation Analysis and Simulation System (TRANSIMS)” http://www-transims.tsasa.lanl.gov

19. “Transportation Management Plan for the Long Life Pavement Project on the San Bernardino Freeway (I-10) In the City of Pamona, California” Caltrans, July 1999

20. “Reducing and Mitigating Impacts of Lane Occupancy During Construction and Maintenance” *NCHRP Synthesis 293*, National Cooperative Highway Research Program, Washington, D.C., 2000, http://www.nas.edu/trb/index.html

21. “Kentucky Contract Time Determination System” Kentucky Transportation Center, Lexington, KY, May 2001

22. Herbsman, Z.J. and Ellis R. "Determination of Contract Time for Highway Construction Projects." *NCHRP Synthesis of Highway Practice 215*, National Cooperative Highway Research Program, Washington, D.C., 1995.

23. Scott, S. "Guidebook to Highway Contracting for Innovation: The Role of Procurement and Contracting Approaches in Facilitating the Implementation of Research Findings." *NCHRP Report 428*, National Cooperative Highway Research Program, Washington, D.C., 1999.

24. Anderson, S.D. and Russell, J.S. “Guidelines for Warranty, Multi-Parameter, and Best Value Contracting” *NCHRP Report 451*, National Cooperative Highway Research Program, Washington, D.C, 2001, http://www.nas.edu/trb/index.html

25. “Life Cycle Cost Analysis (LCCA) in Pavement Design” Report NO FHWA-SA-98-079, FHWA, U.S. Department of Transportation, Washington, D.C., 1998, http://www.fhwa.dot.gov

APPENDIX A

PROJECT DESCRIPTIONS

GEORGIA DOT INTERSTATE 475 PROJECT

Proposed Improvements

This project consists of widening, rehabilitation, and/or reconstruction of the existing concrete pavement. The proposed widening includes adding one lane in each direction in the median area. The project scope also includes replacing existing guardrail and anchorage, re-grading shoulders and medians, upgrading the pavement cross slope, raising overhead bridges, and adding a concrete barrier to the median. An intelligent transportation system (ITS) is also included in the project. The ITS includes installation of fiber optic cable, closed circuit television (CCTV) cameras, video detection systems (VDS), and changeable message signs (CMS).

Objectives

The project objectives identified for the selection process are:

- No additional right of way required;
- Minimize traffic disruption;
- Ease of construction; and
- Prompt design process.

Candidate Section

Some pertinent features of the project are:

- I-475 is a four-lane roadway begins in southern Bibb County at the interchange with I-75. It then proceeds northwest for approximately 23.9 km, terminating at the northern interchange with I-75 in Monroe County (see Figure A.1).
- I-475 is categorized as an Interstate Principal Arterial
- Interstate/regional travelers and local travel demand associated with on-going development of western Bibb County constitute the traffic volume
- The Average Daily Traffic (ADT) is approximately 23,850 in each direction
- Proposed changes would include rehabilitation or reconstruction of four lanes and adding an additional lane in each direction
- Traffic is composed of 26 percent heavy vehicles
- The present level of service is:
    - A.M. - Varies between LOS B and LOS C
    - P.M. - Varies between LOS C and LOS D
- Design traffic (in both directions) volumes are:
    - 47,700 ADT for the year 2002
    - 85,900 ADT for the year 2022
- The structural section of the pavement is:
    - 9" to 10 " of Plain Portland Cement Concrete Pavement
    - 8" Granular Subbase (Top 3" Bituminous Stabilized Material)

Source of Information

Project Concept Report I-475 Overlay and Widening IM-475-I (206) BIBB/MONROE Counties NCHRP 10-50A research Team and Georgia DOT interview presentation, December 22, 2000, Atlanta, Georgia.

MICHIGAN DOT US 23 PROJECT

Proposed Improvements

Improvements to US 23 consist primarily of major rehabilitation work on a 8.37 km pavement section. Proposed improvements also include restoration of guardrails, reconstruction of pavement sections under overpass bridges to meet vertical clearance requirements, complete rehabilitation of one bridge, and rehabilitation of ramps.

Objectives

The project objectives identified for the selection process are:

- Improve pavement condition (MDOT long-range goal of performing long term fixes on high impact corridors with heavy commercial traffic);
- Minimize traffic disruption;
- Accomplish work within existing right of way; and
- Optimize use of available funds.

Candidate Section

US 23 is a four lane divided freeway that runs north-south through the state of Michigan. This roadway consists of two 3.66m driving lanes, a 1.82m inside shoulder (0.91m paved) and a 3.05m outside shoulder (2.74m paved). The candidate section is a jointed reinforced concrete pavement (JRCP) and is located on US 23 in Livingston County. The project begins at M-59 and extends north 8.37 km to Fauset Road (see Figure A.3). The proposed candidate section consists of two 3.66m driving lanes and a 1.22m paved inside shoulder and a 3.05m paved outside shoulder. The existing pavement is severely deteriorated and requires heavy routine maintenance. The scope of this project also includes a complete bridge replacement. This bridge is located between M-59 and Ore Creek.

