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16. Abstract

This report identifies, describes, and discusses various methods of mitigating the adverse effects resulting from the reconstruction or rehabilitation of existing urban highways. The principal adverse effects include traffic congestion, public aggravation, inhibited access to property, hazardous and costly construction operations, and increasingly stressful management conditions for the Department. Those most affected by these urban construction operations are the providers (the Texas Department of Transportation and its agents) and the consumers of highway services (those highway users who operate or who ride in vehicles that travel the state highway system and those, such as abutting property interests, who are dependent upon the highway system for the delivery of clientele as well as goods and services).

Each of the distinct adverse effects can be identified as an economic loss, and some can be credibly quantified, but not all. Traffic delays resulting from highway rehabilitation construction are a costly economic loss suffered by highway consumers; delay caused by construction is generally considered to be the single most adverse economic effect for motorists. There are acceptable and available techniques that enable researchers to quantify these time losses (examples are given in this report). Short-term business losses, on the other hand, can be significant but are difficult to document reliably.

In this report, a mitigation measure is any method that shortens the duration of an adverse effect or reduces its severity. Mitigation measures may vary, ranging from expediting construction by direct measures (such as specifying priorities for construction scheduling), to expediting construction by indirect measures (such as permitting innovative construction practices), to severity-reduction measures (such as adopting an active public relations program). Thus, this report describes and discusses those mitigation measures that appear to have the best potential for implementation by the Texas Department of Transportation.

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EXPEDITING URBAN HIGHWAY CONSTRUCTION

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Research Report 1227-1

Expediting Urban Pavement Construction
Research Project 3-8-90/2-1227

conducted for the

Texas Department of Transportation

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

by the

Center for Transportation Research
Bureau of Engineering Research
The University of Texas at Austin

January 1993

IMPLEMENTATION STATEMENT

Those methods that expedite urban highway construction, when used at the start of the project and throughout the project, could provide considerable benefits to the Texas Department of Transportation and the consumer. Construction which has been expedited could reduce costs for (1) the Department, since agency, field, and administrative costs increase linearly with the duration of the construction; (2) the consumer or highway-user, since fuel loss, accidents, and time delays also increase linearly with the duration of construction; (3) business owners, that is, losses resulting from diminished accessibility; (4) highway contractors, that is, safety and administrative costs that are usually passed to the Department; and (5) third parties, that is, the loss of service resulting from construction (these third parties include public schools, law enforcement agencies, public transit agencies, the fire department, and users of overhead or underground utilities). In addition to these tangible benefits, there are also the intangible benefits that shorter-duration construction could provide the Department, the most important of which is maintaining credibility with the public, whom, after all, the agency is pledged to serve.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

DISCLAIMERS

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

NOT INTENDED FOR CONSTRUCTION, BIDDING, OR PERMIT PURPOSES

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SUMMARY

This report identifies, describes, and discusses various methods of mitigating the adverse effects resulting from the reconstruction or rehabilitation of existing urban highways. The principal adverse effects include traffic congestion, public aggravation, inhibited access to property, hazardous and costly construction operations, and increasingly stressful management conditions for the Department. Those most affected by these urban construction operations are the providers (the Texas Department of Transportation and its agents) and the consumers of highway services (those highway users who operate or who ride in vehicles that travel the state highway system and those, such as abutting property interests, who are dependent upon the highway system for the delivery of clientele as well as goods and services).

Each of the distinct adverse effects can be identified as an economic loss, and some can be credibly quantified, but not all. Traffic delays resulting from highway rehabilitation construction are a costly economic loss suffered by highway consumers; delay caused by construction is generally considered to be the single most adverse economic effect for motorists. There are acceptable and available techniques that enable researchers to quantify these time losses (examples are given in this report). Short-term business losses, on the other hand, can be significant but are difficult to document reliably.

In this report, a mitigation measure is any method that shortens the duration of an adverse effect or reduces its severity. Mitigation measures may vary, ranging from expediting construction by direct measures (such as specifying priorities for construction scheduling), to expediting construction by indirect measures (such as permitting innovative construction practices), to severity-reduction measures (such as adopting an active public relations program). This report documents and discusses the investigations that identify various methods of mitigating adverse effects. These investigations included a literature review and a mail survey of selected correspondents from the Department and from highway contractors. In addition, business owners and operators (whose businesses adjoined a highway construction project) were interviewed in situ in order to better understand the effects of construction operations on their commercial activities. Other selected Department representatives and highway contractors were interviewed at length and their counsel and advice were sought regarding construction mitigation measures. This report describes and discusses those mitigation measures that appear to have the best potential for implementation by the Texas Department of Transportation.

CHAPTER 1. INTRODUCTION

BACKGROUND

As the emphasis of national highway program activity shifts from the construction of new highways to the rehabilitation of older, existing ones, state highway departments are finding that a considerable amount of time and money is needed to offset or to mitigate the adverse effects resulting from construction activities within urban areas. The Texas Department of Transportation, keenly aware of these problems, has made an effort — which is demonstrated by their sponsorship of this research project — to address the issues associated with rehabilitation construction. This report, then, identifies and assesses various methods of expediting urban highway construction. Some of the economic and sociopolitical issues associated with the problem are introduced in this first chapter, along with an outline of the objectives of the research effort.

DEFINING THE PROBLEM

Urban construction operations undertaken to improve, rehabilitate, and reconstruct urban highways and streets represent a significant challenge for state highway departments. These construction operations can generate considerable environmental and public-relations problems (albeit transient) that should be, wherever possible, anticipated and managed. In an urban environment, conflicts between construction operations and consumers of highway services (conflicts that might be considered inconsequential in a less congested environment), become management problems instead of passing events. For example, intense competition may develop between the department's contractor and other users of the rights-of-way for both space and time. It is the responsibility of the department to partition the rights-of-way among the competing interests, and to determine which of (or whether) the competing parties should share project resources of space and time. Thus within a project, the planning and management of the resources of space and time are important responsibilities for the department, inasmuch as misallocation can generate considerable discord among the competing interests.

Unfortunately, most highway design and construction practices were developed for highway construction at new locations or within a rural environment. These older practices do not always adapt very well to urban environments, where intense traffic conditions and land development combine to inhibit construction operations. For example, existing routes warranting improvements are also the routes most likely to carry large volumes of traffic and, hence, to attract substantial business activity dependent upon that passing traffic. With greater traffic and business activity, the likelihood is greater of finding conflicting underground and overhead utilities sharing the rights-of-way. The presence of utilities and their disposition aggravate the other problems that may arise in efforts to accommodate traffic operations and accessibility.

Thus, the execution of urban highway construction activities—while maintaining traffic viability, land management, and utilities services—can generate a number of undesirable effects, including:

(a) congestion, resulting in increased user costs owing to delay;

(b) increased safety costs throughout the construction zone for highway users and the contractor;

(c) higher fuel costs for consumers and, thus, higher vehicle operating costs that result from excessive idling and from having to take longer alternative routes to avoid the construction zone;

(d) restricted access to commercial property, leading to a drop in business during the construction period;

(e) complaints from highway users and property interests because of losses described above;

(f) interference with third parties (particularly utility owners), whose services may be restricted to accommodate construction activities; and

(g) complaints from delivery services dependent on the use of certain highway facilities; this effect can be critical if it involves emergency medical services or fire protection.

In addition, the department's responsibility for maintaining a balance between competing interests can be further complicated if the contractor wants the site conditions changed because of unexpected interference Also, the costs of unexpected congestion and property-accessibility inconveniences can impair the agency's credibility with the public.

These and other negative consequences of improving highway facilities can be reduced if the duration of construction is reduced. Thus, while an effective traffic control plan reduces the undesirable effects of construction operations, it will be a much better plan if the work is accelerated.

Yet these plans and methods are effective only insofar as they are able to redress the grievances of *all* parties involved. In researching this issue, the study team identified five principal interests involved in and affected by the department's construction operations (assuming the contractor is an agent of the department). These five interests, along with some of the construction costs imposed on them, include:

(1) *the department* — increased construction costs and possible loss of credibility;

(2) *highway users* — additional costs (fuel, time, and accidents) owing to traffic delay within construction zones;

(3) *property interests abutting construction zone* — possible economic losses resulting from diminished accessibility;

(4) *the highway contractor* — increased costs that are passed on to the department, and an increased risk of liability that may be passed on to the department; and

(5) *third parties* — loss of services and/or ability to supply public services. (Third parties would include, for example, users and owners of overhead and underground utilities, as well as the fire department, law enforcement agencies, public schools, and public transit agencies, or any public service organization that uses the facilities of the highway.)

By viewing construction operation problems as a system of interrelated obstacles, the department can bring to the construction site a broad range of design and management responses. However, "solutions" to construction problems often create conflict among the five principal interests (an inevitable occurrence perhaps) and may involve both quantifiable and unquantifiable alternatives. The department's assessment of the competing and often conflicting desires of the various interests must be equitable. Ideally, the preferred solution is to minimize the total project cost for *all* interested and affected parties. The total cost in this instance is a combination of the department's construction and maintenance expenditures, and the consumers' transient costs generated by the construction operations. In descending order of quantifiability, the principal economic effects include construction costs, maintenance costs, and consumer-related costs. Each of these will be treated in detail in Chapter 4.

Presently, department responses to problems resulting from construction activities range between two extremes. One extreme is to *eliminate or to avoid all conflicts* that involve construction activities and the parties who consume highway services. An example of this is the planning of disruptive and conflicting construction during periods when the demand for highway services is minimal. The other extreme would be to *minimize the duration of adverse effects* by expediting construction operations. An example of this approach would be a situation in which the contractor is permitted to have exclusive use of the highway rights-of-way for construction operations, while denying highway services to consumers. In this case, conflicting uses of the rights-of-way would be minimized at the expense of consumers, though the duration of the shutdown would be short. In other circumstances, if the effect of construction on fronting commercial activities is the principal concern, construction practices may be modified to minimize the disruption of access. Such modifications may require a slower construction schedule and higher initial costs to accommodate customer access to abutting property. When total system costs are assessed, the slower schedule may represent the most desirable alternative.

The application of appropriate responses to construction-induced problems should be carefully considered by managers responsible for each step of project development. These steps cover planning, design, contract management, and, ultimately, maintenance and operations. Specifically, typical responses might address one or more of the ways of mitigating adverse effects, which are as follows:

(a) innovative construction methods, materials, and equipment;

(b) construction contract provisions providing for incentives and/or penalties for early and/or late completion of work;

(c) innovative design practices;

(d) more sophisticated traffic handling schemes;

(e) end-result specifications;

(f) nontraditional time-periods to conduct construction operations;

(g) intensified program of public responsiveness and information by Department

(h) rescheduling of utility adjustments;

(i) reduction in end-product tolerances for some items of construction work; and

(j) re-assessing the role of risk sharing between the Department and the contractor.

To some degree, the users of highway services (including property interests, customers of other utilities that depend on highway rights-of-way, and vehicle operators) are aware of the Department's construction dilemmas, and they accept the costs of highway services, one of which is their (the user's) forbearance when highway services (and perhaps other utility services) are cut back during construction and maintenance operations. Even property interests have been known to tolerate a reduction in business during construction operations, if there is the prospect that the construction operations will *improve* traffic service. Consequently, highway engineers have some latitude in determining the need for and the degree of reconstruction mitigation measures.

The degree of tolerance to be expected from highway users depends on the degree of traffic congestion and the economic consequences of the congestion. An estimate of consumer tolerance must rely exclusively on local experience (since there are no other guidelines as cogent). It is important to note that these thresholds of tolerance will vary, sometimes dramatically. They might vary from one project to another, or from one location to another on the *same* project, depending on user alternatives, local expectations, and the purpose and characteristics of the traffic, i.e., local traffic, through traffic, percent trucks, and the duration of peak traffic periods. Here, one begins to understand that mitigation (or expediting) measures—to be effective—often require considerable social and public relations skills by the Department; in other words, effective expediting measures can be as much an art form as they are an exact science. This art form, unfortunately, will have to be practiced whenever public agencies undertake activities that require a disruption of public service. Because the public's perception of the problem is never static, individual responses to a given disruption could conceivably range from indifference to outrage. Clearly, the Department lacks sufficient resources to negate every adverse effect during construction and maintenance operations; in fact, in the long run, when more resources are allocated to mitigating short-range problems, there will be fewer resources for constructing new facilities. Again, local experience will guide assessments of user tolerance. Eventually, though, a community's threshold of tolerance will drop as urban traffic conditions worsen and as users become more dependent on the existing highway facilities.

Finally, before any urban construction project is undertaken, there is an essential question that needs asking: "Should this project be expedited?" As this report will show, there is a great range of expediting responses that can be applied to any project. In the end, it could even be said that *whatever* harmonizes the various competing interests — and gets the job done at the same time — is an expediting measure.

SCOPE OF STUDY

The title originally given to this study, "Expediting Pavement Construction," suggests a solution to, rather than a definition of, a problem. Following an initial review of the literature, and after discussions with various representatives from the Department and FHWA, it became evident that expediting pavement construction was only a part of a much larger issue—namely, to *mitigate the adverse effects derived from construction operations*. Accordingly, this study examines *transient* adverse effects derived from construction operations and the costs borne by consumers of highway services because of construction operations. These adverse effects are of *limited* duration, and therefore transient, when compared to the subsequent operational life of the highway facilities provided by the project.

Of particular significance to both the Department and to this study was the point of view of the consumer regarding (within a particular project) problems with the traffic services provided during construction operations. Here, the term "consumers" can represent various interests. The consumers of highway services, for example, are those who use highways for mobility and property access. Additionally, there are utility services located within the highway rights-of-way, and the consumers of these utility services may also be affected by construction operations. Finally, there are the consumers of mobile services (fire protection, ambulance and postal service, and law enforcement) that depend on highway facilities for the transportation of these necessities. The consumer's point of view is this: if adverse effects cannot be eliminated, then the *duration* of these effects should be minimized. Accordingly, an effective method of reducing the duration of construction operations is to expedite pavement construction, since pavement installations probably account for one-half or more of the total cost of the typical urban highway project.

However, there are other significant factors that affect the development and management of a project and that influence construction duration and adverse effects. These other factors, which include the weather and the actions of third parties, can be very unpredictable; yet they are particularly important, since they may aggravate the adverse effects of those projects that are inherently difficult to manage. When considering troublesome projects, planners should attempt to provide consumers with an environment as minimally objectionable as possible. Accordingly, this study, looking beyond pavement construction issues, addresses those factors believed to be relevant to the overall issue.

OBJECTIVES

The primary objective of this study was to find ways of mitigating the adverse effects of urban construction activities. Various mitigating measures, identified by and related to the principal factors affecting highway construction, are categorized as follows:

(1) materials,

(2) design practices,

(3) construction practices,
(4) traffic handling,
(5) utility adjustments, and
(6) public relations.

The study team considered both positive and negative mitigating measures — positive measures being those actions that might be considered innovative to the Department, negative measures being those older standard practices that hinder expediency and that deserve rejection. The effectiveness of a mitigating measure is assessed by both construction duration and identifiable economic costs.

SCOPE OF REPORT

This research report is divided into six chapters. The first chapter presents a background, a definition of the problem, the study scope, and the objectives of the research. Chapter 2 describes the research methods and the sources used in this study. In addition, Chapter 2 explains how the scope of the study was broadened (as a result of these research methods) to include techniques of mitigating the adverse effects of urban highway construction. The discussion particularly focuses on both the literature review and on the results of the surveys of TxDOT officials and highway contractor representatives. Chapter 3 defines some of the environmental and sociopolitical effects of urban highway construction.

In Chapter 4, some of the costs associated with highway construction operations are quantified. These expenditures include Department, consumer (or user), and business costs. The discussion centers on the very substantial costs borne by users, that is, fuel and time losses. Business owners were surveyed several times, and survey results are presented in the last section of the chapter. The results point out, in particular, the various costs that businesses pay when their access and activities are disrupted by highway construction.

Chapter 5 documents and analyzes the results of several surveys garnered from contractors, businesses, and Department officials. Through these survey results, the study identifies those mitigating measures that most effectively harmonize the various interests that are often at cross-purposes during the duration of construction operations. Finally, Chapter 6 describes how these expediting measures can be effectively implemented.

CHAPTER 2. METHODS OF RESEARCH

BACKGROUND

The principal objective of this study was to find and to recommend ways of expediting urban highway construction. As a corollary, the study also addresses the larger issue of finding ways of mitigating the *adverse effects* of urban construction. At the beginning of the study, it was generally assumed that *expediting* construction operations was a certain and universal solution to most of the problems that might arise from construction operations within an urban environment. As the research progressed, the study team found that many parties having an interest in the progress or outcome of a particular highway project did not feel that expediting *per se* was always their foremost concern. It was often asserted that adverse construction effects could be avoided or handled cost-effectively by means other than that of paying a premium for reducing the time of construction for a particular project. From the owner's viewpoint (in this case the Texas Department of Transportation), when planning a project, one should first assess the *need* for fast-tracking or *other alternatives* before hazarding additional *costs* to expedite a project. This would mean that the total cost would include not only the owner's cost, but also the cost allocated to all others affected by or having an interest in the project.

SOURCES OF INFORMATION

Consequently, the research team increased the scope of the investigation to include such issues as the following: users' costs; the effect of construction operations on abutting property interests; contractual means of applying incentive and penalty measures; project management; and the mitigating effects of active project-specific public information programs. In pursuit of their study objectives, project researchers elicited relevant information from the following sources:

- Published literature
- Texas Department of Transportation
- Selected highway contractors and material suppliers
- Other governmental agencies
- Trade and institutional societies
- Property interests

METHODS OF ELICITING INFORMATION

The methods used for finding and evaluating information included the following:

Literature Survey

The Center for Transportation Research operates and maintains a computer terminal having access to the following databases:

TRIS. The Transportation Research Information Service is supplied by the Transportation Research Board and incorporates information provided by many other transportation agencies, including the FAA, FHWA, Maritime Administration, Federal Railroad Administration, UMTA, and selected foreign and international transportation agencies. An estimated 350,000 records are available.

COMPENDEX PLUS. Produced by Engineering Information, Inc., COMPENDEX PLUS is the on-line equivalent of *Engineering Index,* with additional coverage of conference proceedings. COMPENDEX PLUS provides worldwide coverage of engineering and technical literature, including journal articles, technical reports, conference proceedings, engineering society publications, and books. As of January 1988, 2.2 million records were available.

NTIS. Produced by the National Technical Information Service of the U.S. Department of Commerce, this data base contains reports from all research, development, and engineering projects sponsored by the U.S. government and prepared by government agencies, their contractors, or grantees, as well as some research from other countries. The database, updated biweekly, included 1.4 million records as of late 1987.

TTS. The Technology Transfer System (TTS) is an automated information retrieval system for technical materials contained in the Technology Transfer Library of the Texas Department of Transportation.

TAMLIB. TAMLIB is the on-line catalog of Texas A&M University.

UTCAT. The University of Texas Catalogue contains partial holdings of all the libraries of The University of Texas at Austin, and the complete book holdings of the Richard W. McKinney Engineering Library. UTCAT provides author, title, title key word, and subject access to books, reports, and UT theses and dissertations.

In this search, effective key words were found to be fast track, expediting, rapid construction, pavement construction, urban construction, night construction, and precast.

A study team, composed of Dr. Frank McCullough, research associates W.V. Ward and Ken Hankins, and graduate students Bruce Long and Alan Butler, was organized to review and to evaluate relevant material obtained from the data sources listed above. By using selected key words, a body of titles and abstracts was extracted from the various databases; from these, 241 referenced documents were selected for evaluation. After reading and evaluating the 241 documents, the study team finally selected 52 that they considered germane to the objectives of the study. The team members made a final evaluation of the 52 documents by categorizing the essential information and by assessing the relevance of the information contained in the documents. An evaluation form was designed and was used to display the results of the assessment.

Meetings with TxDOT Representatives from Selected District Offices

Officials from several district and administrative offices were selected to participate in technical resource committees that were set up to advise the CTR study team on how best to meet the objectives of the study. Members of the committees represented the concerns of the

Department statewide. Three regional meetings were convened. The regional meetings were attended by the following selected districts:

- El Paso — Districts 4, 24, and 25, and D-8. May 4, 1990
- Dallas — Districts 2, 18, and 19, and D-8. June 25, 1990
- San Antonio — Districts 12, 14, 15, and 21 and D-6 and D-8. June 26, 1990

Meetings with Selected Highway Contractors

Informal meetings were arranged between selected highway contractors and members of the CTR study team. The contractors, who were petitioned for these informal discussions, were recommended by members of the Technical Resource Committee on the basis of their (the contractors) experience in constructing highway facilities in urban areas for the TxDOT. These contractors' suggestions and concerns provided the framework for the questionnaires subsequently prepared for submission to the Department and to other highway contractors.

Survey of Department Representatives

The study team prepared a questionnaire for presentation to the Department's engineers and technicians. The purpose of the questionnaire was to solicit opinions concerning construction expedients and impediments, as well as other issues previously identified and selected from the literature survey, TxDOT regional meetings, and individual contractor interviews. Of the 243 questionnaires submitted to Department employees experienced in highway construction, 239 were completed and returned.

Survey of Highway Contractors

Next, the study team submitted a questionnaire to a group of highway contractors that was similar to the questionnaire the Department received. The questionnaire (modified slightly) omitted references to methods of administering working time. Questionnaires were sent to 300 contractors (representing 210 contracting firms nationwide) who had had contracting experience in Texas. There were 27 questionnaires—representing 17 different contractors—completed and returned.

Institutional and Trade Societies

Several institutional and trade societies associated with or having an interest in highway construction were contacted for relevant information. Those contacted included the following:

- The Asphalt Institute
- The Associated General Contractors of America
- The American Concrete Pavement Association
- The National Association of County Engineers

- The National Asphalt Pavement Association
- The American Public Works Association
- The Portland Cement Association
- The National Stone Association
- The American Concrete Institute

None of the above organizations furnished specific data or information that was directly applicable to the study. The received replies were only of general interest. Typically, these organizations lacked the resources to provide specific information for the study, suggesting instead that the information be elicited from other sources. (The suggested sources were generally included in the information catalog previously identified as available to the study team.)

Property Interests

The study team visited selected project sites in San Antonio, Houston, Dallas, and Childress to appraise the effects of construction operations on abutting property interests. The team intended to interview selected property dependents who had a concern about and knowledge of the effect of construction operations on adjacent property interests. Prior to the field trips, the team met with right-of-way representatives from the TxDOT District 14 office in Austin to discuss adverse property effects. The study team subsequently decided to visit only those project sites whose construction activities affecting abutting property were completed, and whose temporary traffic operations were restored to normal. Project staff predicted that users of property abutting active construction might prematurely judge the long-range benefits of a project based on temporary inconveniences and losses suffered during construction. Similarly, Department representatives believed that interested and affected parties would be more likely to take into account *both* the future benefits of an improved facility and the temporary adverse effects of the construction *after construction* had been completed.

CHAPTER 3. ENVIRONMENTAL AND SOCIOPOLITICAL EFFECTS

BACKGROUND

Accessibility and traffic-operation problems resulting from construction affect both the consumers and the providers of highway services. As a provider of services, the Department is primarily concerned with the consumer's perspective of these problems, as well as with the amount of resources these problems should receive. This chapter, focusing on the environmental and sociopolitical effects of construction, will show that construction-related problems can be understood best if it is known how and to what extent these interests (consumers and providers) interact, since construction-related problems affect both interests simultaneously.

As discussed in Chapter 1, the construction of a highway facility within an urban environment can adversely affect traffic operations and can impede access to property. Although the Department's principal function is to provide highway services, there are many instances when these services, along existing facilities, may have to be abridged or suspended *temporarily* for purposes of maintenance or reconstruction.

These short-range construction-related problems form part of the more general issue of environmental and socioeconomic effects. The need to alleviate temporary construction-related effects can be compared to the need to alleviate any long-range adverse effects which may result from the presence of a highway facility, its associated traffic operations, and induced land use. These mitigation measures can be incorporated into the permanent physical structure of the facility, or installed temporarily where needed and as needed. Similarly, mitigation measures may be used to relieve or to contain the short-range or temporary problems caused by traffic operations.

As outlined in Chapter 1, the two groups affected by construction operations are (1) the consumers and (2) the providers of highway services. Consumers are those individuals who are afforded services, directly or indirectly, by a particular (for the purposes of this study) highway facility; the providers include the Department and its agents. Mitigation measures, on the other hand, are actions by the Department and its agents that reduce consumer aggravation and impediments that result from highway construction activities. Additionally, since any mitigation (or expediting or fast-tracking) measures adopted may require substantial resources, it is also desirable to assess the effectiveness of those measures. Their effectiveness will, in large part, depend on the expectations, resources, and risk tolerance of the various interests affected by the construction operations.

Mitigating adverse construction effects is a *consumer demand*, which is influenced by the consumer's perception of the loss of normal or expected highway services during the construction period. Consumers judge the severity of a service loss by how much and how often their activities and expectations are inhibited by construction activities. An assessment of the *need* for and the scope of the mitigation measures to be adopted is one of the first and most important steps in project planning.

In assessing the need for and the scope of the mitigation measures, it is important to understand the travel-demand characteristics of the highway users in the affected traffic stream.

The trip demands of highway users cover a wide range of consumer needs that vary from commuter trips, to emergency medical evacuations, to pleasure driving. The characteristics of disparate trip demands can have a significant effect on the manner in which highway users perceive and tolerate construction-related restrictions on their anticipated trip benefits. Commuters who frequently pass through a construction zone are likely to be more sensitive to the effects of construction operations than other users who pass through only infrequently; that is, "through" traffic may perceive construction delays differently from "local traffic." And caterers of goods and services will be more aware of increases in operational costs as well as their customers' reluctance to negotiate construction obstacles. Businesses with access to abutting highways have an interest in the passing traffic that is proportional to their dependence upon the passing traffic for clientele. Other consumers of highway services will, in a manner similar to that of highway users, perceive construction effects in accordance with their own interests.

It is important to ascertain and to understand the interests of both the consumers and the providers of highway services if the conflicts among the various users and the providers are to be resolved and if the providers of highway services are to meet the demands of the consumers.

Because an objective of this study is to provide an understanding of these interests so as to suggest feasible mitigation measures that might alleviate service problems, a discussion of consumer and provider interests (along with the associated mitigation measures that affect both) is provided below. The purpose of this discussion is to find a balance between the various interests — one that is at least tolerable, if not acceptable, to all concerned.

CONSUMERS' INTEREST

Direct consumers (referred to as "users" in this study) include the actual vehicle operators and their passengers; *indirect* consumers include property owners who may be dependent upon the use of highway facilities *by others* for the delivery of clientele, goods, and services. For the purposes of this study, the consumers' interests that will be addressed are those *directly* affected by construction operations. There are, of course, *indirect* interests (similar to the *direct* interests) that are adversely affected, but these indirect interests are difficult to identify, and even more difficult to assess in terms of size. For example, traffic moving through a construction zone or being detoured or diverted from a construction zone is said to be *directly* affected. *Traffic using other routes*, when joined by traffic detoured or diverted *from* a construction area, may be *indirectly* affected. Similarly, access to property abutting a construction work zone may be *directly* affected, whereas property that adjoins routes conveying detoured or diverted traffic is considered to be *indirectly* affected.

Users' interests are primarily thought of as economic, since a consequence of construction operations may be a temporary increase in the cost of travel. Travel costs are normally considered to be *time, vehicle operations, and safety.* Time costs, as perceived by the user, may be defined as the *additional* travel time or delay that is incurred from traffic congestion resulting from the requirements of construction activities. Operational costs are the increased cost of operating a vehicle through a construction zone. Such costs result from additional engine idling time and stop-and-go driving conditions. Safety costs are symptomatic of the economic loss associated with any *increase* in the number and/or severity of vehicle related accidents resulting from construction operations. Normally, users' time or delay costs, resulting from recurrent congestion, constitute by far the largest share of users' costs. Consequently, only users' time costs are frequently cited as a severity index or a measure of users' losses resulting from construction operations.

A planner should assume that the experienced highway user will, to a certain degree, tolerate infrequent and brief interruptions of service as part of the cost for using a vehicle. Tolerant behavior is further reinforced by day-to-day traffic-service interruptions such as traffic incidents and inclement weather. There is, however, a threshold level of conditions beyond which even the most tolerant user will begin to feel deprived, perhaps vindictive, unless services are improved. It would be useful in scheduling the allocation of scarce highway funds if the economic cost of a *tolerable* threshold were known. This threshold would also provide a useful means of distinguishing between projects that should be candidates for special mitigation planning and those that should not be. But because such tolerance thresholds are at best subjective assessments, they can never become standards for estimating costs.

However, some user costs, such as service delays and vehicle operations, can be credibly estimated. Costs resulting from impaired access to property, for example, involve loss of business and decline in property values, as well as the general nuisance and exasperation of having one's access impaired. That some of the costs cannot be credibly quantified does not make these costs less acutely perceived by users; accordingly, any justification for adopting a particular mitigation measure will have to be based partly upon quantifiable costs — treated in greater detail in the next chapter — and partly upon subjective evaluations.

OWNERS' INTEREST

The Department's (or in the general sense, the owner's) principal interests are economic and political. The Department has certain responsibilities — namely, to see that the demands of the consumers are fulfilled, insofar as resources permit, and that these resources are expended cost-effectively. The economic interest hinges on the potential cost of mitigation—that is, the allocation of resources for *temporary* services as an *alternative* to investments in permanent (long life-cycle) facilities. If the owner does not provide mitigation measures, the consumer may be penalized economically. This economic loss, in effect, amounts to a temporary tax on the consumer, in the form of a sufferance, as a result of the mitigation measures not provided. There is another way of looking at this temporary tax; from the Department's standpoint, it is a release from an obligation — an obligation otherwise payable. However, by not providing mitigation measures, the Department's credibility with the public may suffer. The Department also has an important political interest which extends beyond its primary responsibility of furnishing and maintaining highway services. This political interest is important because the Department is a public agency, and, therefore, it is accountable to the state's citizens and lawmakers. Good political relations can be maintained with the public by the *manner* in which the primary responsibility is discharged, by realizing the value of the public's support, and through a responsive public relations campaign aimed at earning the public's respect. A public relations strategy should include providing mitigation actions and responding to the expressed concerns of the consumers of highway services by keeping them informed of the Department's plans and operations. An active public relations program is in itself a mitigation measure, since the program may increase consumer tolerance of adverse effects. Even though the Department's credibility with the public cannot be quantified in an economic sense, it should be considered along with the mitigation measures that *can* be quantified.

Department resources are restricted financially and administratively. Limits placed on financial resources determine the amount of services that can be delivered, while administrative constraints (derived from statutory authority) control and limit the Department's ability to deliver certain mitigation measures. These constraints are generally intrinsic to any public agency charged with maintaining high standards of accountability and credibility. Thus, Department-sponsored construction activity is in many ways more circumscribed by laws and regulations than similar work implemented in the private sectors of construction. There is, however, no relevant analogy between providing highway services in the public sector and in the private sector, since practically all public roads are planned, implemented, maintained, and operated by public agencies. The exceptions to this rule may be the toll-road authorities who plan, construct, and operate toll roads; and real estate developers who plan and construct city streets but who do not usually maintain or operate these facilities. It may be argued, nonetheless, that toll road authorities exhibit some of the characteristics of both public and private agencies.

The principal differences between the public and the private sectors in managing construction contracts involve the selection of contractors, the employment of personnel, the use of production incentive measures, negotiating contract changes, public accountability, and an ability to respond to a rapidly changing economic environment. It is interesting to note that these differences are recognized by law and can be abridged, by the state, during times of national emergency or even during times of limited emergency. It is not considered good public policy to employ emergency methods in a normal environment, since such actions may be considered wasteful of resources and lacking in accountability. Consequently, the Department is, to a degree, limited in its ability to manage mitigation measures because of administrative constraints. Examples of these administrative limitations are (1) the ability to attract, train, and retain qualified technicians to manage around-the-clock, seven-day-a-week operations by a contractor and (2) the authority to negotiate the selection of contractors on the basis of price *and* performance. These various administrative boundaries have to be understood and considered when planning and adopting mitigation measures.

CONTRACTORS' INTEREST

Contracting for highway construction always includes an element of risk. Risks are those events and conditions a contractor may encounter that are difficult to predict—particularly their timing, cause, and effect. (Past experience not being a reliable guide.) The most common risks are associated with weather, traffic operations, conflicting utility services, convenience of property access, and third-party involvement. In most cases, except weather, the antecedents for these risks are more likely to be present within an urban environment and to bring about conflicts with construction operations.

Weather-related risks are generally considered acceptable and manageable because both the contractor and the Department have a long history of experience with this problem. Over the long run, weather effects tend to "average" out, in that favorable weather is expected to balance out with unfavorable weather over a 1- or 2-year cycle—if not within the duration of one project, at least within the duration of two or more projects; thus, what is gained on one project may be lost on another, providing the contractor manages to remain in business long enough to experience both favorable and unfavorable weather conditions.

However, contracting for highway projects is not without risk under the best of conditions. The risk may be further aggravated by the potentially hostile and infinitely variable environment that surrounds highways within an urban environment. This risk is even further intensified when a contractor works on existing highways as opposed to new locations. Transporting labor, supplies, and equipment through adjacent traffic can create conflicts that may only be resolved by inhibiting construction operations or traffic operations.

Ideally, from the contractor's standpoint, the increased risk of performing a unit of work may be offset by passing increased bid prices to the Department. When bidding on a project, a contractor is obligated to anticipate various unplanned or unscheduled events that would interfere with construction activities. A contractor's risk (whether high or low) is determined by the contractor's ability to predict the occurrence, time, origin, and nature of these events and to cope with the events if and as they occur. The principal risks are the failure to conform to schedule deadlines, and the possibility of financial loss because of the unpredictability of costs associated with traffic handling, third-party involvement, plan deficiencies, utility conflicts, and atypical weather conditions.

As competition for highway work increases among contractors, it is likely that contractors will shave their prices, even to the point of risking future insolvency. The Department can vary the amount of risk the contractor is obliged to shoulder by assuming more or less of the risk through the inclusion of the appropriate provisions in the construction contract. Risk management is an important issue, and the Department can do much to increase competition among contractors and to reduce not only the risks of the contractor, but also the stress of managing field operations and resolving contractors' claims.

ABUTTING PROPERTY INTEREST

Existing routes which are attractive to traffic — and which consequently are the most likely candidates for improvement — are also the routes most likely to be fronted by intense real estate development. Businesses dependent on drive-by traffic and needing convenient property access are particularly attracted to those routes with a high traffic volume. Additionally, intense commercial development brings with it a demand for more utility services, which further aggravates competition for space within the rights-of-way. When construction of these routes is scheduled, the contractor must, as required by the Department, plan his operations with the intention of maintaining services at some acceptable (according to the consumer) level. Often, there is an inherent conflict of interest between construction contractors who provide highway services and consumers who, for economic reasons, depend on predictable and reliable highway services. The conflict arises because the process of rehabilitating and extending highway services (and in many instances utility services) may increase the risk and consequent cost of performing a unit of work and, in addition, may temporarily diminish the availability of these services.

Property owners and users are primarily concerned about loss of income and a decrease in the value of their property because of impaired access. Their potential loss may vary greatly, depending on how the land is put to use. Businesses that depend on drive-by traffic for clientele would be severely affected by reduced or inconvenient access. Other business interests, being the sole or restricted suppliers of their goods and services, may not be critically affected by restricted or inconvenient access. There is no accepted method of credibly estimating the potential losses suffered by property interests. Even if the losses could be credibly established, there may not be a legal precedent for compensating property interests for such losses. Consequently, *reasonable* access is about the only obligation owed to abutting property during construction. While *reasonable* has been narrowly interpreted to mean *owner* access rather than *customer* access, the resolution of this issue is, properly, a legal matter and therefore outside the scope of this study. As a practical matter, each abutting property interest could be interviewed to assess specific needs and special problems. Perhaps an understanding could be negotiated with troubled property interests—if not to their satisfaction, at least to their acquiescence. Generally, experience has shown that most property interests are willing to tolerate some restrictions to their operations in order to accommodate the requirements of the contractors. This tolerance is increased if the temporary nuisances and losses are followed by the prospects of improved traffic service and a larger market area that such service affords.

The Department's interest is best served by communicating with affected property interests before and during construction and by acting as an intermediary for the contractor and other agents who need the Department's assistance to resolve access problems.

THIRD-PARTY INTEREST

Third parties are those individuals and groups whose interests are connected to a particular construction project. These interests are generally incidental to those of the Department and may be significantly affected by the Department's operations. Utility companies sharing rights-of-way with the Department usually fall into the category of third parties, since they may have facilities located within highway rights-of-way. Other governmental agencies and railroads may also be considered as utility companies. In addition, the clientele of the utilities may occupy property abutting highway rights-of-way and may have strong feelings about any infringement upon their rights of access to the services offered by the utilities. The principal issue concerning third parties is the maintenance of services to their clientele during construction operations. The utilities' problem of serving their customers is similar to the conflict of interest faced by the Department when it elects to diminish service during construction in order to expedite the work. Often a conflicting utility can be taken out of service to avoid the time and the expense of installing a temporary facility and to expedite a contractor's activity. Accordingly, the Department's plans may indirectly affect others; indirect effects should be considered when planning and scheduling construction operations.

Third parties may sometimes act as agents for the Department. Third parties, for instance, may have the responsibility of adjusting their facilities to accommodate the Department's plans and the contractor's operations. As agents, whether or not they are compensated for these adjustments depends on the conditions of the license permitting them to occupy highway rights-of-way.

The Department's interests should also be shared by its agents. The Department employs agents—highway contractors—to translate the Department's plans into services. Utility companies are common examples. Utility companies are collateral providers of service and may use highway rights-of-way for the delivery of their services. In this case, the utility owners are both consumers of highway services (rights-of-way) and providers of services to their customers. These agents also have a strong interest in the process and the outcome of the Department's mitigation measures, since these measures affect their operations, profitability, and public relations.

The Department's principal concern regarding third parties is to identify the affected parties and to negotiate the necessary agreements in order to coordinate the work of the highway contractors with that of the third parties. It is also the Department's responsibility to monitor the operations of third parties and to try to anticipate and to resolve conflicts.

The next chapter will take a more detailed look at the economic costs related to urban highway construction.

CHAPTER 4. PROJECT ECONOMIC COSTS

INTRODUCTION

As indicated in Chapter 1, when discussing urban highway construction expediting measures, research engineers must consider the costs involved. Indeed, any determination of the need for expediting measures should be based solely on the real-world economics of the project. In other words, the actual costs of the expediting measures should be evaluated and assessed in relation to possible benefits. This chapter, therefore, analyzes the issue of project economic costs — particularly those costs borne by owners, users, and abutting businesses. Because certain costs associated with urban highway construction are quantifiable, the various quantifying methodologies need to be assessed. Once researchers determine (by making an economic assessment) that a certain project would benefit from mitigation measures, it then becomes the job of the Department and the contractors to select, from the various techniques available, the measure or measures that best suit the particular project. To assist the Department in this selection process, the next chapter (Chapter 5) identifies, categorizes, and assesses the variety of mitigation measures available to the Department.

ANALYZING COSTS OF URBAN HIGHWAY CONSTRUCTION

Evaluating the economics of a construction project entails an analysis of all the potential alternatives that are capable of providing the minimum required performance. All other things being equal, the alternative that is the least expensive over time should be selected. The usual practice for assessing cost effectiveness in the pavement field has been to consider only capital and maintenance (Department) costs in the economic evaluation. Yet this approach is incomplete, principally because there are additional costs (e.g., user costs) that merit consideration in the analysis. A new approach to evaluating pavement rehabilitation projects was needed and, thus, the study team decided that, in addition to Department costs, the analysis should also include user costs and the economic losses sustained by abutting businesses. This chapter, then, looks at those construction costs capable of being quantified to some extent.

Figure 4.1 shows a schematic representation of how these components (owner/agency costs, users' costs, and costs to abutting businesses) might relate to life-cycle pavement performance expenditures — that is, all of those costs anticipated over the life (or analysis period) of the facility. Such representations, of course, must be accurate, which requires identifying and evaluating properly, over time, the economic consequences of the various alternatives. And while there are several economic analysis methods that compare alternatives, discounted cash-flow methods (e.g., present worth, annualized cost, and rate of return) are the most frequent means of comparison; benefit-cost ratios, break-even analyses, pay-back periods, and capitalized cost methods are used less frequently. In the discounted cash-flow scheme, the factors that will influence the analysis results include inflation, the discount rate, and the analysis period (Ref 1).

The total cost of construction work, which is indicated above, must include the costs borne by the agency, the user, and the abutting business. Those costs specifically associated with the agency include the costs of initial construction, maintenance, ongoing construction, engineering and administration, and traffic-control. User costs, on the other hand, include vehicle operating costs (VOC), user travel-time, and accident costs. Finally, the costs absorbed by abutting businesses are calculated as losses in sales resulting from construction activity.

Project duration, of course, has a significant effect on total project costs. Figure 4.2 presents a conceptual analysis of the effects of project duration on total project costs. Figure 4.2 identifies the effect produced by the key factors of administration, construction, and user costs. In preparing this figure, it was assumed that (1) the owner's administrative costs increase linearly with the duration of the construction; (2) the contractor's construction costs decrease with time until a lower limit is reached and the costs become asymptotic; and (3) user costs increase linearly with time. If user costs are not considered in the first analysis, the optimum (minimum total cost, construction, and administration) duration is represented as D1; but, if user costs are included, the optimum duration of construction is represented as D2 (i.e., less than D1). Therefore, the optimum duration is shorter when user costs are included.

The following discussion focuses on construction costs as they relate to the agency, the user, and to abutting businesses.

AGENCY COSTS

The principal costs that a highway agency must consider when planning highway, rehabilitation, or maintenance construction are presented below. Because these costs are well-known to the Department, they will be described only briefly.

Initial construction costs: Computing the initial cost of construction involves the calculation of the quantities of the materials needed in each pavement structure, as well as the estimation of their corresponding unit prices. Material quantities are, generally, directly related to the thickness of the layers and to the width of the pavement and the shoulders (Ref 2). Unit prices, on the other hand, are dependent on such variables as material quantity, construction procedure, length of the project, location of the project, and type of materials. Therefore, care should be taken in estimating quantities and expected costs.

Finally, an estimation of initial construction costs should also include the costs related to land acquisition (right-of-way), construction (including materials, equipment, and labor), construction financing, insurance and taxes, planning and feasibility studies, architectural and engineering design, field supervision, inspection and testing, contractor's overhead, and mobilization.

Rehabilitation costs: Pavement rehabilitation, which is undertaken to extend the service life of an existing facility, includes placement of additional surfacing material and/or other work necessary to return an existing roadway, including shoulders, to at least its original structural or functional adequacy (Ref 2). Accordingly, rehabilitation costs are those costs associated with rehabilitation projects (though they should not include normal periodic maintenance activities).

Maintenance costs: Maintenance includes those activities that preserve the entire roadway (surface, shoulders, roadside, structures, and traffic control devices) and that make the roadway a safe and efficient transportation utility (Ref 2). The level of maintenance (i.e., the type and extent) determines the rate of deterioration (e.g., loss of riding quality) of a roadway. Therefore, the estimation of all costs, which are essential to maintaining the pavement at a desirable level of service, or at a specific rate of deterioration, plays a very important part in the economic analysis of agency costs.

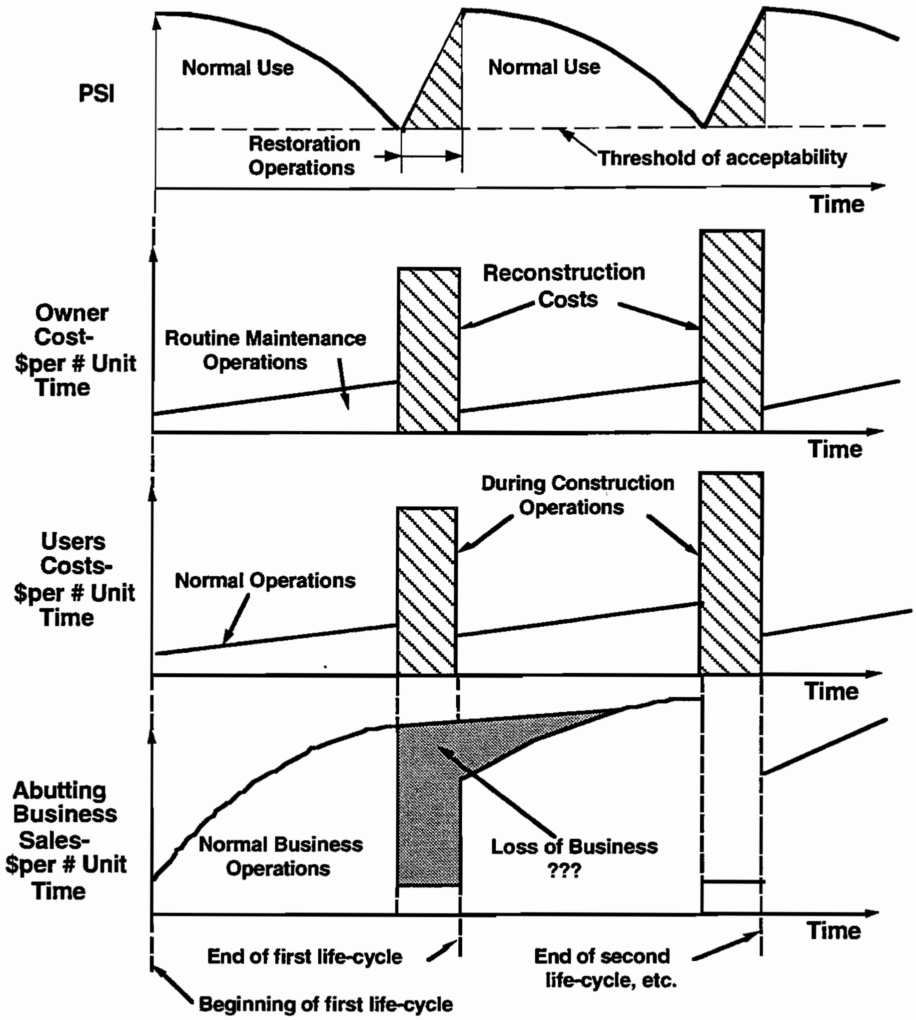

Figure 4.1. Life-cycle costs of construction

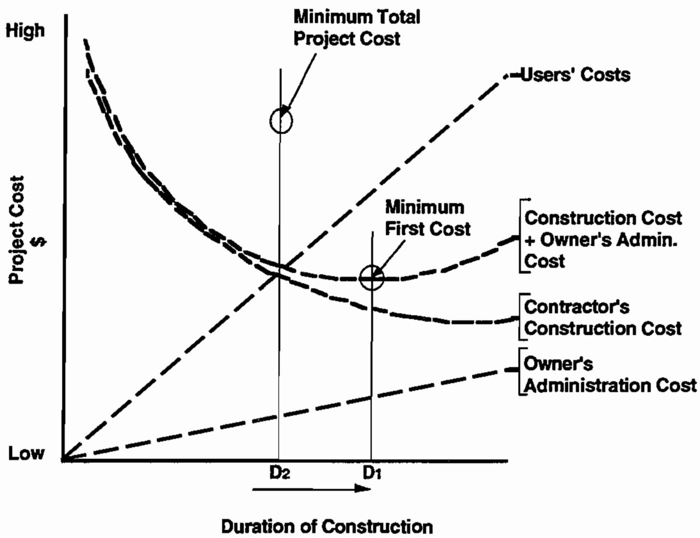

Figure 4.2. Factors affecting total project costs

There are many maintenance operations performed by highway agencies, including maintenance of pavements (e.g., drainage, erosion, patching, filling potholes, scaling cracks, and snow and ice control), shoulders, vegetation, and structures (e.g., bridges). Yet only those categories that directly affect the performance of the pavement should be included (e.g., pavement surface, shoulders, drainage) in a pavement analysis.

Engineering and administration costs: This category includes all costs related to the design, the inspection, and the management of pavement work.

Traffic control costs: Traffic control devices help ensure the safe and efficient movement of all traffic on the highway. The need for traffic control devices is especially important during work-zone activities; signs, channeling devices, and pavement markings are the most frequently used traffic control measures. When selecting traffic control devices and barriers, engineers must consider the maintenance characteristics and the ease of installation and removal of the devices in order to reduce the hazards and the costs for workers and motorists. Accordingly, traffic control costs should include not only the cost of the traffic control devices, but also the cost of their installation, maintenance, and removal (Ref 3).

USER COSTS

Each alternative rehabilitation pavement strategy is associated with a number of indirect, or nonagency, costs that are related to the road user. For example, because user costs are related to the roughness of the pavement, the pavement strategy that provides a relatively smooth surface will result in user costs that are lower than those user costs resulting from a strategy that provides an overall high level of roughness over a long period. In normal highway operations, the three major types of user costs generally associated with a pavement's performance are the following:

(1) Vehicle operating cost

- fuel consumption
- tire wear
- vehicle maintenance
- oil consumption
- vehicle depreciation
- parts replacement

(2) User travel-time cost

(3) Accident cost

- fatal accidents
- nonfatal accidents
- property damage

Each of the costs is related to the roughness level of the pavement, as well as to the vehicle speed dictated by the roughness level.

Major pavement maintenance is generally accompanied by either a disturbance to or complete cessation of normal traffic flow. These disruptions cause vehicle speed fluctuations, stops and starts, and time losses. In general, traffic delay costs are related to traffic volume, road geometry, time and duration of the rehabilitation work; road geometry in the work zone; and implemented traffic management techniques. Traffic delay costs consist of vehicle operating and user time values, changes in speeds, stopping, accelerating, idling, and vehicle accidents. Figure 4.3 presents the main components of the additional user costs generated by work-zone interruption.