The pavement history of US 23 is:

- Originally constructed in 1961;
- Conducted several routine maintenance activities; and
- An intermittent maintenance bituminous overlay was applied to this pavement section in 1997.

The existing structural pavement section is:

- 229mm jointed reinforced concrete;
- 102mm select sub-base;
- 254mm sand sub-base; and
- 38mm intermittent bituminous overlay.

The identified current traffic volumes are:

- 47,000 ADT in both directions

Source of Information

NCHRP 10-50A research team and MDOT presentation interview, April 3, 2001. MDOT Pavement Selection Results, US 23 MDOT Bid Proposal, MDOT Pavement Design and Analysis System, and MDOT Maintaining Traffic Plan for the LCCA and Pavement Selection.

MICHIGAN DOT I-496 PROJECT

Proposed Improvements

Improvements to roadway I-496 consists primarily on major reconstruction work on a 4.07 km pavement section. It also includes reconstruction of 4 bridges.

Objectives

The project objectives identified for the selection process are:

- Improve pavement condition (MDOT long-range goal of performing long term fixes on high impact corridors with heavy commercial traffic);
- No additional right of way required;
- Funds available; and
- Minimize construction duration.

Identify Candidate Section

The existing roadway is a four-lane freeway that runs east-west through Ingham County in the state of Michigan. This roadway consists of two 3.60 m driving lanes with either curb and gutter or a 0.9 m paved shoulder in each direction. The candidate section is a Jointed Reinforced Concrete Pavement (JRCP) and is located on I-496 in downtown Lansing. The project begins at Cedar Street and extends to US-127 with a total length of 4.07 km. The proposed candidate section consists of three 3.60 m driving lanes and a 2.40 m paved inside shoulder and a 3.00 m paved outside shoulder.

The pavement history of I-496 is:

- Originally constructed in 1970

The existing structural pavement section is:

- 229 mm jointed reinforced concrete pavement;
- 100 mm select sub-base; and
- 250 mm sand sub-base.

Current traffic volumes are:

- 67,550 ADT in both directions

Source of Information

NCHRP 10-50A research team and MDOT presentation interview, April 3, 2001. MDOT Pavement Selection Results, I-496 MDOT Bid Proposal, MDOT Pavement Design and Analysis System, and MDOT Maintaining Traffic Plan for the LCCA and Pavement Selection.

CALTRANS INTERSTATE 710 PROJECT

Proposed Improvements

Rehabilitate the pavement structural section and metal median barrier. Outside lanes will be replaced with long life pavement along 22 km of the total length of 25.2 km (Del Amo Boulevard to I-10). The inside lanes will be repaired at spot locations by slab replacement. Outside shoulders will be widened to standards. Ramps will be overlaid with 100 mm of asphalt concrete.

Objectives

The project objectives identified for the selection process are:

- Provide a renewed pavement with a long service life (target 40 years);
- Minimize traffic disruption;
- Provide a safer environment for workers and highways users;
- Minimize short and long-term user costs;
- Minimize project life cycle cost to the agency; and
- Minimize community and environmental impacts.

Some typical project characteristics are:

- Originates at Route 47 in the port area of the city of Long Beach and terminates at Route 210 in the city of Pasadena
- The total length of the I-710 route section is 15.2 miles (Del Amo Boulevard to Route 10). Location of roadway is illustrated in the Figure A.6
- Serves a large volume of truck traffic
- Serves several recreational points of interest and heavy industry
- Operating conditions: Average Daily Traffic Volumes (ADT) for 1996 range from 130,000 - 218,000 for the segment under study for rehabilitation
- Accident data for this route show about 17 areas of high accident concentration, most of them traffic congestion related
- The construction cost has been estimated to be $60,000,000
- Project to be proposed to be funded from the State Highway Operation and Protection Program (SHOPP)
- Structure sections of the pavement are:
  - Basement soil
  - 200 mm Imported subbase
  - 200 mm Cement Treatment Base (CTB)
  - 200 mm Portland Cement Concrete Pavement (PCCP)

Source of Information

On February 16, 1998, the Workshop on Pavement Renewal for Urban Freeway was held at the Beckman Center at UC Irvine. FHWA, Caltrans, and the Transportation Research Board jointly sponsored this workshop to focus on the introduction of innovation to urban freeway pavement renewal. Four different workshop teams presented proposals for pavement renewal on I-710. These teams were designated as Blue, Yellow, Brown, and Green. References include:

- "Get In, Get Out, Stay Out!" (2000). Proc., Workshop on Pavement Renewal for Urban Freeways, Transportation Research Board, National Research Council, Washington, D.C.
- Fact Sheet - Pavement Rehabilitation Project Route LA - 710 KP 17.4/42.6, (PM 10.8/26.5)

CALTRANS I-10 PROJECT

Rehabilitate 2.8 lane-km section of the San Fernando Freeway (I-10) in one 55-hour weekend closure. During the 55-hour weekend closure, 2.8 lane-km of deteriorated concrete slabs would be removed and replaced in Lane Number 3. The location of the project, as seen in Figure A.8, was on eastbound I-10 between Fairplex Drive exit (station 704+80) and Garey Avenue exit (station 736+05). The purpose of the first 51 hours of the 55-hour weekend closure was to replace existing 204-mm concrete pavement slabs (PCC) in Lane Number 3 with the same thickness of new Fast Setting Hydraulic Concrete Cement (FSHCC). In areas where the base was seriously damaged from moisture and erosion, Fast Setting Hydraulic Cement Treated Base (FSHCTB) will be used to replace the existing base (full depth replacement option). The same mix was used for concrete base and slab. For this 2.8 lane-km stretch, Lane Number 4 had previously been rehabilitated through nighttime closures. Plan view of the lane closure tactics can be seen in Figure A.9.

Source of Information

Case Study of Urban Concrete Pavement and Traffic Management for I-10 (Pamona, CA) Project (8); NCHRP 10-50A research team and Caltrans interviews; and NCHRP 10-50A research team site visit during construction.

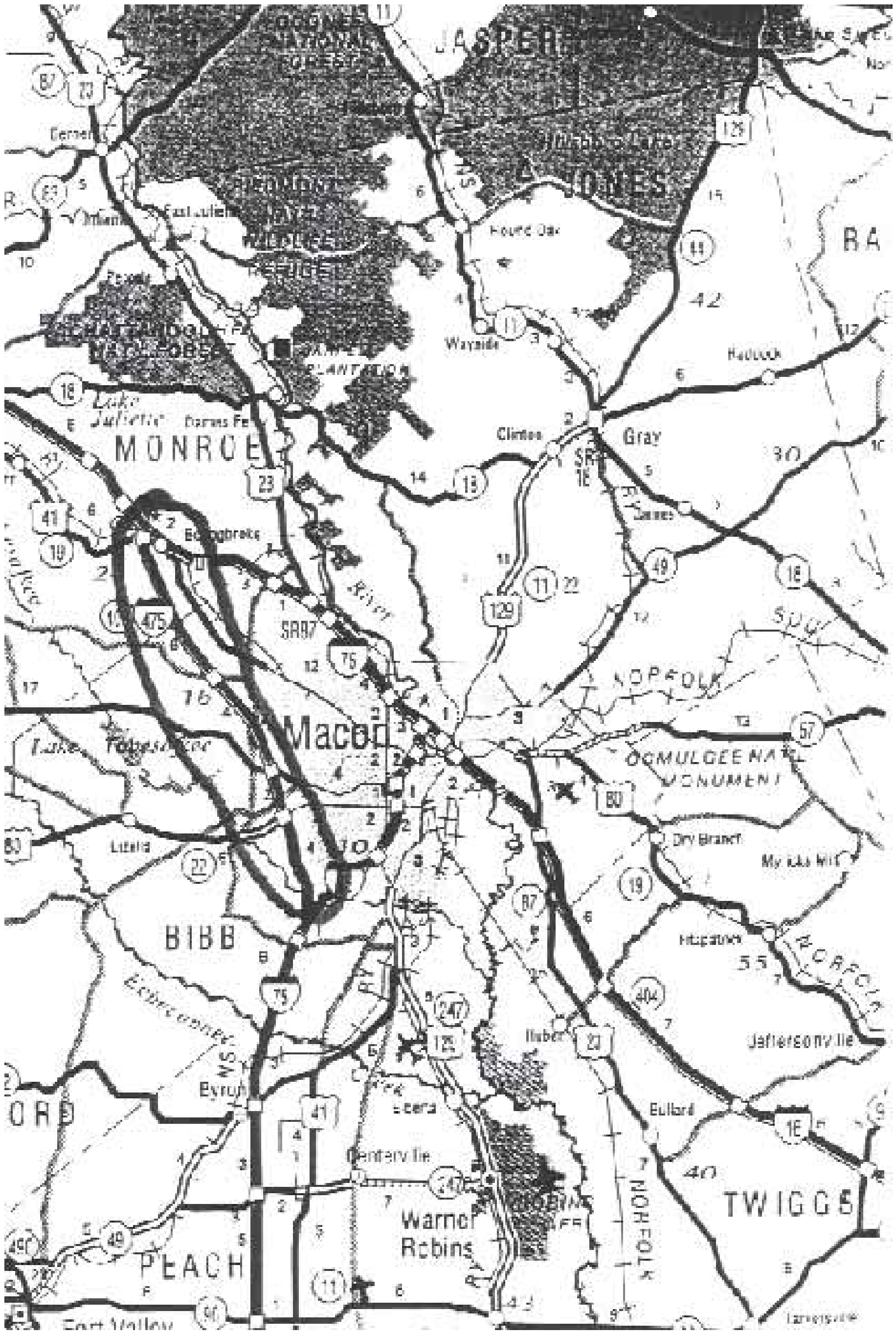

Figure A.1 I-475 Project Location

A typical cross section is shown in Figure A.2.