To evaluate user costs within a work zone, the QUEWZ (Ref 4) computer program was selected to study highways, while the TEXAS model (Ref 5) was chosen to study intersections.

QUEWZ Model: As shown in Figure 4.3, the QUEWZ model (Ref 6) is capable of estimating costs related to delay or travel time, vehicles, speed-change cycling, and accidents (though lack of available data limits the estimation of changes in accident costs). Two general configurations representing lane closures within a work zone are incorporated into QUEWZ: The first configuration involves situations in which one or more lanes are closed in one direction, with traffic moving in the opposite direction not affected. The second configuration involves crossover, whereby all lanes in one direction are closed, and two-way traffic is maintained in the other direction. A maximum of six lanes in each direction can be handled in the model.

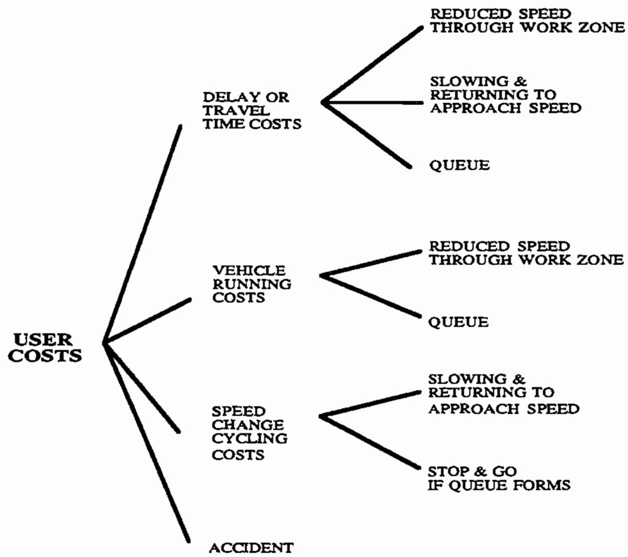

Figure 4.3. Additional user-cost components resulting from work zone interruption

Figure 4.4 presents the input and output data for QUEWZ, while the main components used by QUEWZ to estimate the additional user costs resulting from rehabilitation work are summarized in the following formula:

$$THC = CQUE + CDWZ + CDSC + CSPC + CSPQ + OC + OCQ$$

where:

THC = total hourly user costs;

CQUE = delay cost in the queue;

CDWZ = delay cost of going through the work zone at reduced speed;

CDSC = delay cost of slowing down and returning to the approach speed caused by work zone;

CSPC = operating cost of the speed-change cycle

CSPQ = additional speed-change operating costs, if a queue is formed;

OC = change in vehicle running costs; and

OCQ = additional change vehicle running costs, if a queue is formed.

weekdays (represented by Fridays), and Saturdays. Sunday's distribution presents just one peak, around 6:00 p.m. Weekdays' distribution shows two peaks, one at 8:00 a.m. and the other around 6:00 p.m. Finally, Saturday's distribution presents its high traffic volume between 10:00 a.m. to 6:00 p.m.

For rural areas we find, in general, four different types of traffic distribution: Sundays, Mondays to Thursdays (represented by Thursdays), Fridays, and Saturdays. Sunday's distribution is similar to the urban case; that is, it has one peak at 6:00 p.m. "Weekdays" (not including Friday) is similar to the weekdays (including Friday) urban case, which has two peaks, one at 8:00 a.m. and the other at 6:00 p.m. Friday's distribution has the same characteristics as "weekdays," but the peak at 6:00 p.m. is much more pronounced. Finally, Saturday's distribution shows a plateau from 10:00 a.m. to 6:00 p.m.

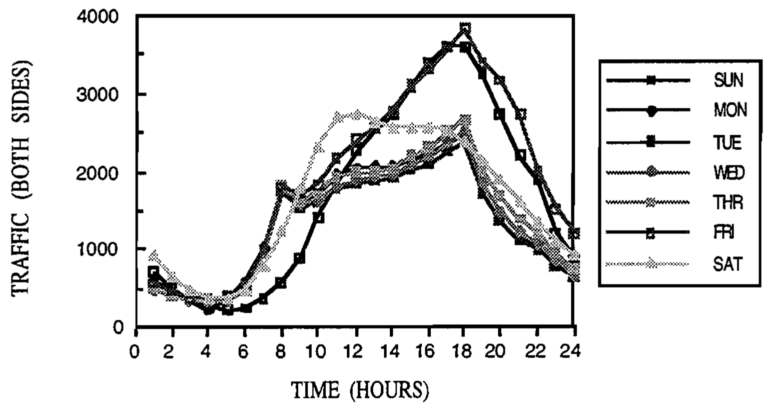

Figure 4.5. Rural traffic distribution example — S-118

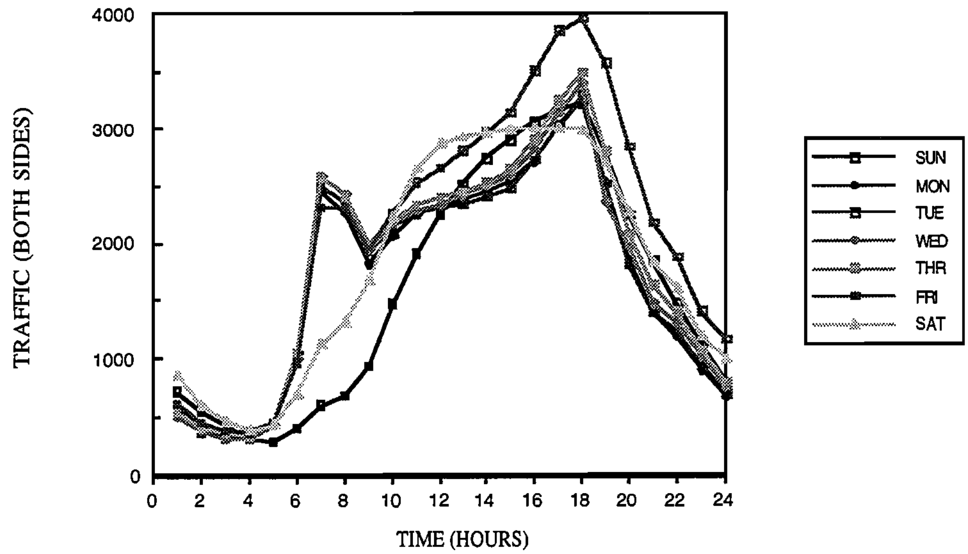

Figure 4.6. Urban radial distribution example — S-125

These data are entered via the first preprocessor package, dubbed GDVDATA. This program utilizes a series of screen prompts to guide the user in entering all required geometric and traffic data.

The other preprocessor package, SIMDATA, is also provided to aid the user in defining additional simulation and traffic-control parameters through a series of prompts and instructions (as in GDVATA). These additional inputs are needed by SIMPRO, which is a program that utilizes the output from two presimulation data processors in SIMDATA, to guide the user through this remaining part of the data-entry process.

Examples of User Costs on Highways

Beginning with a description of the traffic distribution data selected for the analyses, this section presents three examples of user cost estimation, including urban roads (circumferential and radial) and rural roads.

Traffic Distribution Selected (Ref 7): Eleven Texas sites having permanent automatic traffic counters were selected to represent rural, urban radial, and urban circumferential traffic distribution (Ref 8). Table 4.1 summarizes the main characteristics of these locations.

Table 4.1. Characteristics of the sites

Traffic Type	Station No.	Location	AADT	% Directive Distribution 30th High
Rural	S-118	IH-35, 5.7 mi N of US84, Waco	36,361	52
	S-164	IH-10, 3.8 mi. E of US77, Schulenburg	14,635	73
	S-200	IH-45, 0.6 mi S of Spur 67, Madisonville	16,164	50
Urban-Radial	S-125	IH-10, 8.2 mi W of Chambers C., Houston	43,168	55
	S-148	IH-335E, 0.3 mi N of US67, Dallas	143,909	67
	S-165	IH-10, 0.5 mi W of IH-45, Houston	152,901	53
	S-210	IH-35, 1.7 mi N. of Atascosa, San Antonio	15,319	61
Urban-Circumferential	S-146	IH-410, 1.3 mi SW of SH16, San Antonio	103.677	50
	S-171	IH-635, 2.5 mi N of US175, Dallas	66.810	51
	S-182	IH-610, N end Houston Ship Channel Bridge	94.791	55
	S-193	IH-820, W end of L. Worth Bridge, Ft. Worth	45.190	60

1 mile=1.61 km

Figures 4.5 (S-118), 4.6 (S-125), and 4.7 (S-146) show the traffic distributions of one site in each condition. (Ref 7 presents additional information on the original study.) These traffic analyses included eleven urban and rural sites, which were presented as examples of the hourly traffic distributions in Texas. In general, we can see an important difference between urban and rural traffic behavior. While in the former (urban traffic) the weekday traffic is higher than the weekend traffic, in the latter (rural traffic) the weekend traffic is more important than the weekday. (Significant differences between radial and circumferential urban traffic could not be detected from the selected sample.)

In urban areas we find, in general, three different types of traffic distribution: Sundays, In urban areas we find, in general, three different types of traffic distribution: Sundays, weekdays (represented by Fridays), and Saturdays. Sunday's distribution presents just one peak, around 6:00 p.m. Weekdays' distribution shows two peaks, one at 8:00 a.m. and the other around 6:00 p.m. Finally, Saturday's distribution presents its high traffic volume between 10:00 a.m. to 6:00 p.m.

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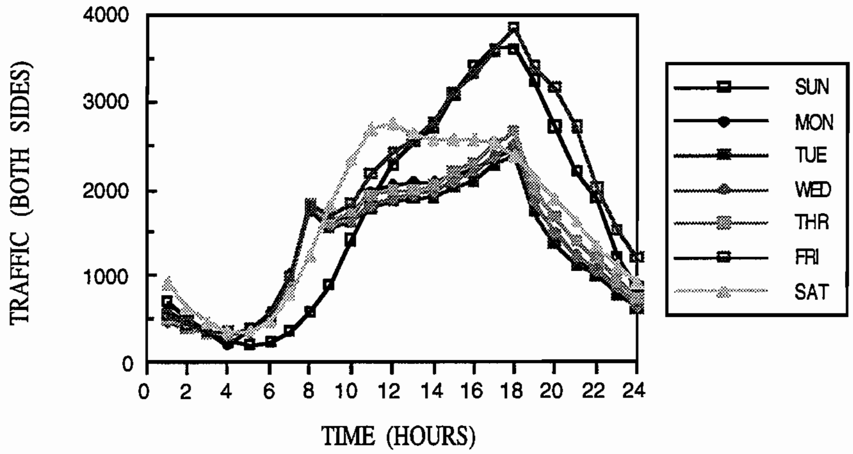


Figure 4.5. Rural traffic distribution example — S-118

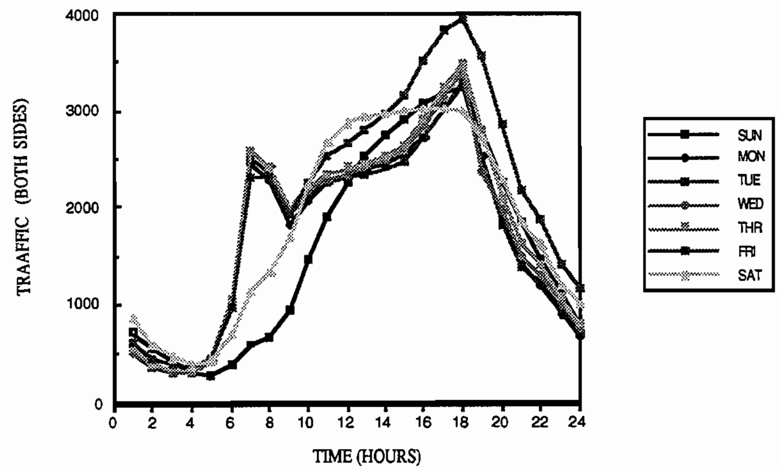


Figure 4.6. Urban radial distribution example — S-125

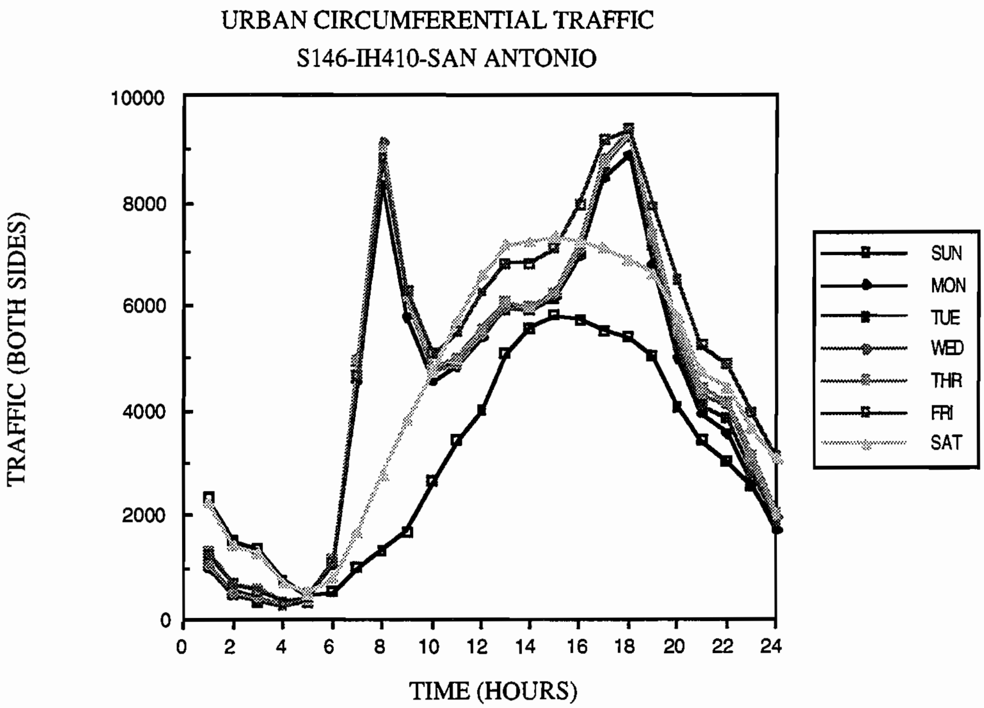


Figure 4.7. Urban circumferential distribution example — S-146

Case #1: Urban Circumferential Roads (Ref 9): This study included twelve user-cost calculations, which are summarized in Table 4.2. Additionally, an average weekly traffic distribution was calculated and used to determine an average weekly user cost for each station. The lane closure alternative that was selected was the single lane closure (SLC), shown in Figure 4.8. The inputs used for the analysis, with the exception of the hourly traffic distribution, are shown in Table 4.3. Table 4.4 presents a summary of the user costs calculated in each case.

Table 4.2. Identification of the user costs calculated

	Station Number			
Day of the Week	S-146	S-171	S-182	S-193
Monday	1	4	7	10
Friday	2	5	8	11
Saturday	3	6	9	12

Table 4.3. QUEWZ input selected

#	INPUTS	DEFAULTS	VALUES SELECTED
1	Problem Title	-	Variable
2	Road Name	-	Variable
3	Free Flow Speed	60 mph	60
4	Level of Service D/E Breakpoint Speed	40 mph	40
5	Capacity Speed After Queue Formation	30 mph	30
6	Is the Closure Strategy Crossover?(Y/N)	-	N
7	Time of Traffic Control Set Up (0-22)	-	0
8	Time of Traffic Control Removed (1-24)	-	24
9	Starting Time of the Actual Work	-	0
10	Ending Time of the Actual Work	-	24
11	% of 1981 Dollars to estimate current Worth	121%	155
12	Total No. of Inbound Lanes (2-6)	-	Variable
13	No. of Open Inbound Lanes	-	Variable
14	Total No. of Outbound Lanes (2-6)	-	-
15	No. of Open Outbound Lanes	-	-
16	% of Inbound Trucks	8%	8
17	% of Outbound Trucks	8%	-
18	Work Length (miles) (0.1-50)	-	2
19	Capacity per Inbound Lane Before Work	2000 vphpl	2000
20	Capacity per Outbound Lane Before Work	2000 vphpl	-
21	LOS DE Breakpoint Volume per Inbound Lane	1650 vphpl	1650
22	LOS DE Breakpoint Volume per Outbound Lane	1650 vphpl	-
23	Estimated Inbound Capacity	1485 vphpl	1485
24	Estimated Outbound Capacity	1485 vphpl	-

1 mph=1.61 km/h

Table 4.4. User costs — Urban circumferential case

Day of the Week	S-146 (AADT = 103,677)		S-171 (AADT = 66,810)		S-182 (AADT = 94,791)		S-193 (AADT = 145,191)	
	ADT	User Costs	ADT	User Costs	ADT	User Costs	ADT	User Costs
Sunday	74,108	9,335	53,401	1,402	60,589	2,230	33,164	551
Friday	119,720	1,160,494	77,965	4,189	112,514	5,218	52,711	2,266
Saturday	103,344	554,904	66,299	2,230	73,856	1,136	41,635	859
Average User Costs	–	909,530	–	3,511	–	4,208	–	1,820
User Costs Using Average Traffic	–	355,886	–	2,230	–	2,894	–	1,351

Case #2: Urban Radial Roads (Ref 10). As with the first case, the second example involves twelve user-cost calculations (three days of the week and four different sites). Table 4.5 presents a summary of the user costs calculated in each case.

The main conclusions of this second case include the following:

- Traffic distribution and ADT greatly affect user costs.
- On urban radial roads, minimum user costs derived from a closed lane occur on weekends, specifically on Sundays. Therefore, maintenance work should be scheduled for Sunday.
- In urban radial areas, maximum user costs (if a lane is closed) occur on weekdays. But the effect of closing a lane is reduced as the number of lanes being opened increases.

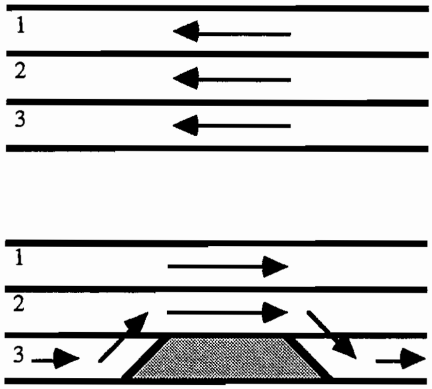
Table 4.5. User costs — Urban radial case

Day of the Week	S-125 (AADT = 43,168)		S-148 (AADT = 143,909)		S-165 (AADT = 152,901)		S-210 (AADT = 15,319)	
	ADT	User Costs	ADT	User Costs	ADT	User Costs	ADT	User Costs
Sunday	38,429	74,658	109,770	445,264	93,571	3,833	15,030	552
Friday	50,480	297,566	166,383	4,369,443	182,083	293,356	17,641	777
Saturday	43,168	114,319	138,668	1,875,269	114,476	6,295	16,664	544
Average User Costs	–	239,544	–	3,452,535	–	210,987	–	707
User Costs Using Average Traffic	–	61,568	–	2,162,967	–	36,107	–	463

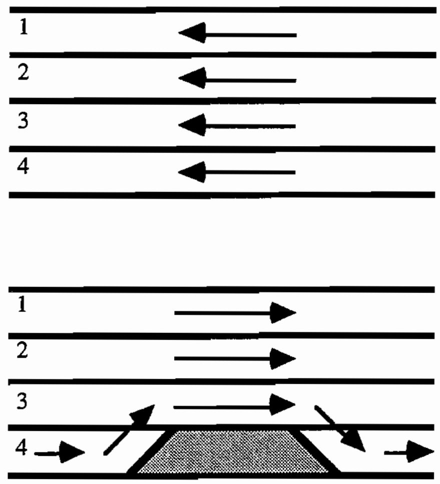
Case #3: Rural Roads (Ref 11). Like the first two cases, the third example involves twelve user-cost calculations using QUEWZ (four days of the week and three different sites). Table 4.6 presents a summary of the user costs calculated in each case.

The main conclusions of this third case include the following:

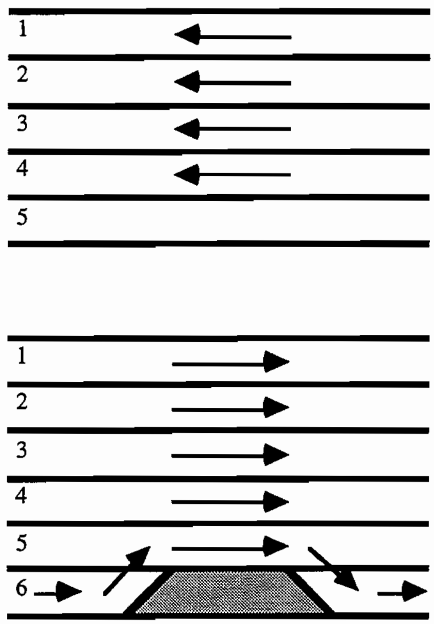
- Traffic distribution and ADT greatly affect user costs.
- In rural areas, the minimum user costs, if a lane is closed, occur Monday through Thursday. Therefore, Monday through Thursday would be the recommended days for maintenance work.
- In rural areas, the maximum user costs, if a lane is closed, occur on Fridays and Sundays. Therefore, maintenance activities should not be performed on weekends.



a) S-146



b) S-171 and 193



c) S-182

Figure 4.8. The single-lane closure (SLC) alternative analyzed

Table 4.6. User costs — Rural case

Day of Week	S-118 (AADT = 36,630)		S-164 (AADT = 14,635)		S-200 (AADT = 16,164)	
	ADT	User Costs	ADT	User Costs	ADT	User Costs
Sunday	40,487	120,886	19,382	2,793	20,305	978
Thursday[1]	34,132	3,531	12,667	452	14,454	222
Friday	46,687	164,242	18,940	1,791	21,175	759
Saturday	39,077	5,615	15,829	994	16,768	376
Average[2] User Costs	–	43,552	–	1,055	–	429
User Costs[3] Using Average Traffic	–	2,539	–	753	–	332

Notes: [1]This traffic represents the Monday through Thursday traffic.
[2]This is the average user cost for the week.
[3]This is the user cost calculated using the average weekly traffic.

Examples of User Costs at Intersections

Two intersections — one T-shaped and the other X-shaped — were analyzed to compare the traffic performance of the before- and during-improvement configurations. The during improvement configurations, referred to as DI1C, DI2C, and DI3C, consist of the following:

DI1C. During Improvement 1 Configuration, which consists of the partial closure (60.8 m or 200 ft) of a lane;

DI2C. During Improvement 2 Configuration, which consists of the partial closure (152 m or 500 ft) of a lane; and

DI3C. During Improvement 3 Configuration, which consists of the total closure (304 m or 1,000 ft) of a lane. (Here, total stands for the maximum inbound lane length the model is able to simulate. It does not imply that the total length of the work zone is limited to 304 m or 1,000 ft.)

To evaluate the construction operations' effect on road users, overall average total delay (OATD) in seconds was selected among the performance indicator outputs of the TEXAS Model for Intersection Traffic. The total delay is calculated by multiplying OATD and Processed Volume. To get the user cost, the total delay is multiplied by the more current value of travel time.

In the T-shaped intersection, the assumed geometric, traffic, and control characteristics, for the most critical configuration, resulted in almost 40 hours of total delay for drivers during a weekday. For the X-shaped intersection, the total delay was almost 85 hours.

An important observation concerns the hourly traffic distribution (K factor), which was assumed to be the same for both roads in the T-shaped intersection case, but different in the X-shaped intersection (i.e., the K Factor on the main street differs from that on the minor street). What this means is that for the X-shaped intersection, up to 24 different combinations of traffic volume might be found; owing to some repeated values in the assumptions, however, only 18 combinations were found. For both the X-shaped and the T-shaped intersection, the stop sign control was chosen.

Input Information: The main and minor streets compose the X-shaped intersection to be analyzed. Figures 4.9 and 4.10 show the X and T intersection, respectively, including the assumed directional movements of the peak hour for each of the legs. For the X-shaped intersection, the main street carries an average daily traffic (ADT) of 12,000 vehicles, while the minor street carries 4,380 vehicles. For the T-shaped intersection, the ADT was 17,500 vehicles. This ADT is made up of passenger cars only (pickup trucks included). Although it is not shown in the figure, the center lanes carry left and through traffic, while the curb lanes carry right and through traffic, for both T- and X-shaped intersections under the Before Improvement Configuration (BIC).

As already mentioned, in the X-shaped intersection, the hourly K factor is different for main and minor streets. However, it is the same for both directions on each street (i.e., the ADT is 50 percent in each traffic direction of the main and the minor streets). This means that V_1 and V_3, as well as V_2 and V_4, are the same at any specific time of the day. In the T-shaped intersection, the ADT is 80 percent for the main road (both directions, 50 percent each) and 20 percent for the minor road.

All of the input information applies to these configurations. Figures 4.11 and 4.12 show, respectively, the DI1C, DI2C, and DI3C for the X intersection, while Figures 4.13 and 4.14 show the same configurations' order for the T intersection.

Examples 1: Results of the X-shaped intersection. The partial closure (60.8 m or 200 ft) of the inbound curb lane along the main street (XDI1C) creates for drivers an extra total delay of almost 60 hours during a day. This amount grows to almost 85 hours under the XDI3C (total closure of a lane).

Figures 4.15, 4.16, and 4.17 illustrate each configuration's total delay; that is, XBIC to XDI1C, XBIC to XDI2C, and XBIC to XDI3C at every hour of the day. Figure 4.18 shows the relation of total delay and processed volume for every X-intersection configuration.

Examples 2: Results of the T-shaped intersection. Again, three graphic comparisons present the difference between TBIC and TDI1C (Fig 4.19), between TBIC and TDI2C (Fig 4.20), and between TBIC and TDI3C (Fig 4.21). The hourly summary of processed volumes and the total delay in hours for each of the configurations are plotted in Fig 4.22. These total delay values in hours were obtained in the same way the X intersection values were obtained. Note that for volumes lower than 1,250 vph, there is no significant effect on the road user.

ECONOMIC EFFECTS ON BUSINESS

According to our literature review, two studies have been published that analyze the effect of road rehabilitation work on businesses. One such study was prepared in 1989 by the Wisconsin Department of Transportation (DOT), while the other study was undertaken in 1987 by the Texas Transportation Institute (Longview). Both are reviewed below.

Wisconsin DOT Study (Ref 12)

This study was commissioned by the Wisconsin State Legislature in 1987. The study examined the economic effects of detours resulting from highway improvement projects and identified problems associated with highway detours. The effect of a detour required by a highway reconstruction project can be grouped into two general categories: effects on businesses and residents located adjacent to or near the reconstruction project, and effects on motorists and commercial haulers using the highway during reconstruction.

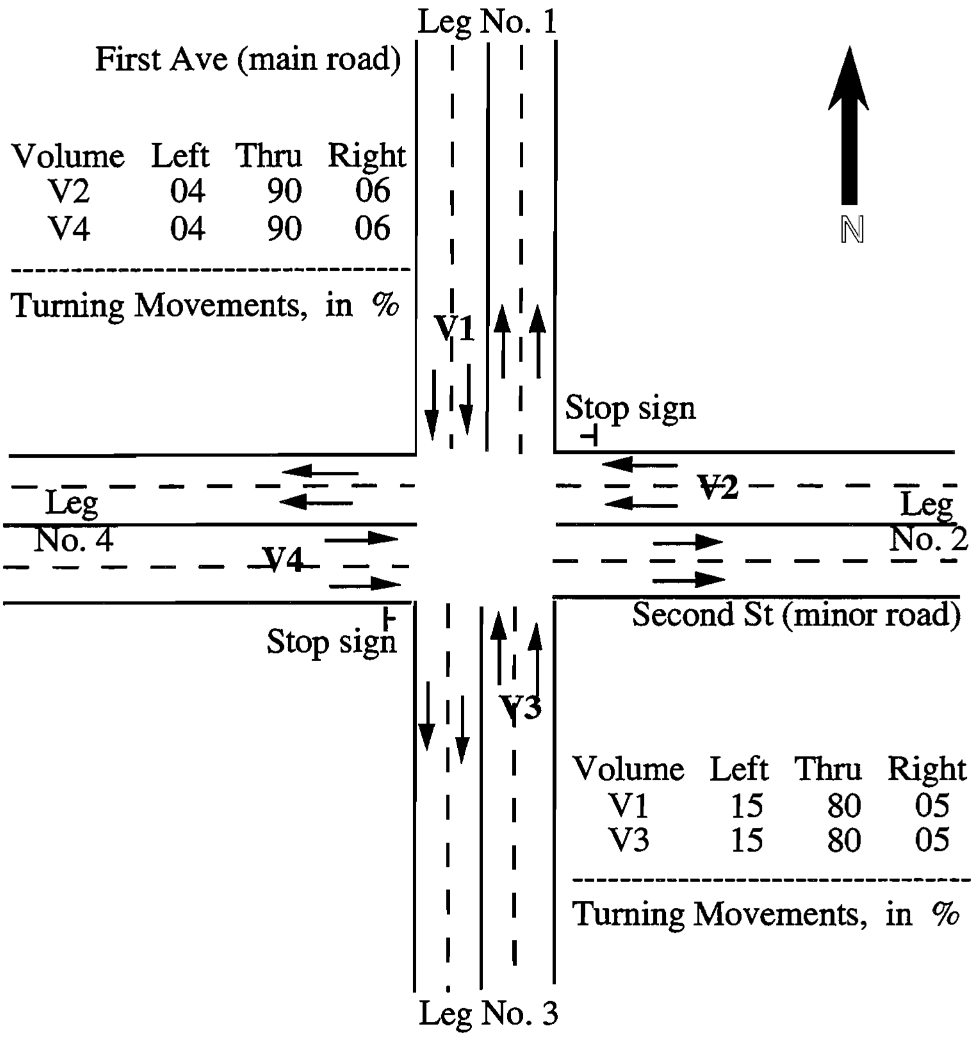


Figure 4.9. X intersection before improvement configuration

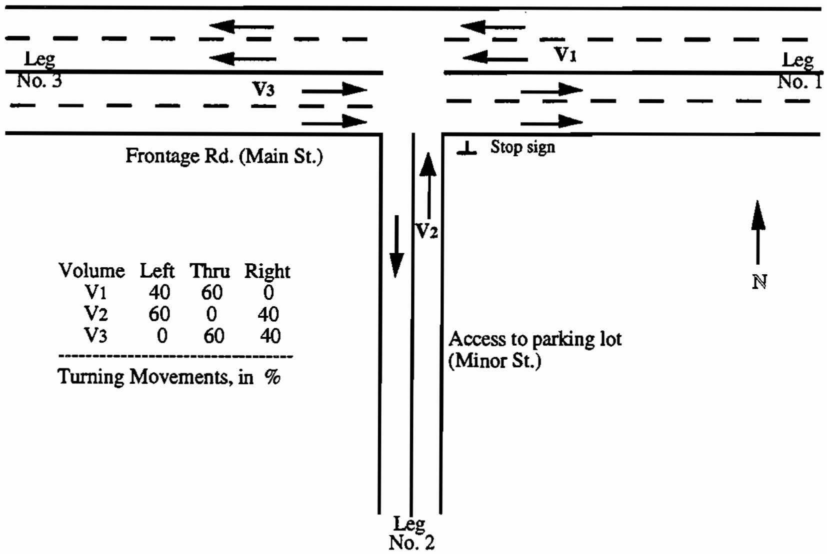


Figure 4.10. T intersection before improvement configuration

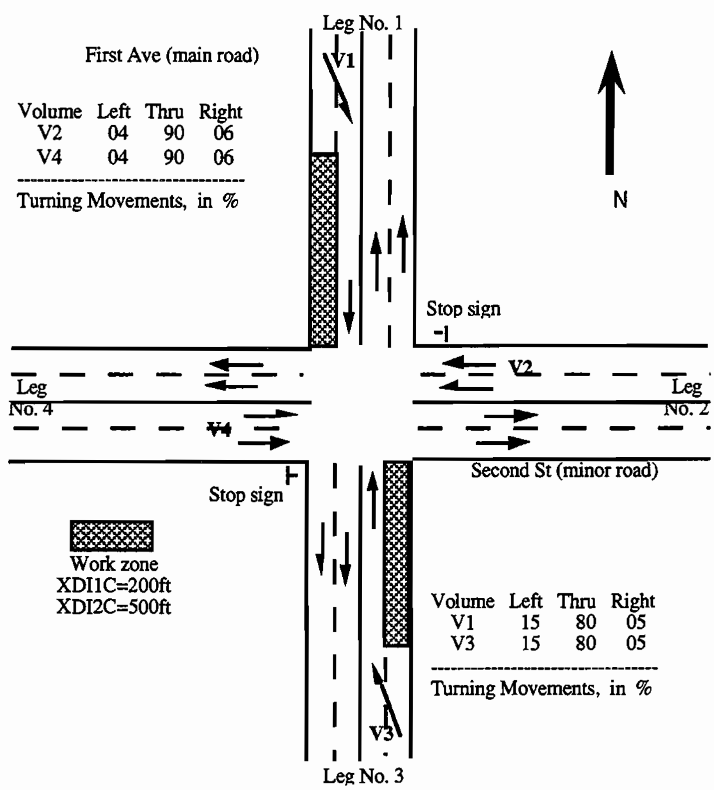


Figure 4.11. X intersection during improvement 1 and 2 configuration

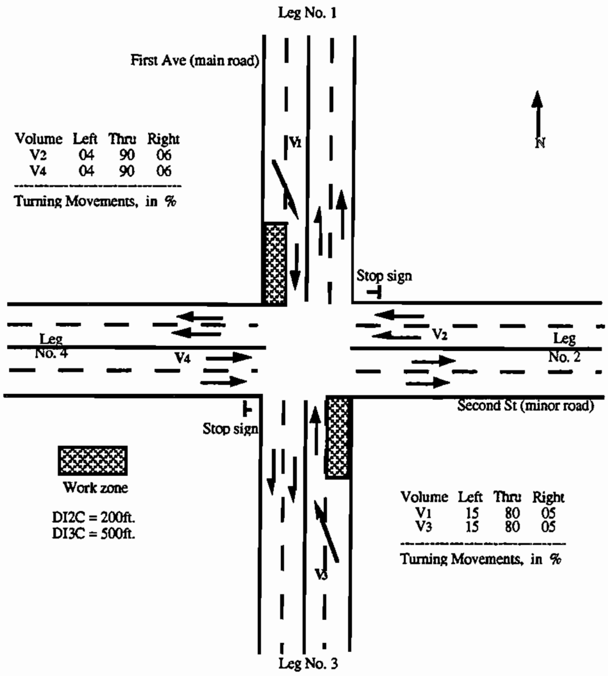


Figure 4.12. X intersection during improvement 3 configuration

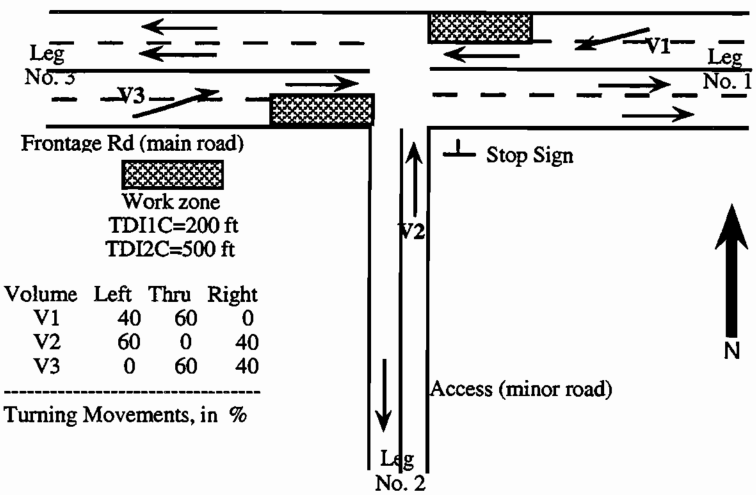


Figure 4.13. T intersection during improvement 1 and 2 configurations

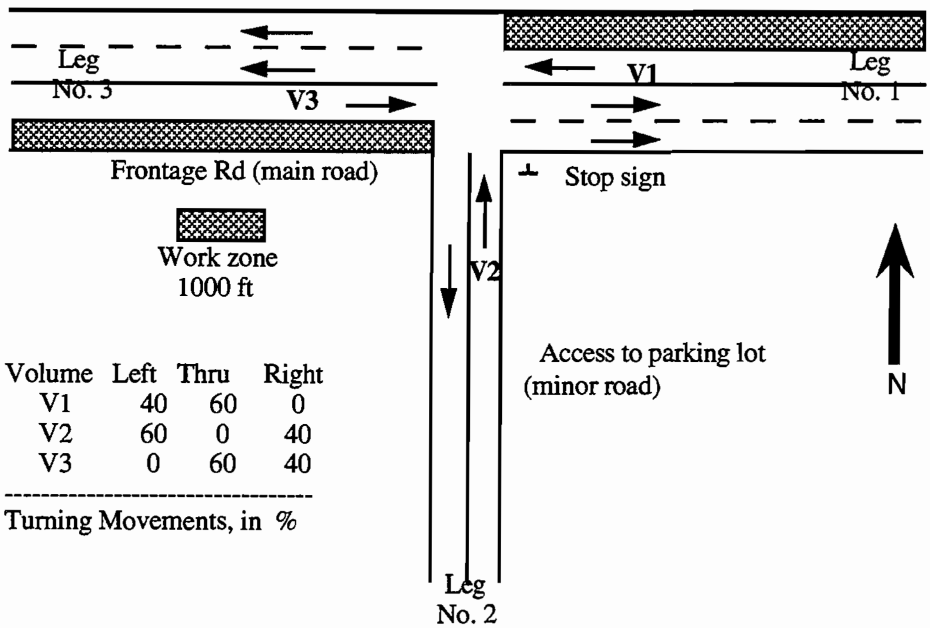


Figure 4.14. T intersection during improvement 3 configuration

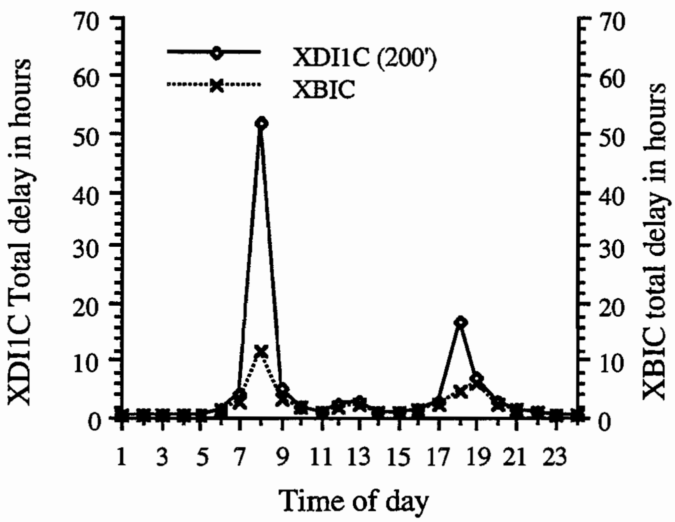


Figure 4.15. X intersection, hourly total delay comparison between BIC and DI1C

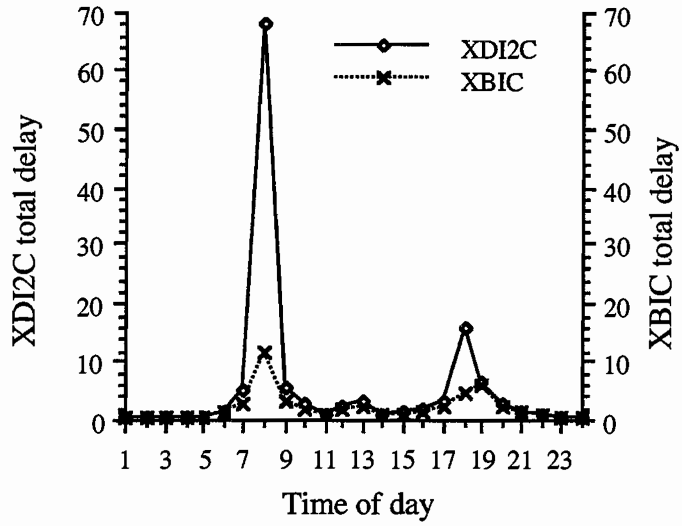


Figure 4.16. X intersection, hourly total delay comparison between BIC and DI2C

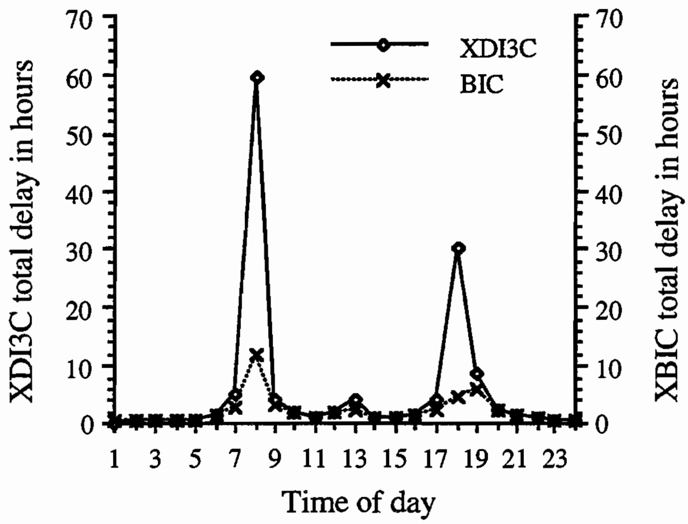


Figure 4.17. X intersection, hourly total delay comparison between BIC and DI3C

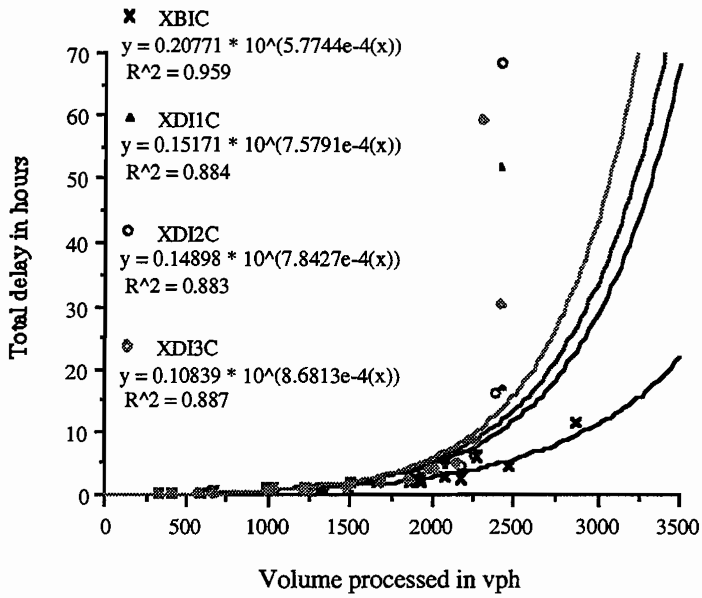


Figure 4.18. X intersection, total delay vs volume processed

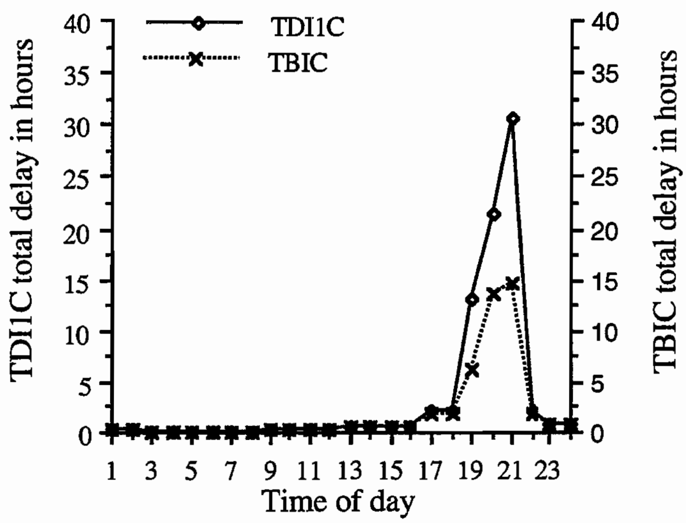


Figure 4.19. T intersection, hourly total delay comparison between BIC and DI1C

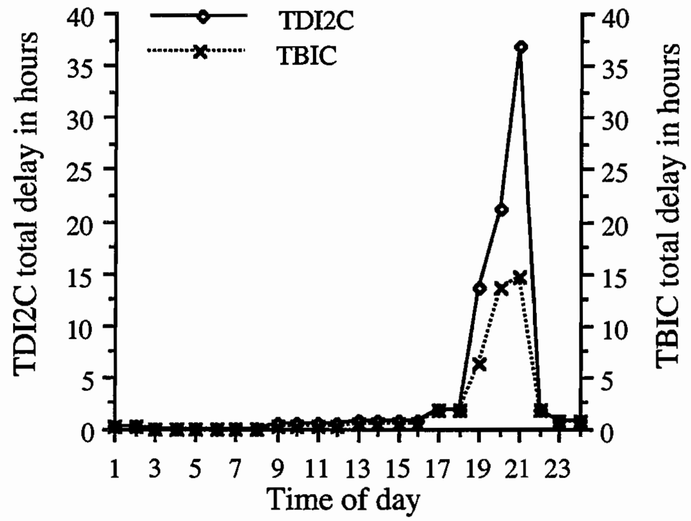


Figure 4.20. T intersection, hourly total delay comparison between BIC and DI2C

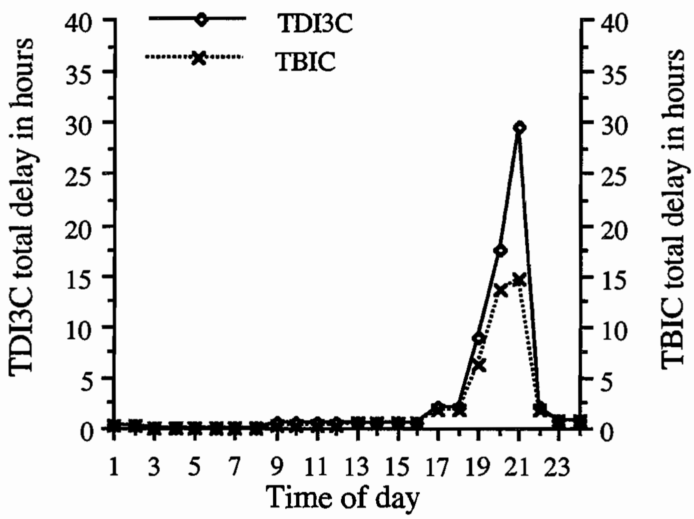


Figure 4.21. T intersection, hourly total delay comparison between BIC and DI3C

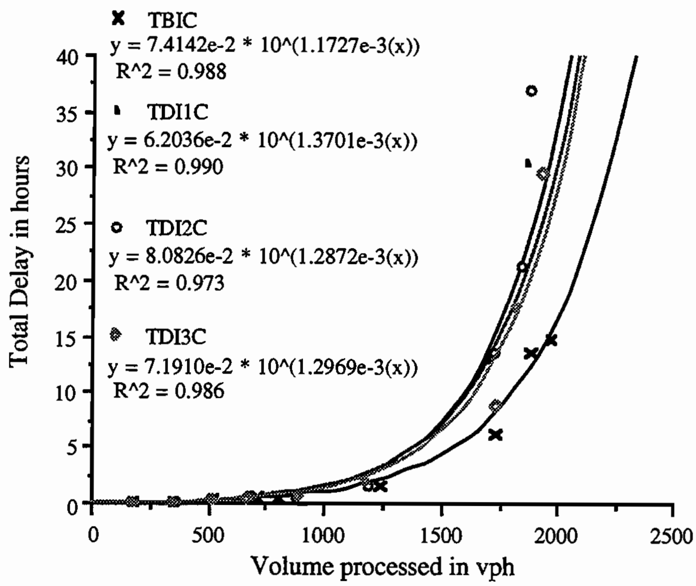


Figure 4.22. T intersection, total delay vs volume processed

The extent to which businesses were affected was assessed by surveying businesses adjacent to a number of reconstruction projects throughout the state. In general, the study showed that the effect on the overall business climate in the area (either a by-passed business or a business adjacent to a reconstruction project) was negative. The overall level of business activity during construction operations declined modestly (averaging -10.8 percent; see Fig 4.23). The long-term effect of the reconstruction project was generally positive (Fig 4.24). The effect on employment was less than the effect on sales, since businesses were reluctant to layoff full-time employees, knowing that the project was causing a short-term, rather than a long-term, decline in business activity (Fig 4.25). Any drastic changes in the level of sales or employment were generally tied to factors other than the reconstruction project.

The economic effects on adjacent businesses resulting from the reconstruction of an existing highway appears to be directly related to the length of time it takes to complete the project. The faster the project is completed (at least to the point where traffic can return to the store fronts), the less severe the effect on the business.

The surveys of businesses also show that, even with a relatively fast completion of the project, businesses can, to a large extent, work within the community to mitigate adverse effects. Businesses within a construction zone that actively attempted to offset any adverse effect benefited from both a lower reduction in sales during the project and a faster return to growth after the project was completed.