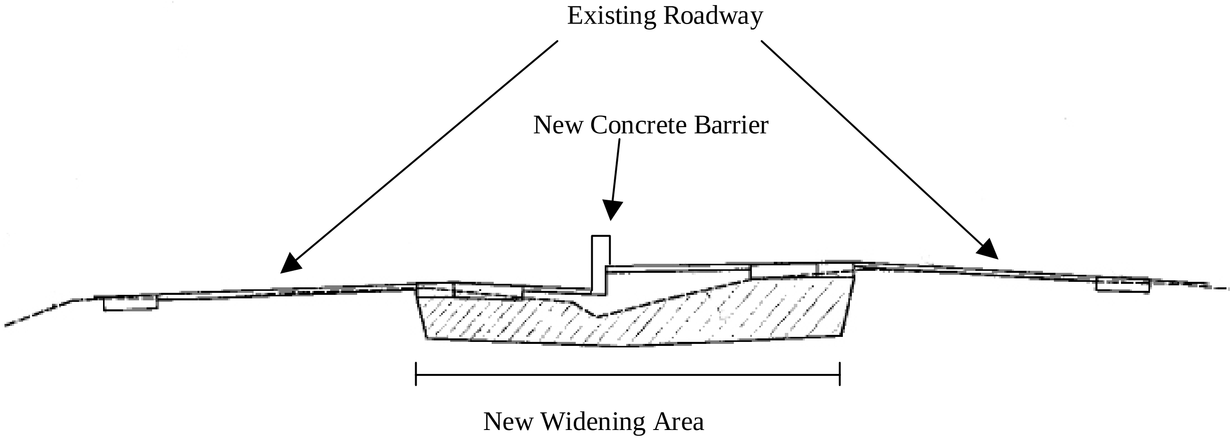

Figure A.2 Typical Improved Roadway Cross Section

Figure A.3 US 23 Project Location (www.state.mi.us; www.siteatlas.com/Maps/Maps/121.htm)

Typical cross section is illustrated in Figure A.4.

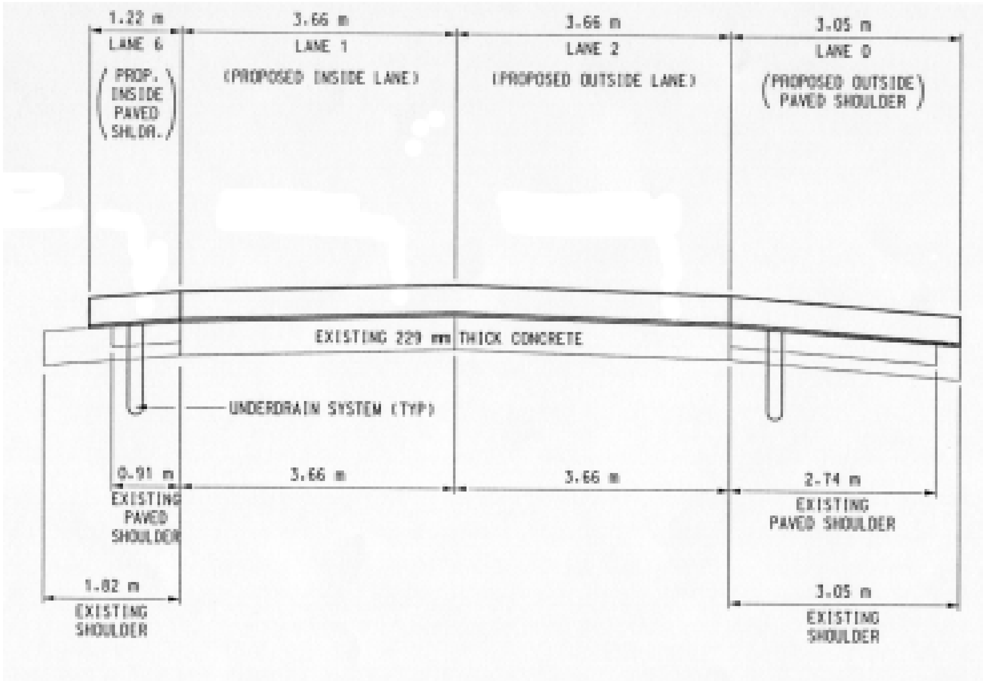

Figure A.4 Typical Improved Roadway Cross Section

Typical pavement cross sections are illustrated in Figure A.5.