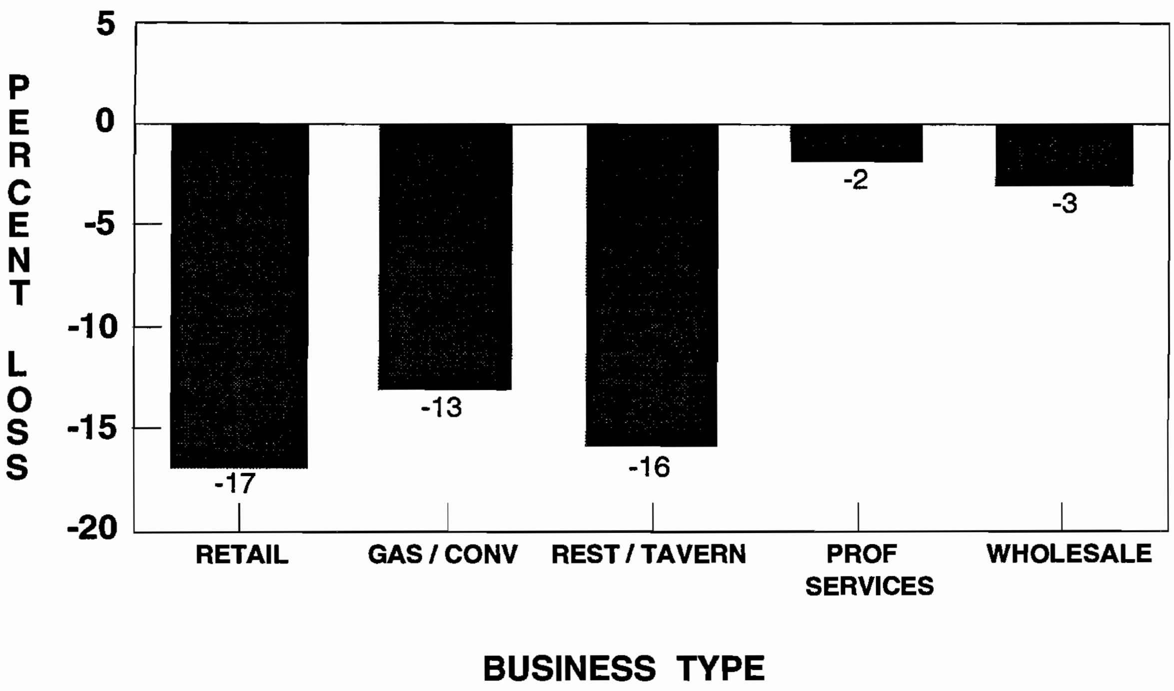


Figure 4.23. Percent loss in sales by business type

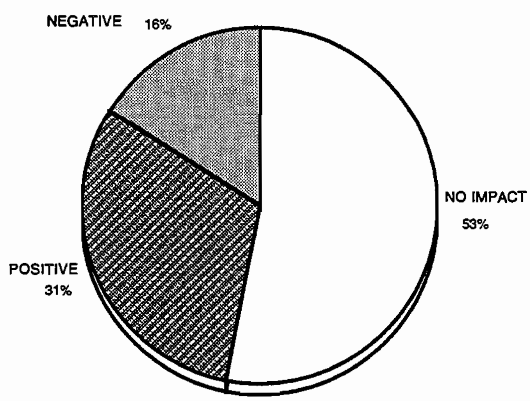


Figure 4.24. Long-term effect on adjacent businesses

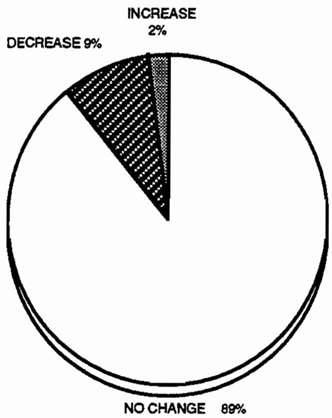


Figure 4.25. Change in employment during construction

Longview Study (Ref 13)

All 356 businesses abutting Marshall Avenue (U.S. Highway 80 Business Route) between Fisher Road and Eastman Avenue in Longview, Texas, were surveyed by mail or in person regarding the actual and/or the expected effects of widening the street. All of those businesses abutting widened portions of Marshall Avenue were contacted in person, because they had already experienced some of the effects of a widened facility. Many of them were in operation during the construction period when this facility was widened at five major intersections (two widened in 1986 and three in 1974). The summary of the findings and the conclusions of this study are presented below.

Estimated effect on business: The responses of businesses located on the widened portions are more positive than those businesses located on the unwidened sections. This is a significant finding and should be reassuring to the businesses on the unwidened sections. Also, the expected effect on employment is not as negative when the responses are weighted by the number of employees of each business. Construction activities are more likely to have a negative effect on the per-day gross sales and net profits of a business, rather than on usable parking spaces or full- or part-time employees.

Estimated impact on parking: The parking surveys reveal that 98 percent of the parking loss will result from the unavailability of shoulder parking after construction of the widened facility. Also, of the businesses having ten or fewer parking spaces left after construction, only a few are presently experiencing an overcapacity of parking space.

Estimated effect on motorists: There are several effects on motorists resulting from the construction of the continuous left-turn median. In all cases, the estimated effects are positive, resulting in benefits to motorists. Overall, the discounted benefits to motorists total $30.7 million. The estimated cost (including maintenance) is about $9 million, giving the improvement a benefit-cost ratio of 3.40.

Estimated economic effect on Longview area: The estimated economic effect of widening the 10.4-km (6.46-mile) section of Marshall Avenue should be very positive in the long term. In the short term, i.e., during the construction phase, the effect will be negative because businesses and motorists alike will be inconvenienced. Some of the businesses will lose sales, while the mobility of motorists will be impeded. Offsetting these negative effects will be the additional business generated by the expenditures of the contractor and his employees.

Perhaps the greatest long-term benefits will be realized by motorists. For every dollar spent installing and maintaining the improvement, $3.40 will accrue in benefits. Widening projects enhance public safety and can save 10 to 13 lives over a 20-year period.

Businesses also stand to gain from the installation of a two-way continuous left-turning lane, an addition that will greatly facilitate left-turning customers' access to the businesses of their choice. The loss of parking on the shoulders, along with other negative effects of construction, may cause a few marginal businesses to fail. If the contractor carefully follows a "business-sensitive" traffic control plan during the construction phase, most of the marginal businesses could survive.

Follow-up Questionnaire for Businesses

After meeting with TxDOT and other experts, a five-part questionnaire was developed to assess more fully the effect of rehabilitation projects on Texas businesses. The first part of the questionnaire identifies the business and the contact person. The second part asks general questions about the business and its relation to the construction activity. The third part is intended to focus on the effects of construction on the business, while the fourth part focuses on the effects on the business after the rehabilitation work is finished. Finally, part five allows the interviewer to make concluding comments.

The following steps should be followed in applying the questionnaire to a specific site:

a) Select a construction site;
b) Contact, inform, and discuss the questionnaire with the district engineer;
c) Identify a business to interview at that site;
d) Contact the business, identify a contact person, and set up an appointment;
e) Perform the actual interview. If the person is not available at that time, leave the questionnaire with the first three parts already completed and ask him/her to return the completed questionnaire within two weeks.

After obtaining as many responses as possible, researchers should follow the steps listed below when analyzing the results of this questionnaire:

a) Summarize the results;
b) Attempt to categorize the answers, e.g., using HOT diagrams;
c) Compare the answers of the questionnaire with trends in the area by using information from the Comptroller's Office or by applying a similar questionnaire to another corridor (control corridor) near the study corridor; and
d) Establish conclusions and recommendations.

CHAPTER 5. MITIGATION MEASURES

INTRODUCTION

This chapter identifies and discusses various methods used by experienced highway engineers, contractors, and others to mitigate the adverse effects of urban construction operations. As indicated in Chapter 2, these techniques have been derived primarily from surveys, literature reviews, and from discussions with selected Department representatives and highway contractors. In adopting mitigation measures, these practitioners of highway engineering and construction could either plan and execute some special action designed to alleviate the adverse effects of urban construction activities, or they could recognize and adopt specific, efficacious planning and construction measures.

DETERMINING THE APPROPRIATE MITIGATING MEASURE

In Chapter 3, the *need* to apply mitigation measures was discussed as a prerequisite to action. Following the determination of need is the determination of *what* action to adopt, which is influenced by the project's physical environment, physical structure, and the resources available to the Department. For example, ambient weather conditions—and the susceptibility of any construction activity to inclement weather—can be a determining factor in selecting a particular mitigation method. Therefore, the selection of a more expensive construction material less affected by moisture changes can be considered a mitigation measure, even though the inclement weather, while anticipated, is only a *probability*.

In addition, the *expectations* of the consumers affected by the project can be a factor in adopting particular mitigation measures. If it is anticipated that the quality of service during highway construction will drop significantly, then it should be assumed that the consumers' expectations are not likely to be accommodated and that additional measures may be called for. A common example includes those measures usually taken to accommodate freeway traffic within a construction zone (compared with the measures taken to accommodate city street traffic within construction areas). Similarly, an active public relations program can serve as a mitigating measure for a specific project and should be considered in light of anticipated consumer responses.

However, the circumstances warranting the application of particular mitigation measures are so varied that it is impractical to assign specific measures to specific types of projects or specific types of environments. Although the *type* of services afforded by the various segments of the highway system are pretty much alike—differing only in quality—the *delivery* of these services through the construction of highway facilities requires the customizing of construction planning to adapt each construction project to a unique environment. *Planners should weigh each project mitigation measure according to the nature of the candidate project and should select only those measures which seem to be appropriate to the circumstances.* Thus, this study report hopes to serve as a guide for (1) identifying those techniques that are useful in mitigating adverse construction effects, (2) assessing the *need* for using mitigating measures, and (3) determining *what* measures to adopt.

The mitigation measures that were identified have been classified according to the sources used by this study (discussed in Chapter 2). These sources are as follows:

1. meetings with Department representatives from selected districts to discuss regional interests,
2. a review of published literature,
3. a survey of Department representatives selected from all districts,
4. a survey of selected highway contractors,
5. interviews with selected highway contractors,
6. inquires sent to institutional and trade societies.

The first source — interviews with Department regional representatives — related to brainstorming sessions that were used chiefly to advise and direct the study team as they pursued study objectives and relevant sources of information. These regional meetings were also conducted to determine if there was likely to be any special regional problems associated with the study. It was apparent from these regional meetings (held at the beginning of the study) that "fast-tracking" or "expediting" construction was not the sole answer to adverse effects, and that there are institutional constrictions relating to innovative contract and personnel management that inhibit or prohibit the use of some mitigation methods.

The next three source categories, which included a review of published literature, a survey of Department representatives selected from all Districts, and a survey of selected highway contractors, are the primary sources for the mitigation methods identified and discussed in this chapter. The mitigation measures found in a literature review of societal and trade journals, for example, are documented as action taken on a specific project, while the measures identified from the surveys of contractors and Department officials are compiled from the responses to a questionnaire distributed by the study team (these measures proved to be more general in character than those identified in the literature review).

Category 5 — interviews with selected highway contractors— relates to meetings with selected contractors arranged to obtain advice and guidance on the direction and content of the study.

Category 6 — inquiries to institutional and trade societies — was not productive in that none of those who responded had compiled any specific body of literature or conducted any investigations relating to "fast-tracking" or "expediting." In almost every case, any relevant material provided by the various organizations contacted had already been located in the literature survey. Of particular significance, however, was the April 1991 conference in Kansas City, "Fast-track Pavement Conference and Drainage Systems," sponsored by the American Concrete Pavement Association and several governmental agencies. Having the parallel objective of discussing ways and means of expediting construction work, the conference provided this report with a valuable assessment of the various measures currently available. A brief account of the conference, which two members of the study team attended, has been prepared as a technical memorandum and is included as appendix A.

Thus, the measures outlined below were identified primarily from a literature review, from questionnaires, and from discussions with selected Department representatives and highway contractors.

MITIGATION MEASURES IDENTIFIED FROM LITERATURE SEARCH

The literature survey reviewed current and experimental practices employed to mitigate adverse effects of highway pavement construction through expediting procedures. Using the information obtained through the literature search, the study team then compared results of this search with the findings of the contractors and the highway department surveys discussed below. These findings are summarized in categories that include expediting through (1) design; (2) construction techniques and equipment; (3) innovative materials; (4) project management; (5) traffic management; and (6) public relations.

Expediting through Highway Construction Design (Literature Review)

The findings of the literature search suggest that expediting highway pavement construction should be considered at all stages, from the preliminary planning and design of the project to completion. Properly designed plans can be instrumental in reducing construction time, reducing costs, and minimizing the adverse effects associated with the operation. Innovative design methods that expedite pavement construction include the use of full-depth material, minimum number of layers, and thicker pavements.

Expediting through Construction Techniques and Equipment (Literature Review)

Expediting through construction techniques and equipment is another category suggested by the literature search, with some of techniques identified including the use of prefabricated elements, vacuum treatment of Portland cement concrete, in-place recycling of pavement materials, roller-compacted concrete, use of geogrid as a base supporter, and use of such exotic materials as polymer and fly ash.

Construction equipment also plays an important role in minimizing construction time. Advanced construction equipment can considerably reduce the duration of highway construction and, therefore, minimize the delay associated with the operation. Fast-track equipment identified in the literature search included slip-form pavers, automatic dowel bar inserters, improved pulverizers and stripers, and diamond wire saws.

Expediting through Innovative Materials (Literature Review)

Fast-tracking materials may be the answer to the many problems associated with delays caused by construction operations. For example, high-early-strength materials are effective in reducing the time required to reopen a facility to traffic. And although substantial costs may be associated with the use of these materials, the cost-effectiveness, in many cases, is justifiable. The use of these exotic high-early-strength materials can reduce the duration of construction operations in heavy traffic zones.

Expediting through Traffic Management (Literature Review)

Efficient traffic management and good traffic handling strategies should be implemented during highway construction to minimize traffic delay, minimize negative effects on abutting properties, and to provide the required level of safety at the construction site. Traffic handling strategies found in the literature survey include complete closure or partial closure of the facility, off-peak-hours construction, and provision of effective detours.

Expediting through Project Management (Literature Review)

Efficient project management, including multiple contract letting, contraction incentives/disincentives, and computer applications are, as suggested by the literature survey, proven methods for accomplishing satisfactory results.

Expediting through Public Relations (Literature Review)

While this is an important strategy, one that can in fact work in lieu of other strategies, the literature survey revealed no particular techniques currently practiced or favored. This mitigation measure is, however, treated below in the discussion of the survey responses.

RESEARCH QUESTIONNAIRE

The 1227 study team distributed two versions of a questionnaire relating to methods for minimizing the adverse effects of urban pavement construction; one version was sent to contractors in pavement construction around the state, while another, slightly modified version was distributed to officials and engineers at TxDOT. Both questionnaires (samples of which are included in appendixes B and E) consisted of questions pertaining to pavement construction in urban areas (13 questions in the case of the contractors, 15 questions in the case of the Department). CTR received 27 responses from the contractors and 243 responses from various areas of TxDOT (239 of these TxDOT replies were identifiable). Table 5.1 summarizes the number of responses by district, as well as the number of responses for each question.

The returned surveys provided CTR with valuable information, with numerous ideas and techniques expressed by respondents. Although the study noted broad diversity in opinions and ideas, there was, on balance, a consensus among all parties on some of the most important concerns in pavement construction. Such agreement was manifest in issues ranging from minimizing phases and steps taken in construction, to issues dealing with traffic management and public relations. The information received from both surveys is summarized below.

METHODOLOGY FOR ORGANIZING THE RESEARCH FINDINGS

Because there are both differences and similarities in the opinions relating to the same issue, organizing and presenting the information received in the questionnaires proved difficult.

After considering various approaches, the study team finally divided the ideas in the questionnaires into several categories, with each category representing a main concern or issue. These concerns and issues were then arranged and ranked using the Hierarchy of Objective Techniques (HOT). In a format that duplicates that used in a standard table of contents, HOT categorizes the main concerns as chapter headings, with various sections following as sub-entries. For a full explanation of this technique used to summarize the survey results, see appendix C.

FINDINGS OF THE TXDOT SURVEY

TxDOT survey findings suggest that the Department is concerned with seven basic strategies used to mitigate urban highway construction, with the main objective or concern being the reduction of the negative impacts associated with the operation. Figure 5.1 ranks all seven strategies suggested by TxDOT officials, giving in addition the frequency of responses for each of the strategies. While appendices C and D use these responses (in HOT diagram form) to construct a comprehensive reference guide to identify *all* ideas reported in the TxDOT survey, this discussion will limit itself to identifying only those strategies considered particularly effective in mitigating the adverse impacts of urban highway construction. The order of these strategies reflect their importance, as ranked in Figure 5.1.

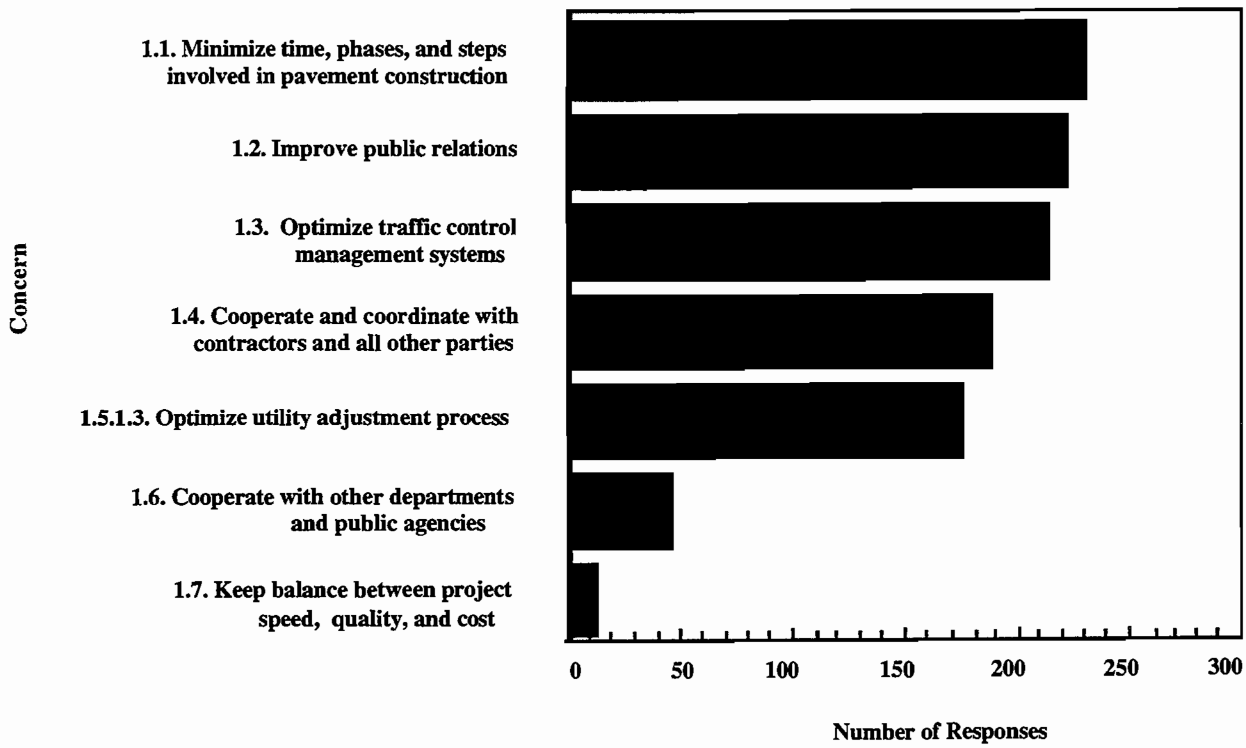


Figure 5.1. Main concerns in minimizing negative effects of urban highway pavement construction (TxDOT survey)

Table 5.1. Tabulation of responses by TxDOT and highway contractors

Responses from TxDOT	No. of Responses	Question Number														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
District 1 (Paris)	10	10	10	10	10	9	9	8	10	10	9	10	9	10	8	
District 2 (Ft. Worth)	16	16	13	16	16	15	13	16	14	15	16	16	16	12	4	
District 3 (Wichita)	6	6	5	6	6	6	6	5	5	6	6	6	6	4	6	1
District 4 (Amarillo)	12	11	10	9	12	11	12	12	12	12	12	12	12	11	6	4
District 5 (Lubbock)	5	5	5	4	5	5	4	5	5	5	5	5	5	5	2	1
District 6 (Odessa)	7	7	7	7	7	7	6	4	6	7	7	6	4	2	4	
District 7 (San Angelo)	6	5	5	6	6	6	6	6	6	5	4	6	6	4	2	1
District 8 (Abilene)	11	11	11	11	11	11	11	11	11	11	11	11	11	11	5	2
District 9 (Waco)	14	12	12	14	14	14	14	14	13	14	13	13	12	11	7	2
District 10 (Tyler)	7	5	5	6	7	7	7	6	7	7	7	7	7	7	2	
District 11 (Lufkin)	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
District 12 (Houston)	16	15	15	15	16	14	1	15	15	16	16	16	16	14	10	
District 13 (Yoakum)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
District 14 (Austin)	6	6	6	6	6	6	6	6	5	6	4	6	6	5	4	3
District 15 (San Antonio)	34	34	34	33	32	34	33	34	31	33	33	31	31	33	18	12
District 16 (Corpus Christi)	11	11	11	11	11	10	11	11	11	11	11	10	9	7	6	3
District 17 (Bryan)	4	4	4	4	3	2	4	4	4	4	4	4	2	2	1	
District 18 (Dallas)	32	28	28	30	28	26	29	30	28	27	29	15	25	26	16	9
District 19 (Atlanta)	8	8	8	8	7	8	8	8	8	8	8	8	7	6	5	3
District 20 (Beaumont)	7	7	6	7	7	7	7	5	4	6	7	4	6	7	4	
District 21 (Pharr)	5	5	5	5	4	5	5	5	5	5	5	4	5	4	3	2
District 23 (Brownwood)	5	5	4	5	5	5	5	5	5	4	3	5	5	5	2	
District 24 (El Paso)	11	11	10	11	11	9	10	11	11	11	11	11	11	10	8	2
District 25 (Childress)	6	6	5	6	6	6	6	6	5	5	6	6	6	6		
Total -TxDOT	243	232	223	234	234	227	217	231	225	232	231	216	221	206	124	45
Responses from Highway Contractors	27	26	25	21	22	18	19	22	15	14	18	20	12	16		

Minimize Construction Time (Strategy No. 1)

An analysis of the survey shows 230 respondents from different areas within TxDOT believe that minimizing time and phases required in the construction operation substantially reduces the negative impact of the operation. This reduction in construction time may be achieved in several ways, as shown in Figure 5.2. In the TxDOT survey, 222 out of 239 responses suggested that reducing construction time is best accomplished by the use of high-early-strength materials. The practice of minimizing the number of layers ranked second in importance in reducing construction time, with 218 responses. Implementing accelerated fast track methods was ranked third, and so on, as shown in Figure 5.2. More specific ways of minimizing construction time are presented in appendixes C and D.

Improved Public Relations (Strategy No. 2)

According to the survey, over 220 TxDOT officials believe improved public relations is the most important strategy for minimizing the negative effects associated with urban highway pavement construction. Improved public relations, as suggested by those officials, is achieved through minimizing user costs, minimizing adverse effects on abutting properties, and through improved aesthetics. Figure 5.3 summarizes these suggestions, ranking them according to their frequency of response. As the survey responses affirm, minimizing negative effects on adjacent properties is good public relations. And because abutting property interests should be considered at all times, it is important, say Department officials, to gain the cooperation of property owners early in the project. Such cooperation can minimize conflicts, minimize delay, prevent unpleasant disruption, and, hence, minimize the adverse effects of the construction. Again, specific details on improving public relations are given in appendices C and D.

Optimize Traffic Control and Management Systems (Strategy No. 3)

Optimizing traffic control and management systems was identified in the TxDOT survey as the third most effective expediting method, with over 200 respondents endorsing this method as the leading issue or concern in minimizing the adverse effects associated with highway pavement construction. If alternative routes established to divert traffic represent little or no disruption to the highway user, then the duration of construction would be of minimum concern to most users. Accomplishing this goal, however, may require great effort and cost.

Proper traffic management strategies reduce conflicts, increase safety, and speed the construction operation. According to the TxDOT survey, traffic control strategies range from full-closure of the facility under construction (190 responses) to partial closure and detours. Figure 5.4 shows the different strategies suggested in the departmental survey to optimize traffic control.

Cooperation Between Parties Involved in the Construction Process (Strategy No. 4)

This cooperative approach to meeting the initial objective, i.e., minimizing the adverse effect of highway pavement construction, ranked fourth according to 188 TxDOT respondents.