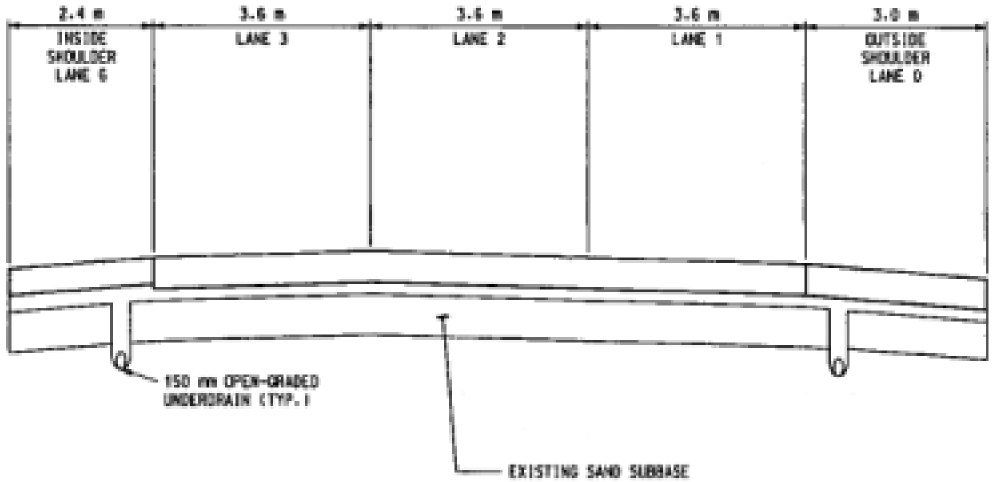

Figure A.5 Typical Improved Roadway Cross Section

Figure A.6 I-710 Project Location

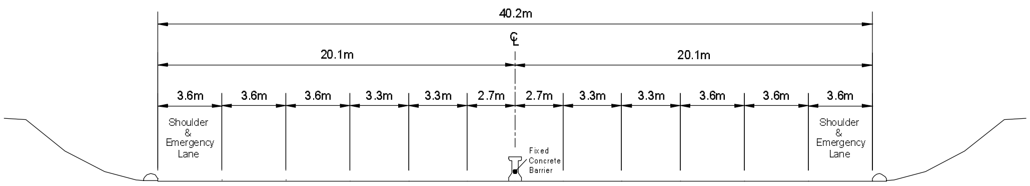

Figure A.7 Typical Improved Roadway Cross Section

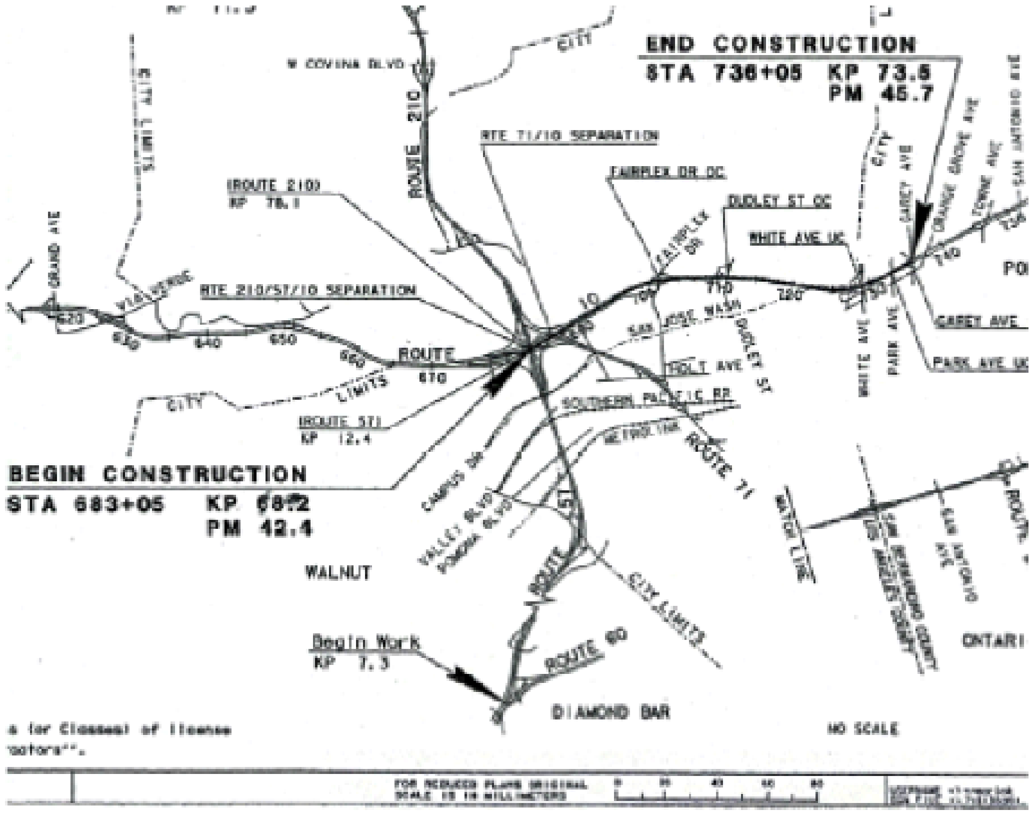

Figure A.8 Detailed layout of the I-10 project

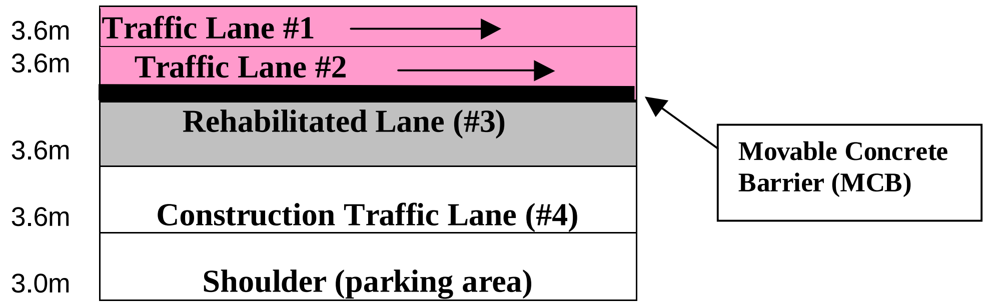

Figure A.9 Plan view of lane closure tactics

APPENDIX B

ILLUSTRATIONS FROM CASE STUDIES

STEP 3 SCREEN POTENTIAL STRATEGIES

Identify Feasible Strategies

Caltrans I-710 Project

Efforts by four different teams in the workshop on pavement renewal for urban freeways only identified the feasible strategies that could be applicable for project I-710 (see Appendix A for description). Therefore, Step 4, *Evaluate Feasible Strategies*, was not performed.

However, Caltrans did proceed with further evaluation of MRR strategies for the I-710 project. This effort resulted in a number of different iterations concerning the project. Each iteration evaluated another MRR strategy, at least to some extent. The following summarizes the strategies that were or are currently under consideration:

- Caltrans consider rehabilitating lanes three and four in each direction by replacing only the concrete pavement with a new pavement. The cement treated subbase was still considered adequate and did not need to be replaced as was suggested in the two feasible strategies presented under Step 3. Rehabilitating two lanes as an option was not pursued because Caltrans believed that eventually lanes one and two would have to be rehabilitated as well so the focus shifted to rehabilitating all four lanes in each direction.

- The next option considered was the use of innovative asphalt pavement design. This option was analyzed in some detail and a Project Scope Summary Report was prepared to allow the option to proceed into design. However, Caltrans management was not convinced that the asphalt pavement would last 30 to 40 years. The asphalt design that was specified had not been proven yet in terms of its design life. Caltrans has experienced long life from their PCC pavements. This option was not pursued for the portion of I-710 included in the case study presented herein. However, Caltrans opted to use the asphalt pavement design on another segment of the I-710 from Pacific Coast Highway north to I-405. This project will serve as a basis for testing the asphalt design both in terms of construction practices and design life. The project is currently under construction.

- The current option being considered for I-710 is a two phased approach using a concrete pavement. The first phase project will cover the I-710 freeway from I-405 to Firestone Blvd. This phase will focus entirely on pavement replacement with no bridge rehabilitation or replacement. The second phase will cover the segment of I-710 from Firestone Blvd. to I-10 as well as bridges from I-405 to Firestone Blvd. Again, pavement replacement will occur. In both projects, the subbase will remain in place (cement treated) and a new and thicker pavement will be placed.

STEP 4 EVALUATE FEASIBLE STRATEGIES

Analyze Traffic Alternatives

Georgia DOT I-475 Project

In the Georgia DOT I-475 project, two feasible MRR strategies were carried forward for further detailed evaluation. Figure B.1 provides a brief summary of some areas that were considered when assessing the impact of the two alternatives on traffic and the public in general. Notice that two approaches to handling traffic were analyzed for the concrete unbonded overlay option.

Caltrans I-10 Project

Caltrans developed a comprehensive traffic management plan (TMP) for their 55-hour weekend concrete placement project (see Appendix A for a project description). The cover of this plan is shown in Figure B.2. The TMP covers many of the issues considered relevant to extremely high traffic volume projects in urban situations. The main objectives of this plan are to minimize delay and maximize safety to the construction workers and the motoring public during the proposed three extended weekend closures, by:

- reducing traffic demand on Route 10
- managing/maintaining traffic flow through the corridor
- providing a safe environment for the work force and motoring public

The TMP consists of eight sections: 1) construction strategies; 2) public awareness campaign; 3) changeable message signs; 4) highway advisory radio; 5) construction zone enforcement enhancement program (COZEEP); 6) freeway service patrol; 7) traffic management team; and 8) alternate routes.