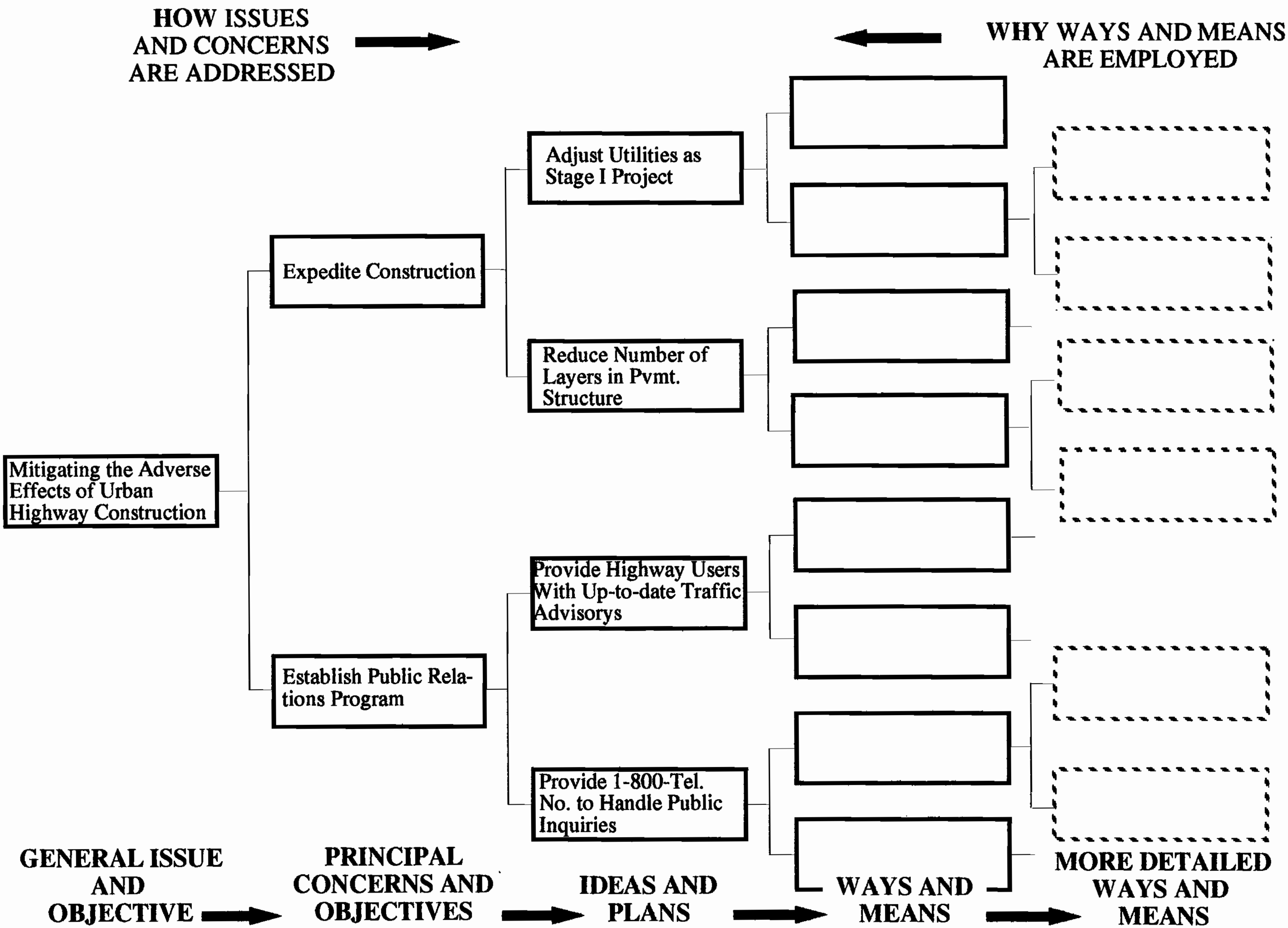


Figure 5.2. General plan of HOT method of collating knowledge base

These officials suggest that negative effects could be minimized by establishing cooperation among all parties, especially between the Department and the contractors of the project. Such cooperation, they feel, reduces conflicts and defines responsibilities. Moreover, it eliminates confusion and misunderstandings. Figure 5.5 itemizes the methods suggested by the Department survey to achieve cooperation among all parties. Flexibility in planning, scheduling and specifications, and considering incentives/penalty contracts are among the tools recommended.

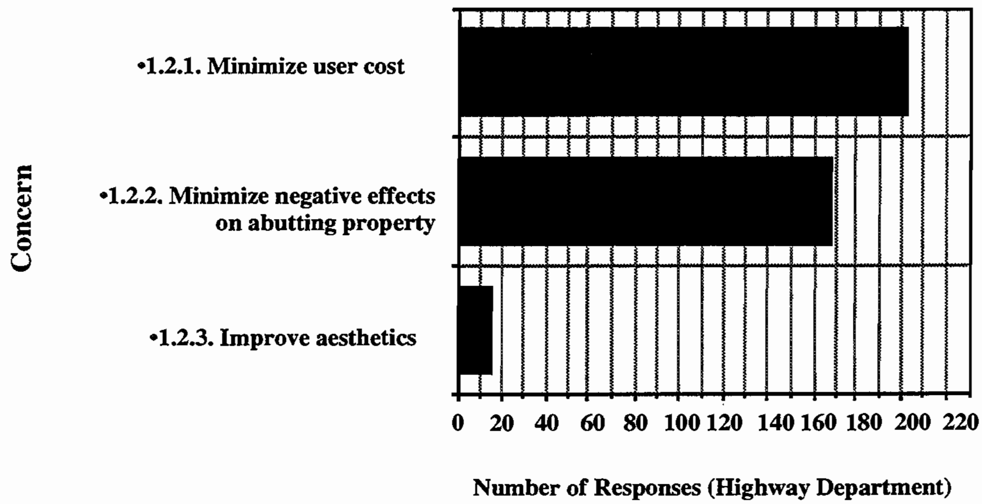


Figure 5.3. Strategies and techniques to improve public relations (TxDOT survey)

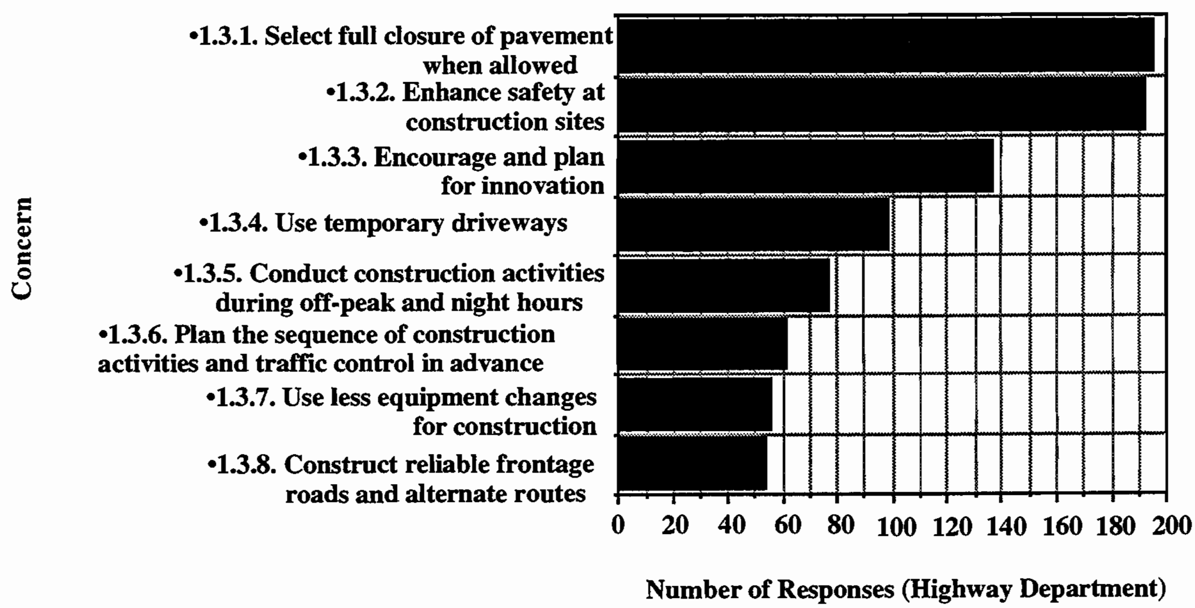


Figure 5.4. How to optimize the traffic control and management systems (TxDOT survey)

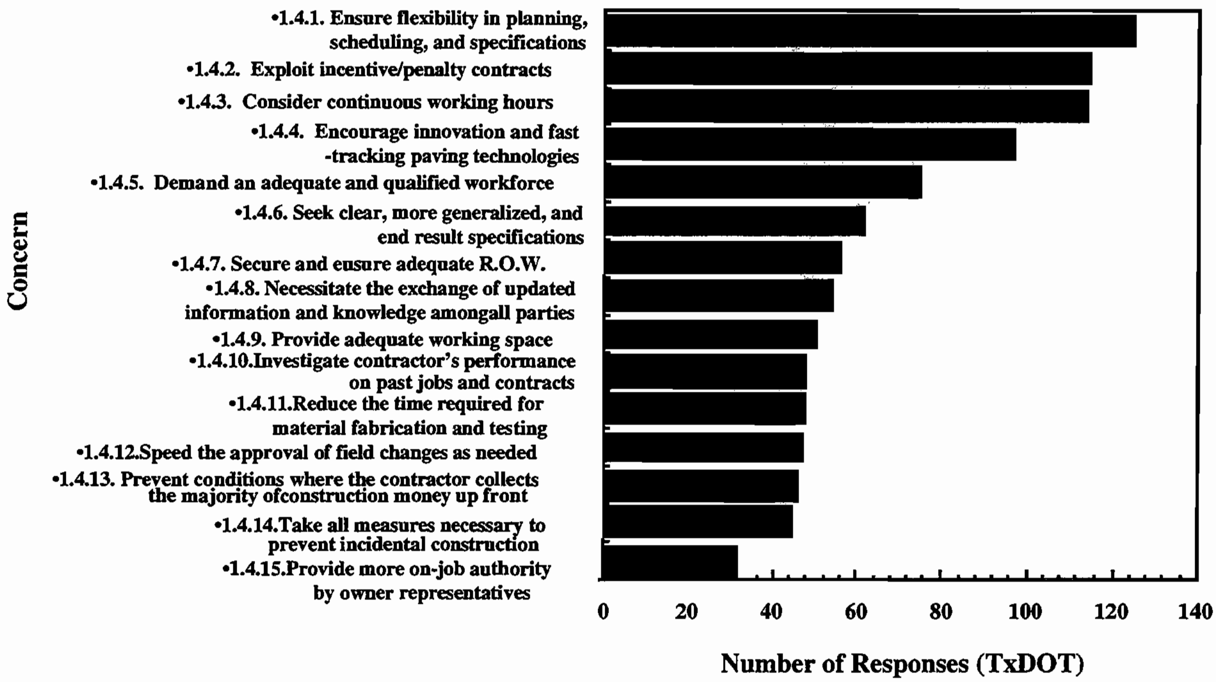


Figure 5.5. How to cooperate and coordinate with contractors and all other parties (TxDOT survey)

Optimize Utility Adjustment Processes (Strategy No. 5)

Because of the different types of utilities, the various associated parties, and the various problems that may occur, utility-related issues are highly complex. These problematic issues could be avoided by the proper procedures and techniques. Through sufficient and accurate planning, and through cooperation between the Department, contractors, and the utility owners, issues pertaining to utility should be easy to handle. Updated maps describing the types of utilities and their locations should be provided.

In the views of 175 TxDOT officials, minimizing the adverse effects of highway pavement construction is partly achieved through the proper and efficient handling of utilities. As summarized in Fig 5.6, techniques suggested in the survey to optimize utility handling process include advanced relocation of utilities, advanced and automated methods, and cooperation among all parties.

Cooperation Between the Department and Other Public Agencies (Strategy No. 6)

There are other parties that may be involved indirectly in the highway pavement construction process. These parties include FHWA, FAA, EPA, and others. The TxDOT survey advises that cooperation between the Department and other public agencies can speed the construction process, therefore minimizing the negative effects on the public and on the Department itself. This cooperation should include specific coordination with the Department and the FHWA, and general coordination with other agencies (such as the EPA). With such cooperation is place, productivity is increased, construction time is reduced, and cost is decreased. According to the breakdown shown in Fig 5.1, about 50 out of 239 respondent in TxDOT believe that this cooperation is an important issue in minimizing the unfavorable consequences that result from urban highway construction.

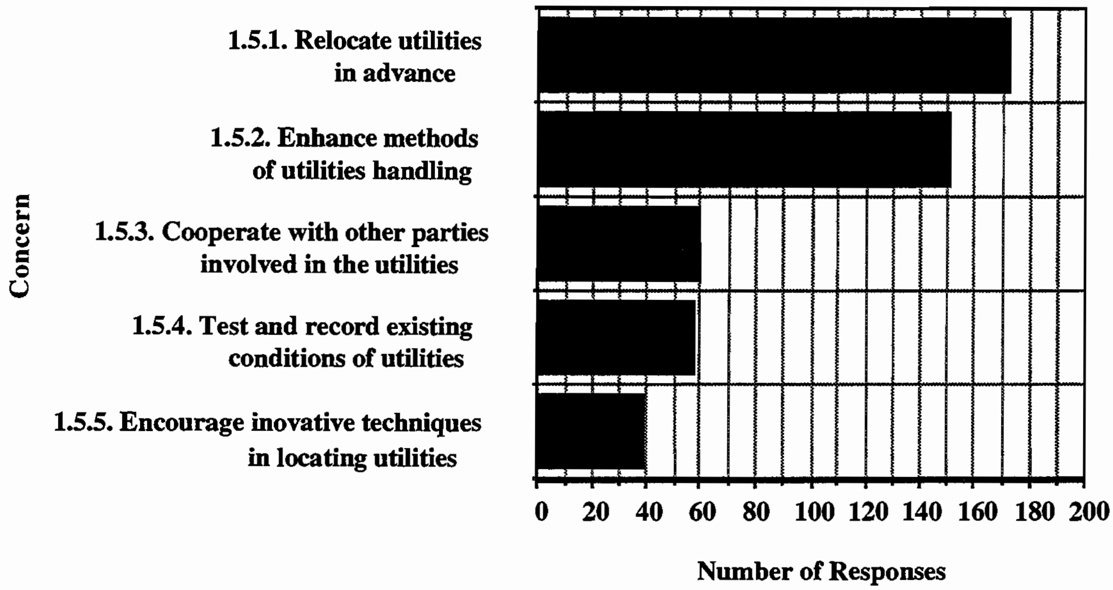


Figure 5.6. How to optimize the process of adjusting and handling utilities

Balancing Project Speed, Quality, and Cost (Strategy No. 7)

While this issue was important to some respondents in the TxDOT survey (see Fig 5.1), the strategy may actually have adverse effects and unwanted results in some cases; in yet other cases, it may impede the process of construction and increase the delay. However, if the overall quality and user cost (including delay and inconvenience) are considered, this strategy may yield good results.

FINDINGS OF CONTRACTOR SURVEY

Although the contractors' responses are fewer in number, the sample received is representative, and of great importance to the study. Ideas and lessons learned in the contractors' survey are very similar to those in the TxDOT. Contractors agree on the main objective of highway pavement construction, namely reducing the negative impact of the operation. They also agree on the tactics to accomplish the main objective. However, the contractors consider traffic management second in importance in achieving the main objective. In contrast to the TxDOT survey, contractors consider public relations least effective in accomplishing the common objective. Figure 5.7 shows the first level concerns in the contractors' responses and their frequencies. Figures 5.8 through 5.12 show tools associated with these concerns and their frequencies in the contractors' survey. A detailed summary of ideas and lessons are given in appendices F and G in HOT outlines and diagrams.

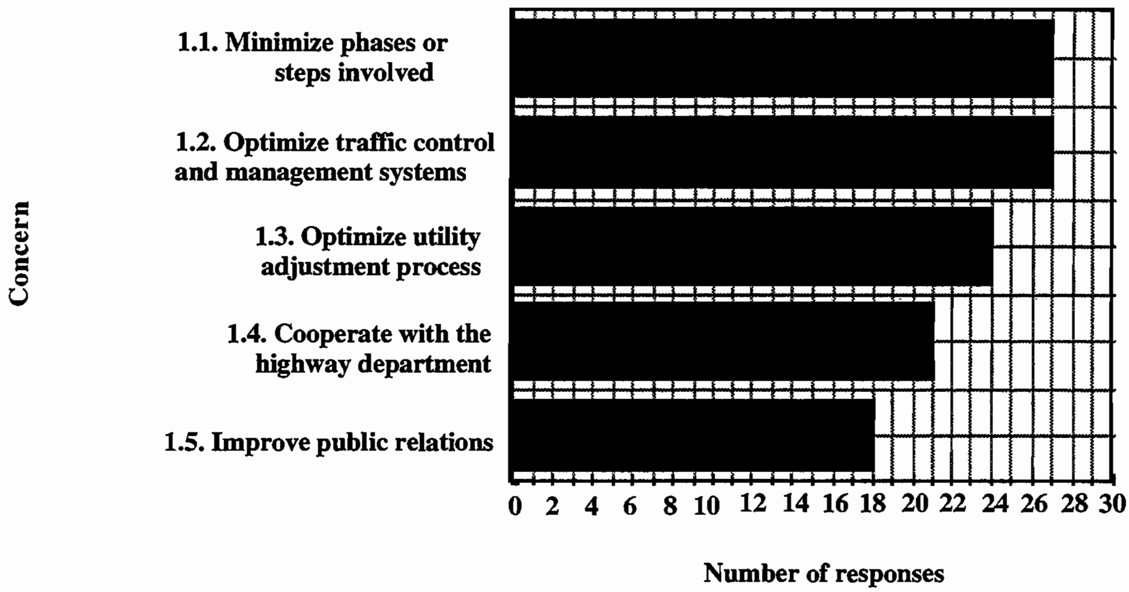


Figure 5.7. Main concerns in minimizing negative effects of highway pavement construction (contractor survey)

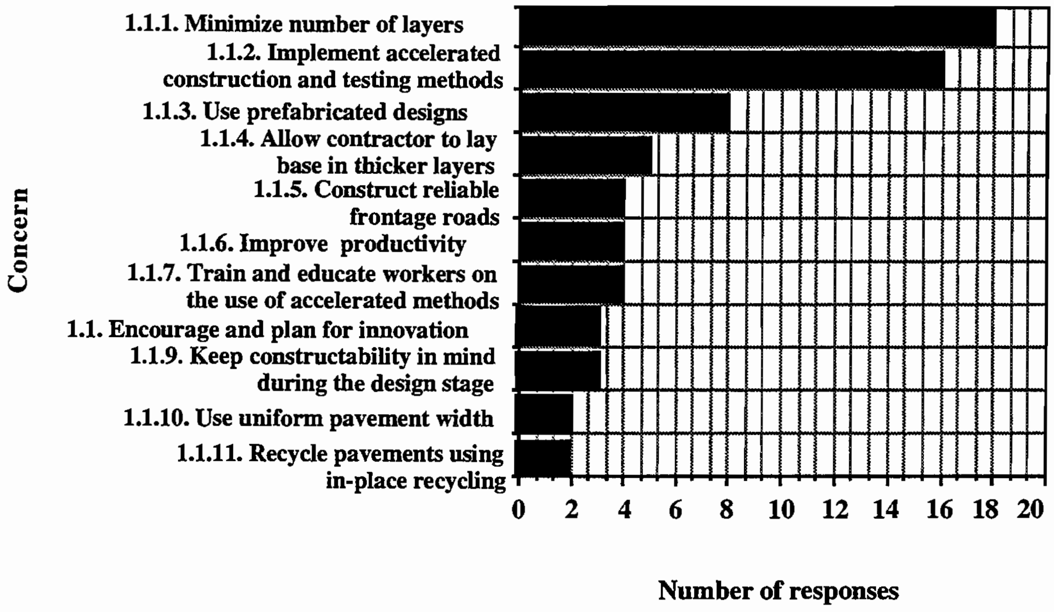


Figure 5.8. How to minimize construction time (contractor survey)

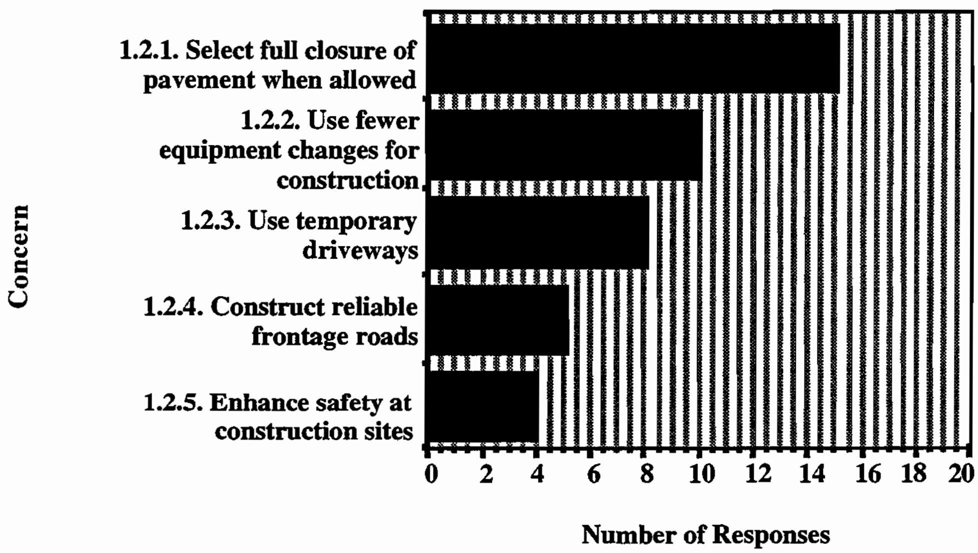


Figure 5.9. Strategies to optimize traffic control and management systems (contractor survey)

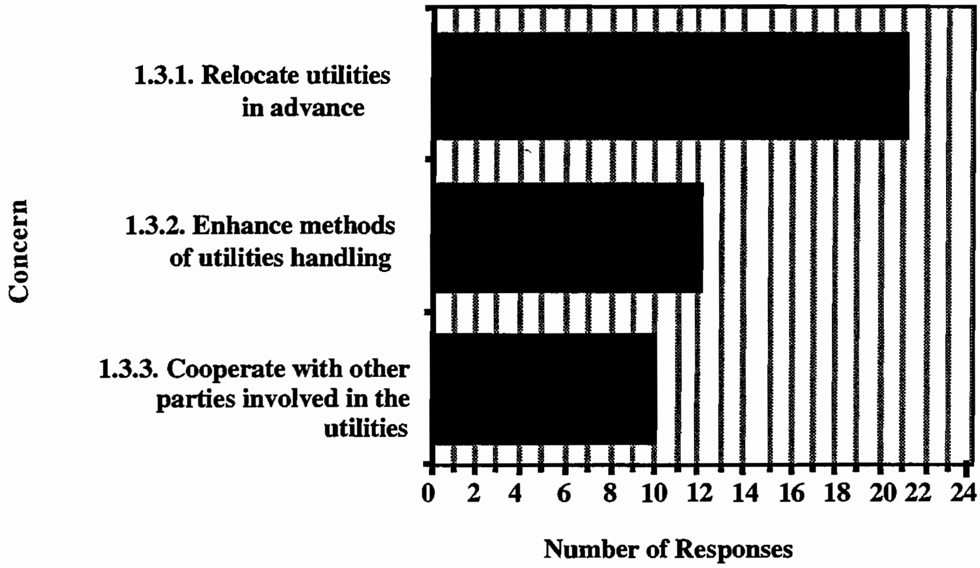


Figure 5.10. Methods to optimize the process of adjusting utilities (contractor survey)

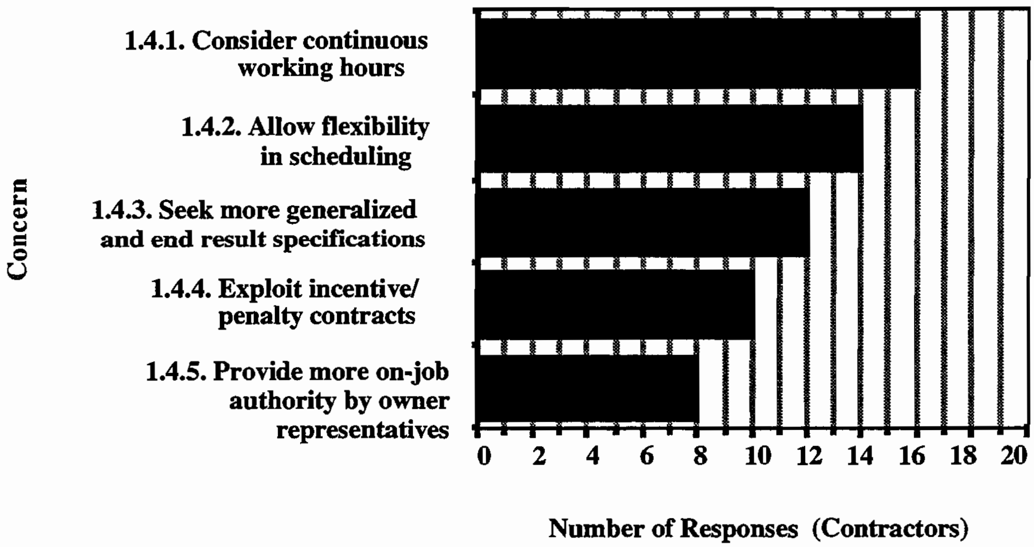


Figure 5.11. How to cooperate and coordinate among parties (contractor survey)

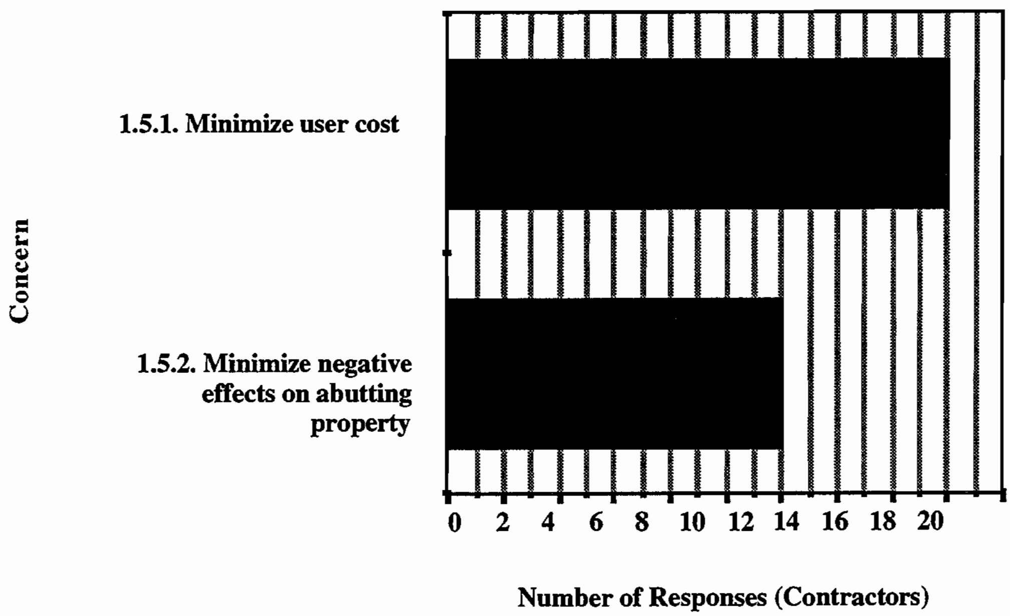


Figure 5.12. How to improve public relations (contractor survey)

CHAPTER 6. RECOMMENDATIONS FOR IMPLEMENTING EXPEDITING TECHNIQUES

INTRODUCTION

Both the survey and the literature review discussed in the previous chapter suggest that engineers should consider expediting pavement construction at the beginning and throughout the entire project. Moreover, field survey and case studies conducted in previous CTR research (Ref 15) reaffirm and substantiate our findings.