The construction strategies presented in the plan involve: 1) utilization of a movable concrete barrier instead of rubber cones or K-rail due to its advantage for quick installation, dismantling, and moving of the barrier system in short construction windows; 2) use of incentive/disincentive clauses to encourage as much rehabilitation during the 55-hour weekend closure as possible while maintaining adequate quality; and 3) use of extended weekend closures to test production rates.

The goal of the public awareness campaign is to provide timely information and regular construction updates to the local communities and motorists affected by the project. The primary objective of the changeable message signs is to reduce traffic congestion on the freeway mainline by distributing traffic demand throughout the corridor. Highway advisory radios will be used to inform motorists of the construction work and the work limits. Furthermore, along with changeable message signs, they can be used to provide information on alternate route traffic conditions and to reroute traffic to underutilized detours. The California Highway Patrol (CHP) will be utilized primarily on the mainline to: a) assist in the installation and removal of lane closures; b) aid disabled motorists; and c) provide presence to maintain the integrity of the work area. The freeway service patrol is a contracted towing service provided by the Metropolitan Transportation Authority and administered jointly by Caltrans and the CHP to assist and remove disabled cars to minimize congestion. The traffic management team will be used during the extended weekend closures to prevent accidents by warning motorists of abnormal downstream traffic congestion on the freeway. To relieve congestion and reduce motorists delay time, three primary city street detour routes will be signed to facilitate the movement of traffic.

Perform Constructability Analysis

Georgia DOT I-475 Project

The constructibility analysis for the Georgia DOT I-475 project included an assessment of proposed construction phasing (staging) strategies for each feasible MRR strategy. As pointed out during the traffic assessment, two phasing approaches were proposed for the concrete unbonded overlay and one for the asphalt overlay. These phasing approaches are shown in Figure B.3. A total time estimate for construction was also determined for each phasing approach.

Other construction related issues that were addressed when developing the phasing approaches included:

- Area to dispose of unwanted material
- Routes to transport unwanted material and incoming material during construction
- Bridges that did not meet the required vertical clearance
- Future rehabilitation work for each feasible alternative

This was necessary to insure a realistic analysis and that constructible approaches were proposed. Contractor input through a local professional association supported the analysis of the phasing approach for the unbonded concrete overlay.

Caltrans I-10 Project

Because of time constraints and safety considerations, Caltrans used a moveable barrier to set up the work zone for the 55 hour I-10 project. The barrier was set up prior to closure along the shoulder of I-10. The machine that moves the barrier to the location commenced work around 10:00 p.m. Friday evening. The barrier was moved one lane at a time, and its placement took a little over 30 minutes. Figure B.4 shows how this machine can place the barrier quickly even under traffic. Figure B.5 illustrates that when the barrier is in its position, a safe work zone is established for construction operations and the workers. Traffic can safely move through the work zone.

Georgia DOT I-475 Project
Traffic Assessment

- Assess ramp acceleration/deceleration lanes. They are in compliance with present criteria set forth in the Georgia DOT construction details. For that reason, no redesign of ramp configurations would be required.
- Assess mainline vertical alignment. It was in compliance with the 65/mph minimum design criteria. Therefore, no vertical realignment would be required to meet speed design.
- Assess traffic impact on proposed alternate routes. It was recommended that considerations be given for truck traffic being rerouted along I-75 during construction.
- Address traffic and public impacts using different traffic control approaches on I-475 and alternate routes. From this effort two traffic handling techniques were determined appropriate for the concrete overlay alternate and one traffic control approach was considered for the asphalt overlay treatment. Therefore, three MRR strategies were considered for further analysis.
- Use radio and television media to inform the public about the project and the potential alternate routes the public might consider using to avoid traffic congestion.
- Conduct public meetings.
- Perform surveys of the affected community and local public. The result of these surveys showed that 68 percent of the public supported the project with any of the proposed alternatives, and 6 percent did not. The issues that were frequently listed by the public on the survey were:
    - The need of noise or sound barriers along the roadway
    - The need of lights on exit lamps
    - The need of additional traffic signaling
- Install ITS (Intelligent Transportation System) changeable message signs on main road and alternate routes to inform traffic users traveling the road about updated conditions during construction

Figure B.1 I-475 Project Traffic Assessment

SETS FASTER, LASTS LONGER

TRANSPORTATION MANAGEMENT PLAN

For the

LONG LIFE PAVEMENT PROJECT

On the San Bernardino Freeway (I-10)

In the City of Pomona, California

JULY 1999

STATE OF CALIFORNIA
GOVERNOR GRAY DAVIS

BUSINESS, TRANSPORTATION AND HOUSING AGENCY
Secretary Maria Contreras-Sweet

DEPARTMENT OF TRANSPORTATION
Director José Medina

DISTRICT 7
DIVISION OF OPERATIONS

Figure B.2 Traffic Management Plan, Interstate 10, Pomona California

Alternative One

- Proposed treatment:
    - Widening and overlay with 250 mm plain portland cement concrete pavement
- Proposed basic traffic control strategy:
    - Maintain three lanes of traffic (for both directions) during construction phase
- Total time to complete: 25 months

Proposed Construction Stages

- Phase I
    - Reconstruct northbound outside shoulder (temporary lane closures)
    - Southbound traffic remain in place
    - Time to complete: 3 months
- Phase II
    - Shift traffic to northbound outside lanes
    - Construct inside northbound lane and shoulder
    - Construct temporary median
    - Southbound traffic remains in place
    - Time to complete: 5 months
    - Overlap of two months with Phase I
- Phase III
    - Shift traffic to new northbound inside lane
    - Overlay existing northbound lanes and outside shoulder (requires northbound exit and entrance ramps)
    - Southbound traffic remains in place
    - Time to complete : Five months
    - Overlap of one month with Phase II
- Phase IV
    - Shift northbound traffic back to existing northbound lanes
    - Reconstruct outside southbound shoulder (temporary lane closures)
    - Time to complete: two months
    - Overlap of one month with Phase III
- Phase V
    - Shift traffic to outside southbound lanes
    - Construct southbound inside lane and shoulder
    - Construct median including drainage
    - Install guardrail
    - Northbound traffic remains in place
    - Time to complete: five months
    - Overlap of two months with Phase IV
- Phase VI
    - Shift traffic to new southbound inside lane
    - Overlay existing southbound lanes and outside shoulder (requires southbound exit and entrance ramps to be closed for a period of 12-24 hours)
    - Northbound traffic remains in place
    - Time to complete: five months
    - Overlap of one month with Phase V

Figure B.3 (a) Georgia DOT I-475 Project Construction Staging Analysis for Alternate 1

Alternative Two

- Proposed treatment:
  - Widening and overlay with 250 mm plain portland cement concrete pavement
- Proposed basic traffic control strategy:
  - Maintain four lane traffic during construction phase
- Total time to complete: 27 months

Proposed Construction Stages

- Phase I
  - Reconstruct northbound outside shoulder
  - Southbound traffic remains in place
  - Time to complete: 3 months

- Phase II
  - Shift traffic to northbound outside lanes
  - Construct additional inside northbound lane and temporary lane
  - Construct temporary median and drainage
  - Southbound traffic remains in place
  - Time to complete: seven and half months
  - Overlap of two months with Phase I

- Phase III
  - Shift traffic to new inside northbound lane
  - Overlay existing northbound lanes and outside shoulder (requires northbound exit and entrance ramps to be closed for a period of 12-24 hours)
  - Southbound traffic remains in place
  - Time to complete: six months
  - Overlap of one and half months with Phase II

- Phase IV
  - Shift northbound traffic back to existing norhtbound lanes
  - Shift southbound traffic to new inside northbound lanes
  - Overlay existing southbound lanes and outside shoulder
  - Time to complete: nine and a half months
  - Overlap of one month with Phase III

- Phase V
  - Shift traffic to outside southbound lane and shoulder
  - Construct both inside shoulders and insider southbound lane
  - Construct median and drainage
  - Install guardrail
  - Northbound traffic remains in place
  - Time to complete: eight months
  - Overlap of two and a half months with Phase IV

Figure B.3 (b) Georgia DOT I-475 Project Construction Staging Analysis for Alternate 2

Alternative Three

- Proposed treatment:
  - Widening and overlay with asphalt
- Proposed basic traffic control strategy:
  - Maintain four-lane traffic during construction phase
- Total time to complete: 24 months

Proposed Construction Stages

- Phase I
  - Reconstruct both outside shoulders (temporary lane closures)
  - Time to complete: 6 months

- Phase II
  - Shift both directions of traffic to outside lanes
  - Construct both inside lanes and shoulders
  - Construct median and drainage
  - Time to complete: 10 months

- Phase III
  - Overlay both direction under traffic
  - Shape median
  - Time to complete: five months

- Phase IV
  - Shift traffic to existing northbound and existing southbound lanes
  - Complete median
  - Install guardrail
  - Time to complete: three months

Figure B.3 (c) Georgia DOT I-475 Project Construction Staging Analysis for Alternate 3

Figure B.4 Movable Concrete Barrier

Figure B.5 Safe work zone area, I-10 Pomona, California