Fast-track methods can revolutionize the way in which highway pavement construction is conducted. However, a distinction should be made between fast-tracking or expediting highway pavement construction, and minimizing or mitigating the adverse effects associated with highway pavement construction operations. Fast-tracking and expediting, in most cases, imply minimizing the adverse effects of the construction. And the mitigation of these effects on the different parties may be achieved through various means, excluding the fast-tracking or expediting methods. As suggested by sources explored in this study (see Fig 5.1), fast-tracking can be an effective strategy to minimize the negative effects associated with the construction operation. However, one should not disregard the fact that, in some cases, fast-tracking or expediting highway pavement construction may result in more delays, unjustifiable costs, and inconvenience to the public. Full-closure of traffic lanes, for example, may increase user delay and create disruption in traffic flow around the construction site. In addition, while the use of high-early-strength or exotic materials is a way of fast-tracking pavement construction, application of such expensive materials on low-traffic roads is not cost-effective and may push the cost of construction beyond the capabilities of the Department.

Thus, the process of selecting the proper fast-tracking and expediting methods in highway pavement construction is complex, a fact that was emphasized in the previous chapter. Yet all methods of fast-tracking and expediting should at least be explored. All activities pertaining to the project, from the project's conception to its completion, should be considered when implementing fast-tracking and expediting procedures. Expediting and fast-tracking methods should not conflict; they should be consistent at all stages throughout the project.

Different methods of fast-tracking or expediting pavement construction (identified in the literature search, in meetings, and in the CTR survey) are identified and explained in the following subsections. The order of appearance of these methods and strategies does not reflect their importance; rather, they are ordered according to the specific stage in the project at which they may be utilized.

Expediting through Preliminary Planning and Design

As mentioned above, expediting highway pavement construction should be a priority throughout the life of the project, from the project's conception to its completion. The rights and interests of all parties affected by the project must be considered as the preliminary plans and designs take shape and throughout the entire life of the project. Agreement should be reached without compromising public benefits. Protecting the public interest, after all, is the main objective of highway pavement projects. Proper planning is accomplished by conducting the necessary studies regarding the feasibility of the design and the implementation stages of the project. Any issue related to planning, designing, and implementation must be investigated. In addition, the negative effects associated with the construction operation should be identified and dealt with at early stages. Regulations and rules should be complied with; problematic issues that may arise during construction should be avoided, since these disputes and conflicts arising during the implementation period greatly impede construction. If not considered early, these issues can be intractable and costly.

The construction site environment, traffic type and behavior, socioeconomics, and other issues must be considered in the planning and the designing of the project. While this evaluation may represent a costly process, its cost-effectiveness may be justifiable in the long term. Cooperation with other agencies is essential when collecting planning data and design data. Using innovative techniques and strategies, engineers can identify the best alternatives available for the project. The best alternative should be selected after a careful analysis. The selection process, for the following items, must be comprehensive, unbiased, and impartial: bidding of the project, acquisition of right-of-way, relocation of utilities, design, and implementation. Some of the expediting techniques and strategies used in the planning of a project include allocation of adequate ROW and advanced relocation of utilities. Good traffic handling plans, conducted early in the project, expedite pavement construction and show appreciable results in minimizing the adverse effects of the construction.

Methods of expediting pavement construction through design include reducing the number of layers in the pavement structure and using full-depth materials. Figure 6.1 illustrates some design strategies for expediting pavement construction.

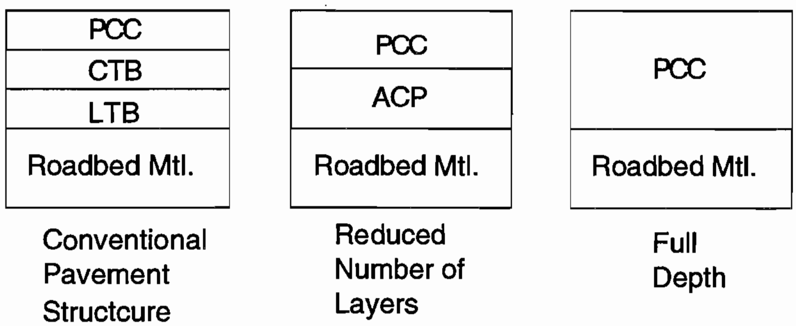


Figure 6.1. Design of reduced number of layers and full-depth sections to expedite pavement construction (Ref 1)

The city of San Rafael, California, constructed a full-depth asphalt concrete pavement in a parking lot for the city's bus fleet (Ref 3). This pavement consisted of 38-cm- (15-inch) -thick asphalt concrete pavement and was placed on the "Bay Mud," an often unconsolidated clayey-peat with high saturation and high void ratio. A conventional layered design would have necessitated a total structural section thickness of 0.60 m (2 feet) (Ref 3). Other examples of expediting through design can be found in a host of countries.

Expediting through Construction

Expediting through construction includes expediting and fast-tracking in construction materials, equipment, and techniques. Issues related to construction or implementation stages are, perhaps, the most sensitive and important of all concerns. Fast-tracking techniques and automated methods are highly applicable at this stage, helping to speed the construction operation, to reduce material curing time, and, therefore, to minimize the time required for completion before opening the facility to traffic. The expediting process undertaken during this period include three components: construction materials, construction equipment, and construction techniques.

Expediting through Construction Materials

Many construction materials were identified both in the literature search and in CTR's survey. High-early-strength materials, new exotic materials, and modified materials can all play big roles in expediting highway pavement construction. However, while fast-track materials are available throughout the pavement industry, these materials, in general, are costly. The applications of such materials should be justifiable in all cases. Their use may be cost-effective in heavy traffic areas where delay results in high costs to consumers and adjacent properties. The cost-effectiveness of their use may also be justifiable in areas where a lengthy construction period may endanger human lives. High-early-strength materials such as jet cement, new cement, fast-track portland cement concrete, prefabricated structures, stabilizers, and fly ash are examples of fast-track materials; other examples include roller-compacted concrete, vacuum treated PCC, accelerators, and polymer concrete.

These materials have been tested in different parts of the world. Between 1987 and 1988, fifteen fast-track projects were conducted in three states: twelve were built in Iowa, two in Michigan, and one in Illinois (Ref 3). Several other fast-track projects were tested between 1989 and 1990 in Iowa, in Virginia, in Pennsylvania, and in other states.

In 1986, the first fast-track pavement construction was conducted in Buena Vista County, Iowa. With the construction involving 11.3 km (7 miles) of US 71, this fast-track portland cement concrete pavement allowed traffic on the facility 24 hours after construction (Ref 3). Although the US 71 fast-track operation increased the cost of the project by $1 (from $2 to $3) per square yard, this increase in cost was offset by the reduction in costs for detours, rerouting, and liabilities (Ref 15). Iowa's project demonstrated that fast-track concrete can re-open a highway in a very short time, usually less than 12 hours after the completion of construction in some cases (Ref 15).

Expediting Using Construction Equipment

Using the proper equipment in pavement construction can substantially increase productivity and, therefore, reduce the duration of the construction. Advanced and automated construction equipment can be instrumental in speeding construction operations. Some of the equipment suggested by the literature search and CTR survey include automated dowel bar inserters, zero clearance pavers, slip-form pavers, accelerated testing equipment, extended width pavers, nuclear gauges, diamond saws, and pavement pulverizers. Other fast-track equipment is listed in Appendices C and F.

Applications of the equipment were conducted in many states. For example, automatic dowel bar inserters were used in North Central Pennsylvania (Ref 15); diamond wire saws have been used for cutting reinforced concrete in recycling operations in several states; slip-form pavers have been used in Utah (Ref 15); and pavement pulverizers have been used at Atlanta International Airport (Ref 15).

Expediting through Construction Techniques

Some of the construction techniques that were suggested by the literature survey and CTR survey for expediting highway pavement construction included the use of prefabricated elements, vacuum treatment of portland cement concrete, in-place recycling of pavement materials, roller-compacted concrete, geogrid as base supporter, and the use of such exotic materials as polymer and fly ash.

Prefabricated PCC slabs were used in the Netherlands to install road surface between two consecutive rush hour peaks (Ref 15). These slabs are connected to each other with a special dowel configuration (Fig 6.2). The slabs were lifted into place and laid on lean concrete (for support) using large cranes. Slab thicknesses vary between 17.78 and 21.59 cm (7 and 8.5 in.) according to the site conditions. Prefabricated slabs with longitudinal load transfer were used in two traffic lanes (Fig 6.3). Vacuum treatment of portland cement concrete was used in the Netherlands to produce a concrete with a low water/cement ratio. The purpose of the vacuum is to remove excess water in order to facilitate the transport and placement of the material. This process helps to achieve the pavement strength that is required to open the road for traffic in a shorter time than normal.

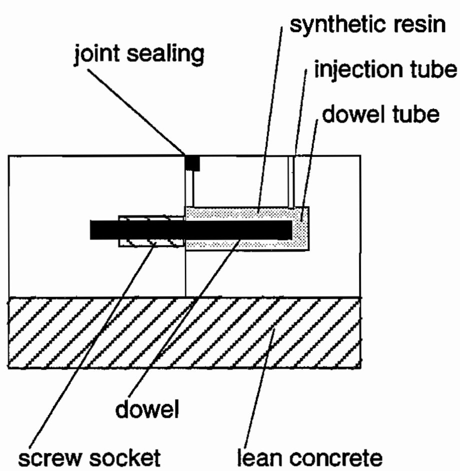


Figure 6.2. Transverse joint construction in prefabricated portland cement concrete slab

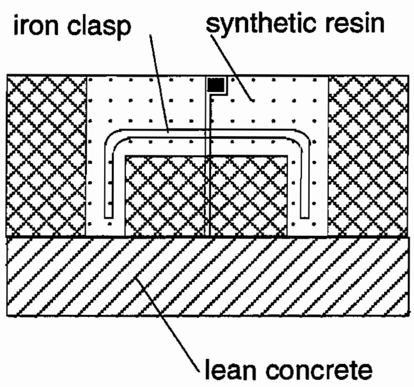


Figure 6.3. Longitudinal joint construction in prefabricated portland cement concrete slab

Expediting through Traffic Management

Two traffic management strategies (there are other strategies, of course) are complete closure of the facility under construction and partial closure of traffic lanes. Figure 6.4 shows two of the traffic control strategies and their effect on the road user and on work output. When traffic is maintained at the normal level, work output is very low and traffic delay is minimal. As the level of traffic flow on the facility under construction is reduced, work output is increased and traffic delay is decreased.

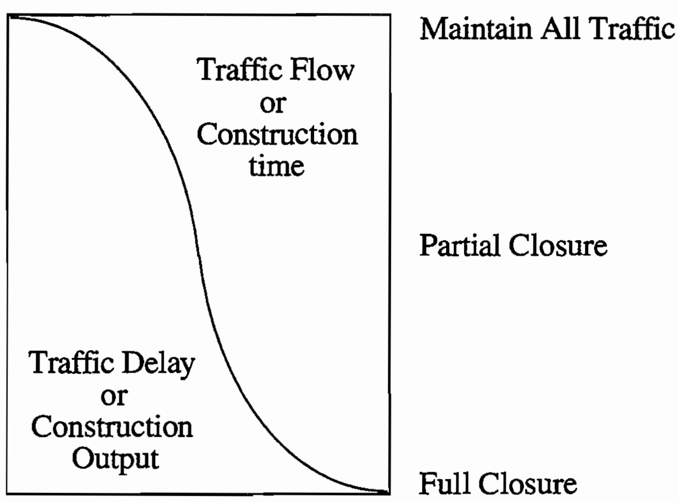


Figure 6.4. Some traffic control strategies and their effects on traffic and pavement work

Traffic management strategies are of little or no concern to most highway users, as long as inconvenience and delay are kept to a minimum. Full-closure of the facility, while providing sufficient and convenient detours, may be the optimal strategy for expediting pavement construction through traffic management.

Other strategies to control traffic during highway construction include authorizing construction during off-peak hours, increasing safety at the construction site, maintaining access to adjacent properties, and implementing advanced innovative techniques in traffic control. Details on these strategies and how to achieve them are given in Appendices C and F.

Selecting the best traffic control strategies for any highway project depends on many factors, including traffic conditions, traffic characteristics, type of project, project duration, the area containing the construction site, safety issues, economics, environmental concerns, and many other issues related to traffic and construction operations.

User delay, safety issues, public relations policies, updated public notifications on construction matters — all of these important considerations must be examined when deciding which traffic-control strategy to select.

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APPENDIX A:

Technical Memorandum of Kansas City Conference
on "Expediting Urban Pavement Construction"

TECHNICAL MEMORANDUM
CENTER FOR TRANSPORTATION RESEARCH
The University of Texas at Austin
3208 Red River, Suite 200
Austin, Texas 78705-2650
512/472-8875
FAX 512/480-0235
April 9, 1991

To: Files, Research Study 3-8-90/2-1227, "Expediting Urban Pavement Construction."
From: W. V. Ward and H. de Solminihac
Subject: Report on "Fast-track Pavement Conference" and "Drainage Systems" Workshop Kansas City, Missouri, April 2- 4, 1991

The undersigned participated in the subject conference co-sponsored by the Federal Highway Administration, the Missouri Department of Highways and Transportation, the Kansas Department of Highways, and the American Concrete Pavement Association. The attendees, about 150 total, represented the Federal Highway Administration, municipal departments of public works, state highway departments, consulting engineers, trade institutions, materials and equipment suppliers, and highway contractors. In addition, there were several attendees from outside the U.S.

The subject conference was a continuation of a dialogue, initiated by previous Fast-Track Conferences convened over the past several years, concerning the utility of installing concrete pavement where ambient conditions demand rapid completion. Highway contractors who specialize in concrete pavement construction, for example, were concerned that their product would not be considered by highway decision-makers as an economically attractive and feasible alternative to installing asphaltic concrete overlays for rehabilitation projects.

It is widely recognized that asphalt overlays are used to rehabilitate old concrete pavements because it is relatively expeditious to place AC under extant traffic conditions and in this sense the installation of ACP overlay is considered as a "fast-track" rehabilitation method even though AC might not be the most durable material. Such a decision by a highway engineer to use AC, in lieu of more durable materials, certainly recognizes the cost and inconvenience to highway users during the rehabilitation operations. Consequently, the stimulus for finding faster methods of installing concrete pavement was engendered by the highway contractors responsible for organizing the American Concrete Pavement Association.

Earlier conferences addressed the "how" of fast-tracking, which was primarily related to materials and construction techniques. Later conferences began to address methods of instituting and administering fast-tracking, some of the economic consequences of fast-tracking, and the broader scope of project development.

This memo reviews some of the more interesting findings reported at the conference.

FAST-TRACK PAVEMENT CONFERENCE

Tuesday, April 2, 1991

SESSION I - INTRODUCTION AND HISTORY

History of Fast-track

M.J. Knutson, P.E., President ACPA

- The installation of bonded concrete overlays (BCO) is considered a fast-track method.
- One of the concerns in using BCO is the fear of (materials?) failure. This attitude has contributed to the current dilemma: the only way to overcome the fear of failure is to install a BCO, which will not happen because of this fear. Consequently, the design engineer needs assurance from the materials engineer, contractor, and construction engineer.
- High-early strength in BCO when air temperature is $\leq 70^\circ$ is assured by using a curing blanket having a thermal coefficient of transmission of $R \geq 0.5$.

FHWA Special Project 201

Ted Farragut, P.E., Coordinator of Demonstration Projects Program, FHWA, Washington, D.C.

- An intersection was constructed in 8 hours in Cedar Rapids, Iowa.
- The warrant for a fast-track project is traffic, traffic, traffic.
- Drivers are growing increasingly more sensitive to loss of traffic services, and less tolerant of congestion at and around construction sites. Fast-tracking reduces the duration of construction-induced congestion. FHWA is aware of these conditions and encourages fast-tracking.
- To the FHWA, fast-tracking extends beyond fast-setting concrete materials to include all phases of construction and preparation for construction.
- A curing blanket is effective in achieving high early strength. It is important to have a uniform temperature gradient through BCO.
- Experiments have been conducted using spray-on foam insulation as a curing blanket. If this works, it enhances the possibility of beginning concrete curing immediately following the completion of surface finishing. A curing blanket can't be deployed until the riding surface has hardened sufficiently to accommodate the blanket.
- Rapid quality-assurance testing needs to be developed and used by the contracting agency as a supplement to those fast-track methods used by the contractor.
- The "pulse-velocity" method of determining the strength of in-situ concrete appears to be satisfactory.
- Fourteen states have permitted the contractor to *bid in* working time at some value established by the contracting agency. The working time bid in by the contractor becomes the benchmark for determining a bonus payment or penalty assessment.
- Other states provide incentives/disincentives by the *lane-rental* method of bidding. The contractor is permitted to bid in the cost of renting a traffic lane(s) to be taken out of service at the discretion of and as an accommodation to the contractor (so as to have

more working room to expedite construction). The contracting agency establishes the unit rental rate of the lane or lanes which can be removed from service.

- There are various reasons why there are technology "losers" and why there are so few advances in highway technology:
  - Insufficient research and development (R&D)
  - No champion
  - Too technical or complicated
  - Industry opposition
  - Lack of persistence or using new ideas at the wrong place and wrong time
- More demonstration projects are needed.
- There are three kinds of people involved in highway engineering:
  - People who make things happen
  - People who watch things happen
  - People who wonder what happened

SESSION II - BENEFITS OF FAST-TRACK

Time versus User Costs

Clinton Solberg, ACPA Staff

- The shortest distance between two points is always under construction.
- People value travel time highly because they can have more time at the beginning or end of the work day to do what *they* want to do.
- Construction can be expedited by Strategic Highway Improvement Techniques or, better, Network Optimization: Do Everything Logically in Advance of Yesterday.
- Communication with the public is of highest importance.
- Use signs (passive and real-time), pamphlets, radio, newspapers, and television.
- Attitude adjustments can be wired positive instead of negative—providing the public can be kept informed.
- Sensitive projects warranting fast-track methods are categorized as follows:
  - Where substantial increases in users costs may be involved. "Substantial" is defined as $100,000 or 20% of the estimated cost of the project.
  - Projects where the delay is 10 minutes or more for each vehicle passing through.
  - Projects where access to retail businesses will be restricted or inconvenienced because of construction operations.
- 3 C's of fast-tracking: Communications, Commitment, and Cooperation

- *Communication* with the public; *Commitment* by the owner and contractor; and *Cooperation* between the owner and contractor.

- Ways and means of mitigating construction site inconveniences:
  - Incorporate utilities adjustments with highway contract
  - Train personnel to develop better traffic management
  - Increase communications with utility companies
  - Challenge construction industry to develop innovative methods and techniques to expedite construction
- If all else fails, it is easier to beg forgiveness than to prepare.

Safety Considerations

Johnny Dahl P.E. FHWA, Kansas Division

- Experience indicates that the number of accidents and fatalities associated with work zones is twice that of normal roads.
- Concerns for safety include the driver, the construction site worker, and pedestrians.
- Problems with construction zone "signing"
  - Sign substitution
  - Sign orientation
  - Too many signs
  - Restricted sight distance
  - Sign coverage
  - Sign size
  - Sign maintenance
- Problems with channelizing devices (plastic barrels, delineators, etc.) and barricades:
  - Poor alignment
  - Improper spacing
  - Improper maintenance

Contractor's Operation

Jim Mikulanec, President Central Paving Corporation

- Benefits of fast-tracking:
  - Increased productivity

- Meets public demands
- Challenges traditional concrete practices as to what is feasible
- Addresses the issue of *measured* quality
- Lowers risks

Opening to Traffic

Larry Cole P.E., Portland Cement Association

- On opening concrete pavement to traffic after construction: There is a wide range of specification requirements among the different states. These vary according to the parameters of: curing time and cement content; curing time, cement content, *and pavement thickness*; curing time *and flexural strength;* etc.
- Temperature at time of placement is very important in its effect on early strength and minimum acceptable opening time.
- Factors affecting early opening to traffic and minimum acceptable strength: construction loads, early traffic loads, location of loads, expected fatigue damage, joint stresses, and fatigue properties.
- Consideration should be given to pre-loading sawed joints in order to enhance the chances of opening.

SESSION III - FAST-TRACK MIX DESIGN HISTORY AND ISSUES

Fast-track Mix Design Development

Bernie Brown P.E., Chief Materials Engineer, Iowa Department of Transportation

- The strength gain of high-early strength concrete can vary substantially depending upon the *brand* of cement being used.
- In order to achieve desirable characteristics for high-early strength concrete, the Iowa DOT has permitted the use of fly ash and various accelerators such as calcium chloride, Daraset, and Pozzolanth 555.
- (Iowa DOT?) Has developed a variety of mix designs for a variety of desired early-opening times.

Innovation in Testing of Mix Designs

Suneel Vanikar, Demonstration Projects Program, FHWA

- Referred to demonstration projects Nos. 20 and 75, whose objective was the investigation of accelerated construction time for concrete pavements and included innovations in concrete mix designs.
- Innovations in testing procedures involved both destructive and non-destructive testing such as:
  - Destructive: split tensile

- Non-destructive:

    penetration resistance
    surface hardness
    pull out
    twist out
    pulse velocity
    maturity method

- The maturity method involves recording and integrating the time-temperature profile of the curing concrete, and correlating this with time-temperature strength curves developed from laboratory specimens of similar concrete. The temperature of the in-situ concrete is acquired with embedded thermocouples and recorded into an electronic recording and data processing device. The FHWA displayed one recording device which could record multiple (12?) channels and print out the results. This device costs about $1500.
- Bonded concrete overlay projects have recently been completed in Missouri, Virginia, and Louisiana.
- Heat build-up in bonded overlays must be uniform or the durability of the overlay may be adversely affected. Recommend use of thermal blanket to control heat accumulation in overlay.
- Had difficulty in duplicating strength test results using the split tensile method.
- Recommends the maturity method as being the most reliable and useful. Believed the maturity method to be superior to the pulse velocity method.

Enhancing Mix Design with Admixtures

Mike Mickes, Master Builders Inc., St. Louis, MO.

- Described the characteristics of the various generic types of water-reducing (cement dispersal) agents. Apparently there have been some advances in the formulation of these water-reducing agents, and some of the undesirable effects prevalent a few years ago have been mitigated.

Particle Distribution in Mix Design

Jim Shilstone, President Shilstone & Associates; Dallas, Texas

- Expounded at great length on the virtues of *well-graded* aggregate mixtures in designing concrete mixes. Particle distribution is very important in contributing to concrete durability. There is too much gap-graded concrete being produced.
- Cited U.S. vs Spearin, 1917 U.S. Supreme Court Decision, to wit: "Owner must be responsible for worst-case interpretation of his (owner's) specification."
- Quality and durability is affected if the owner does not have a good, clear objective definition of acceptability. He can't expect the contractor to deliver what he (the owner) doesn't understand or can't define.
- What's needed is a good definition (specification) of a 40-year pavement.

- Rheology is the science of the flow of materials. Good mix design (well-graded aggregates) enhances workability, which includes pumpability and susceptibility to vibrator compaction.

Wednesday April 3, 1991
SESSION IV - CONSTRUCTIBILITY

Concrete Mix Considerations
Jim Thompson, Ash Grove Cement Co.; Overland Park, Kansas

- Recommends well-graded (continuous as opposed to gap-graded) aggregate mixtures.
- Recommends the use of the maturity method of strength evaluation

Curing and Protection
John Scanlan, Master Builders Inc.

- Emphasized the importance of proper curing and protection against freezing.
- Skeptical of the efficacy of most curing compounds.
- The lower the placement temperature, the better the concrete.
- Make trial mix designs at realistic temperatures of 40° and 90°F rather than at 70°F usually required by specifications.
- The ASTM water retention test for evaluating curing membranes is neither very reliable nor repeatable.
- Concrete surfaces which have been allowed to dry out without proper curing will become carbonated.

Joint Design and Construction
Mark Kaler, P.E., Dayton Superior Company

- Purpose of Joints: thermal movement, dynamic movements, plastic shrinkage, slab termination points
- Joints Types: contraction, construction, expansion
- Design Parameters: traffic, environment, concrete materials, sub-base, shoulder type, joint sealant, past joint performance
- Seal Characteristics: elasticity, low modulus, adhesion, cohesion, weather ability, compatibility, shape factor, length ability
- Seal Types: hot pour, cold pour single component, cold pour two components
- Saw Type: dry, wet

Equipment Innovations
Chapin Sipherd, CMI Corporation

- Zero-clearance paving machines
- Minimum-clearance paving
- Dowel bar inserters
- Slipform paving machines

SESSION V - SPECIFYING FAST-TRACK

State Specifications. Panel comprised of Bernie Brown from Iowa, Bill Trimm from Missouri, Rodney Maag, Kansas, and Jim Mikulanec, Central Paving Corporation.

Bernie Brown.

- Requiring fast-track methods should be justified because it costs more.
- Recommend Value Engineering Concepts. Give contractor opportunity to use initiative
- Have had joint problems with fast-track methods. Trouble getting joints to dry out after sawing so the fresh joint will adhere to and secure the joint sealing material.
- Opening-to-traffic time for fast-track projects is when flexural strength is 450 psi as opposed to 500 psi on regular jobs.
- Permit membrane cure with application rate of 150% of normal in lieu of insulated blanket with R value of 0.5 or greater.
- Iowa uses incentives and disincentives to achieve desirable pavement thickness and ride quality.

Bill Trimm.

- 3 C's of fast tracking are communications, commitment, and cooperation.
- Missouri recently completed bonded overlay project and is letting another in May 1991.
- BCO project was planned as a fast-track project without a specific time table.
- Missouri does not permit the use of river gravel in pavement concrete. Crushed limestone is required because of low coefficient of thermal expansion.
- Has had problems with sawing.
- Require maximum and minimum limits in surface texturing.
- In fast-tracking texturing limits are not required. Specify only tine spacing and depth of tining.
- No problems with maturity tests. Have found good agreement with destructive tests.
- Arizona DOT and Oklahoma Turnpike Authority have a performance specification as opposed to end-results specification.

- Understands the Europeans are using more performance-type specifications for flexible type pavement designs.
- Missouri has use-incentive and -disincentive-type specifications for a diamond interchange project.
- BCO project included 18 test sections and is part of the SHRP program.
- New BCO project on I-70 west of Booneville will include incentive and disincentive provisions with a bonus for early completion and a penalty for late completion. Contractor can use his own mix design but must deliver 3500 psi concrete in 18 hours. Require primary and secondary surface preparation. Primary is to be cold milling. Cold milling cutter heads have been greatly improved and cold milling is considered competitive with shot blasting. Secondary preparation allows for shot, sand or water blasting. Grout is not required. Concrete curing is curing compound plus polyethylene sheeting. Goal is opening to traffic at 3500 psi compressive strength in 12 to 18 hours.

Jim Mikulanec.

- Would like to see performance specifications with quality-of-workmanship warrant for several years.
- Likes maturity meter for evaluating concrete strength.
- Likes standard deviation method of measurement for determining pavement thickness.
- Big issue with respect to performance specifications is how to pay for performance rather than end-results.
- Value Engineering is of questionable utility. Does not see why contractor should have to share profit with anyone if he (contractor) comes up with a good idea and takes all the risk.
- Sawed joint should be sealed immediately.
- Sees problems with spalls and cracks if joint is sawed too soon.
- Grout should be eliminated in BCO construction. Can improve ride quality if the paving train does not have to stop and start to accommodate grouting operations. Afraid also of grout drying out too quickly.

SESSION VI - CASE STUDIES

Missouri 4" Bounded Overlay

Henry Haggard, Resident Engineer on Bonded Concrete Overlay Project, Missouri Department of Highways.

- Project located on U.S. 67 south of St. Louis in Jefferson County. The project provided for the rehabilitation of 8.5 miles of the two northbound lanes of existing 4-lane divided highway. Northbound lanes constructed in 1955 of 8-inch-thick, non-reinforced concrete, jointed pavement with 20-foot joint spacing and no dowels. Southbound lanes added later.

- The entire 8.5 miles of overlay was placed in 10 working days. The entire project took about 100 days, of which the existing road was closed for 6 weeks. The cost of the project was $1,987,000 or $117,000 per lane-mile.
- Existing pavement repaired prior to overlay.
- The existing surface was rotomilled prior to overlay.
- The surface was shot-blasted and air-cleaned immediately prior to placing concrete.
- Grout was placed just in front of the paving spreader.
- All "working" cracks were "stitched" with reinforcing bars. The re-bars were secured to the pavement surface with shot nails and tie wires.
- Used a lateral belt conveyor to carry concrete to paving machine. Concrete was delivered along existing shoulder which had to be reworked to hold up under construction traffic.
- Paved a 24-foot width using a CMI-450 slip form paver.
- Used 100 sf/gal curing membrane application plus curing mats.
- Specs called for sawing through BCO into existing joints. Had three concrete saws on job, plus spare.
- The 18 test sections provide for a variety of joints and joint fillers and sealers.
- The existing pavement was profiled with profilograph and was found to produce 70 inches per mile. The BCO averaged 6.2 inches per mile. The contractor earned a bonus for ride quality for about 1/3 of the total overlay.

Bonded concrete overlay project in Virginia.

- Fast-track project completed in spring of 1990 involved one mile of two-lane road.
- Concrete requirements, 3,000 psi in 24 hours. Opening-to-traffic in 48 hours.
- Used regular range water reducer.
- Specs required 200 psi shear strength to be determined by guillotine method. Shear surfaces were guillotine tested with grout, without grout, and through the substrata (existing pavement). Tests showed that the shear strength was very close to the same at all shear faces.
- One-half of project was grouted and one-half was not. Wetting and grouting was required within the non-grouted section if the surface temperature at time of placement was 90°F or higher. The purpose of the wetting was to cool the surface.
- Curing membrane plus insulated blanket (R ° 0.5) was required.

City Street Fast-track

Bruce McCallum, Public Works Director, Manhattan, KS

- Project provided for improving Anderson Ave.,a 3 to 5 lane street.
- The concrete was covered and cured for 24 hours.
- The street was opened to traffic in 25 hours.

- Cost analysis for fast-track: placing and finishing were not considered as extra costs; reduced payroll taxes, reduced equipment cost.
- Considering all costs involved, the fast-track alternative was cheaper.
- Planning was very important to the success of the project.
- The sequence of work provided for building the project one lane at the time, and finally, the intersections.
- Computer schedule was used by the contractor to schedule each day's activity by crew.
- Job coordination was also important.
- Contract time: 120 days, construction time: 60 days.
- Job characteristics using fast-track technique: cost effective, time reduction, safety aspects, and limited access to property. (Author's note: just how the limiting access to abutting property was not explained.)

Fast-track Intersections

Jim Grove, Iowa Department of Transportation

- The Transportation Research Record No. 1282, recently published, presents an article about this experience.
- They worked from 6 pm to 6 am, during night.
- The project was two miles long.
- They worked Monday through Friday only and finished in two weeks.
- The main steps for the intersection job were the following: first night: close part of the intersection, break up and remove the old pavement, place asphalt concrete as a temporary surfacing and open to traffic; second night: close the same part of the intersection, remove the temporary asphalt concrete, and place the fast-track concrete mix and open to traffic. This operation was repeated until all intersections were finished.

Fast-track Hypothetical Project Exercise

Introduction by Jim Mikulanec, Central Paving

- All participants were divided into four groups; each group studied the strategy that would require the shortest time to finish a specific rehabilitation work and involve the least amount of money for lane rentals.

DRAINAGE SYSTEMS WORKSHOP

Thursday, April 4, 1991
SESSION I - DESIGN AND CONSTRUCTION FEATURES
PERMEABLE BASES

Introduction and Policy Considerations

John Hallin, Pavement Division, FHWA

- Rigid pavement design should consider thickness, joint, and drainage.
- Permeable bases should be used when there is a lack of natural bases.
- Design consideration of permeable bases: material must be permeable and stable, longitudinal edge drain collector system, filtered to protect permeable material.
- Types: unstabilized and stabilized (AC and PC).
- The type of stabilizer should be left to the contractor.
- California produces a good design and construction of good, stable permeable bases.
- Drainage can be constructed after the pavement is laid out.
- A geocomposite system is not good.
- The outlet is a critical area that needs to be periodically maintained.

Design

Bob Baumgardner, Pavement Division, FHWA

- The four layers that comprise a rigid pavement are: PCC slab, open-graded base (permeable), separate aggregate layer, and sub-grade.
- Crown section will take the water faster.
- Day lighting is not recommended.
- Permeable base: K° 1000 feet/day for 2 hours minimum time to drain (recommended).
- Infiltration ratio for AC is 0.33 and for PCC is 0.5.
- AASHTO № 57 is the maximum open recommended for open permeable bases.
- AASHTO № 89 is the smallest open recommended for open permeable bases.
- Aggregate trenches are not recommended.

Construction

Dan Mathis, District Engineer, Iowa Division, FHWA

- The presence of water in the pavement structure is the primary cause of distress.
- AASHTO Road test K° 2 ft/day.
- AASHTO 57 K° 3000 ft/day.
- The K is the coefficient of vertical permeability.

- New Jersey has a very good untreated base with 200-2000 ft/day.
- The construction of a permeable base requires more care than a normal base.
- Concerns: stability, displacement, segregation, contamination.

APPENDIX B:

Questionnaire Prepared for
Texas Department of Transportation

TEXAS STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

EXPEDITING PAVEMENT CONSTRUCTION SURVEY

1) Identify the top five construction items, procedures and specifications which severely impede progress.

2) List the top five construction practices, ideas and solutions which will speed the pavement construction process.

3) What improvements can be made at critical intersection locations to quicken the construction process?

4) Discuss the benefits and disadvantages of the following items concerning expediting pavement construction. Include any personal experiences and whether or not you would recommend the item as an useful solution to speed construction.

a) nighttime construction

b) precast pavement elements

c) multiple smaller contracts instead of a single large contract

d) exotic materials such as high-early strength cements, fiber-reinforced concrete, etc.

e) improved public relations with the highway user

5) Identify innovative construction equipment (automated dowel bar inserters, zero clearance pavers, etc.) currently available which will improve efficiency.

6) Would the use of bonus/penalty specifications provide earlier completion dates? On what bidding basis should the contract be awarded? Identify any advantages and disadvantages.

TEXAS STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

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5) Identify innovative construction equipment (automated dowel bar inserters, zero clearance pavers, etc.) currently available which will improve efficiency.

6) Would the use of bonus/penalty specifications provide earlier completion dates? On what bidding basis should the contract be awarded? Identify any advantages and disadvantages.

7) Is there a preference towards pavement materials type and/or pavement structure design which will allow for faster and easier construction?

8) Describe problems encountered with traffic control plans and traffic handling. What would be practical solutions.

9) What problems are encountered with abutting property owners on construction sites which severely impedes operations? What solutions would you recommend?

10) Would changes or greater flexibility in the project plans and specifications expedite construction? Provide examples.

11) What steps can be taken in the preliminary planning and preparation phase of a project to minimize delays?

12) Would moving all traffic off of the construction site to a nearby detour have a significant impact on expediting construction? Provide any anticipated problems and advantages with this traffic management suggestion.

13) Which procedures are used to estimate the number of working days on a contract? Does the procedures provide a fair (and legally defensible) estimate of working days which still allows for timely execution of the work? Would using calendar days instead of working days help expedite construction?

14) Please identify construction project sites, past and present, which can serve as case studies. Suggested sites should have used some method to expedite pavement construction (successful or not) or have been a location where expediting pavement construction would have greatly enhanced the project. These sites will be used to document the problems encountered and the solutions used to expedite construction.

15) If you feel this questionnaire is incomplete or doesn't address some other important issue, please feel free to provide any additional suggestions and recommendations below.

Thank you for participating in this study. Your time and effort is greatly appreciated.

APPENDIX C:

Hierarchy of Objectives Technique (HOT) Outline Used to Categorize Responses to Questionnaire Prepared for the Texas Department of Transportation

PRESENTATION OF SURVEY FINDINGS USING HOT SYSTEM

The survey findings in this report have been documented and presented using the Hierarchy of Objective Techniques (HOT) system. HOT outlines are simple and efficient computer software tools used for categorizing ideas and presenting them in hierarchic order. HOT *diagrams*, as opposed to HOT outlines, take complex issues and break them into basic components, making it easier to understand the relationships of the different ideas involved. The form of these diagrams is referred to as a "Tree." The advantage of this technique is its flexibility: unreasonable ideas may be deleted from the tree structure, while new ideas may be added.

By way of analogy, it might be instructive to compare the HOT diagram structure to that of a standard table of contents, as illustrated in the figures below.

Book

Ch.1
- Sec.1.1
- Sec.1.2

Ch.2
- Sec 2.1
  - sec 2.1.1
  - sec 2.1.2
- Sec 2.2
- Sec 2.3

Ch 3...

Fig C1. Contents of a book in outline form.

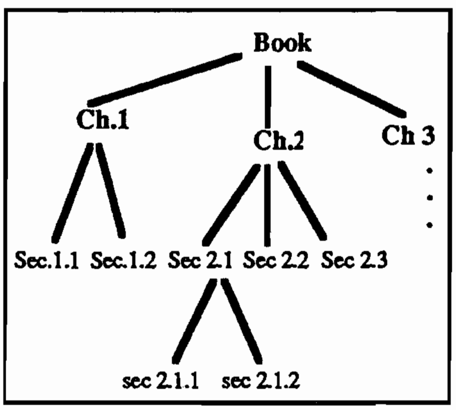


Fig C2. Contents of a book in tree-structure form.

While there are several software packages available for use with the HOT system, this study used MORE (Ref 14), an especially effective tool for representing and organizing information. This technique provides a sequential understanding of ideas as it categorizes and records these ideas in a microcomputer database. Using the information and ideas collected in the CTR survey, the software represents these ideas in both outline and diagram (tree) form (see Fig C3). Once concerns and issues have been identified, it is then possible for the software to categorize subordinate ideas according to their specific level of importance in the information tree (see Fig C3). When the particular element is identified, the diagram can then be utilized to deal with the full scope of that element (see Fig C4).

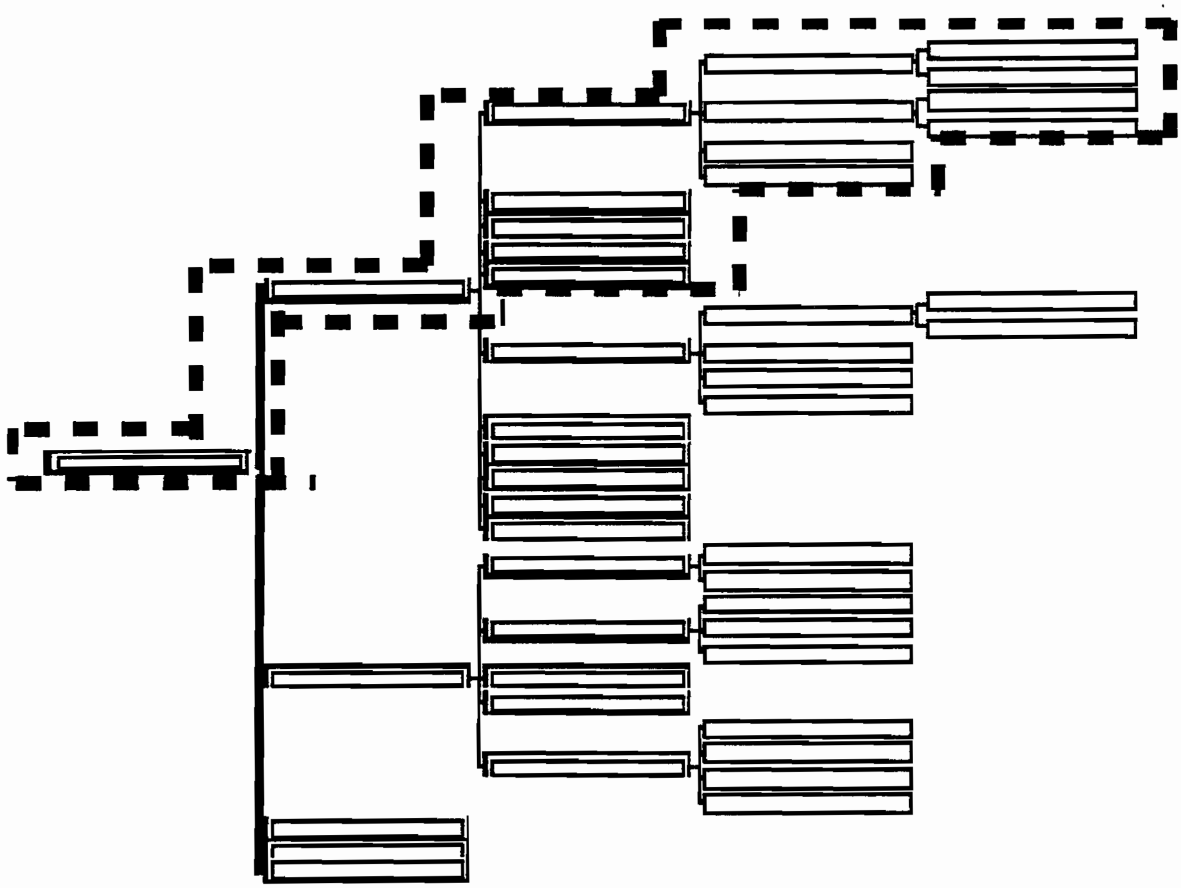


Fig C3. Information tree taken from contractors' survey.

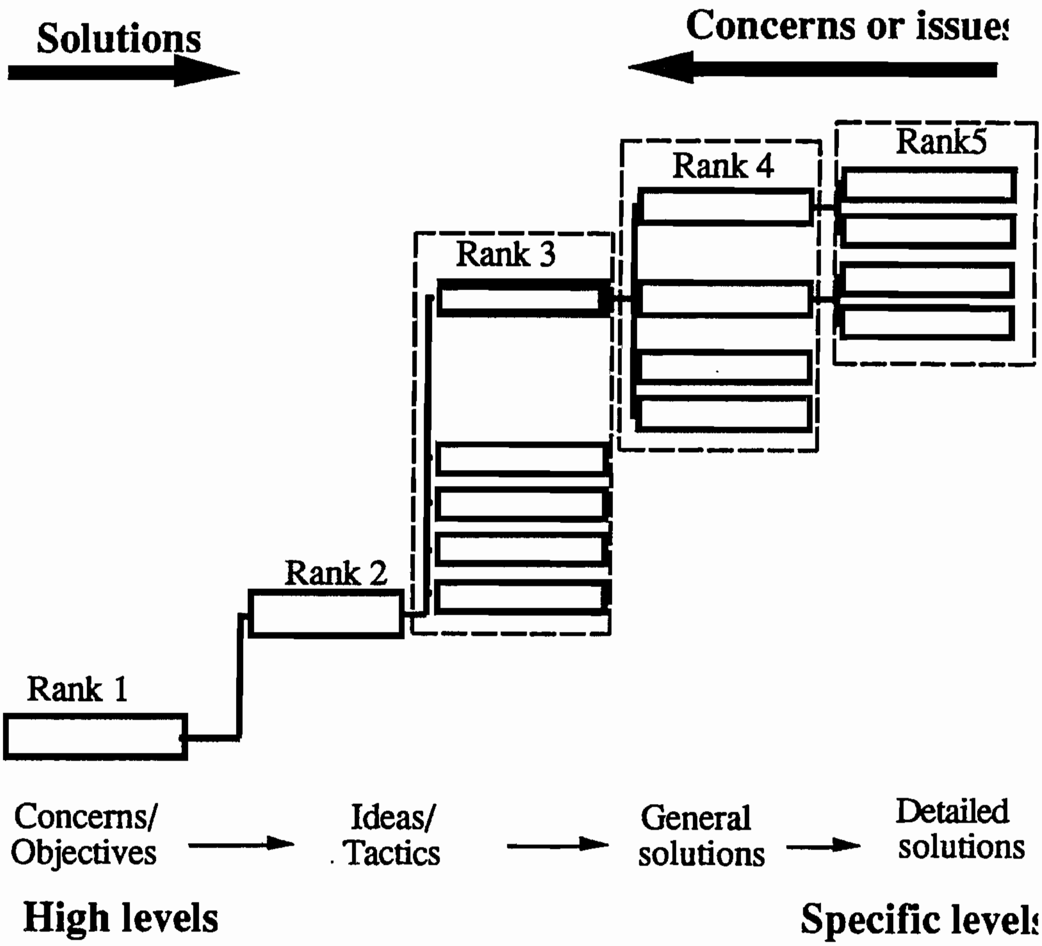


Fig C4. The basic concept of the Hierarchy of Objective Techniques (HOT) diagram (Ref 15).

Development of HOT Outlines

The format of the HOT outline is rather simple: As indicated above, after concerns and issues and their suggested solutions are identified, they are then structured as hierarchical outlines. As one reads the sub-entries in an outline from top to bottom, the question of "HOW" is answered. Conversely, the question of "WHY" is answered as the reader moves from the bottom to the top in the sub-entries. The numbers associated with each sub-entry represent the hierarchic order (rank) of that specific sub-entry. Figure C5 shows a sample HOT outline, where the sub-entry 1.2 is presented as a way to accomplish the main objective (1. minimizing adverse ...), and where sub-entry 1.2.1 is presented as a way to achieve the second-order objective (1.2 with rank = 2).

+ 1. Minimizing Adverse Effects of Urban Highway Construction Operation

- **+ 1.2. Optimize Traffic Control and Management Systems**
  - **+ 1.2.1. Select full closure of pavement when allowed**
    - **- 1.2.1.1. Provide sufficient detours**
    - **- 1.2.1.2. Divert traffic to adjacent routes**
  - **+ 1.2.2. Use fewer equipment changes for construction**
    - **- 1.2.2.1. Use multiple application machines and equipment**
    - **- 1.2.2.2. Implement procedures requiring less equipment**
    - **- 1.2.2.3. Remove unnecessary equipment from the site**
  - **- 1.2.3. Use temporary driveways**
  - **- 1.2.4. Construct reliable frontage roads**
  - **+ 1.2.5. Enhance safety at construction sites**
    - **- 1.2.5.1. Provide more working space**
    - **- 1.2.5.2. Adopt higher safety standards**
    - **- 1.2.5.3. Have sufficient lighting for night hours**
    - **- 1.2.5.4. Use special safety features at night time and during bad weather**

Fig C5. An example of HOT outline showing the hierarchical order of sub-entries.

Development of HOT Diagrams (Trees)

HOT diagrams or trees are created using the trees concept. The root (i.e., the node having the highest ranking concern) is connected by edges, from left to right, with second-order concerns. If more than one element or concern exists in the second level, then these elements are ordered according to their importance from top to bottom. The tree may be expanded accordingly until the specific solution, if available, is reached. These specific solutions (the end nodes) are called the tree leaves. As in HOT outlines, the question "HOW" is answered as the reader traverses the tree from left to right. Conversely, as the reader moves from right to left in the tree diagram the question "WHY" is answered. Figure C6 shows an example of a sub-tree using the outline given in Fig C5.

In the case of the CTR survey, the ideas obtained were categorized and ranked according to their frequency of appearance in the responses. Specific ideas relating to the reduction of the negative impacts of urban highway construction are thus presented in the form of paths using the HOT diagrams, or in the form of sub-entries using HOT outlines. By moving left to right, from the main concern or objective (first level or rank) to the terminating strategy, one arrives at a systematic solution to meet the given objective. In this report, the main objective, as suggested in the survey at hand, was "minimizing the adverse effect of urban highway construction." To review those strategies that meet this objective, one should first seek more detailed issues pertaining to the given objective, and then consider specific solutions. By using this conductive procedure, one arrives at a systematic way of achieving the main objective.

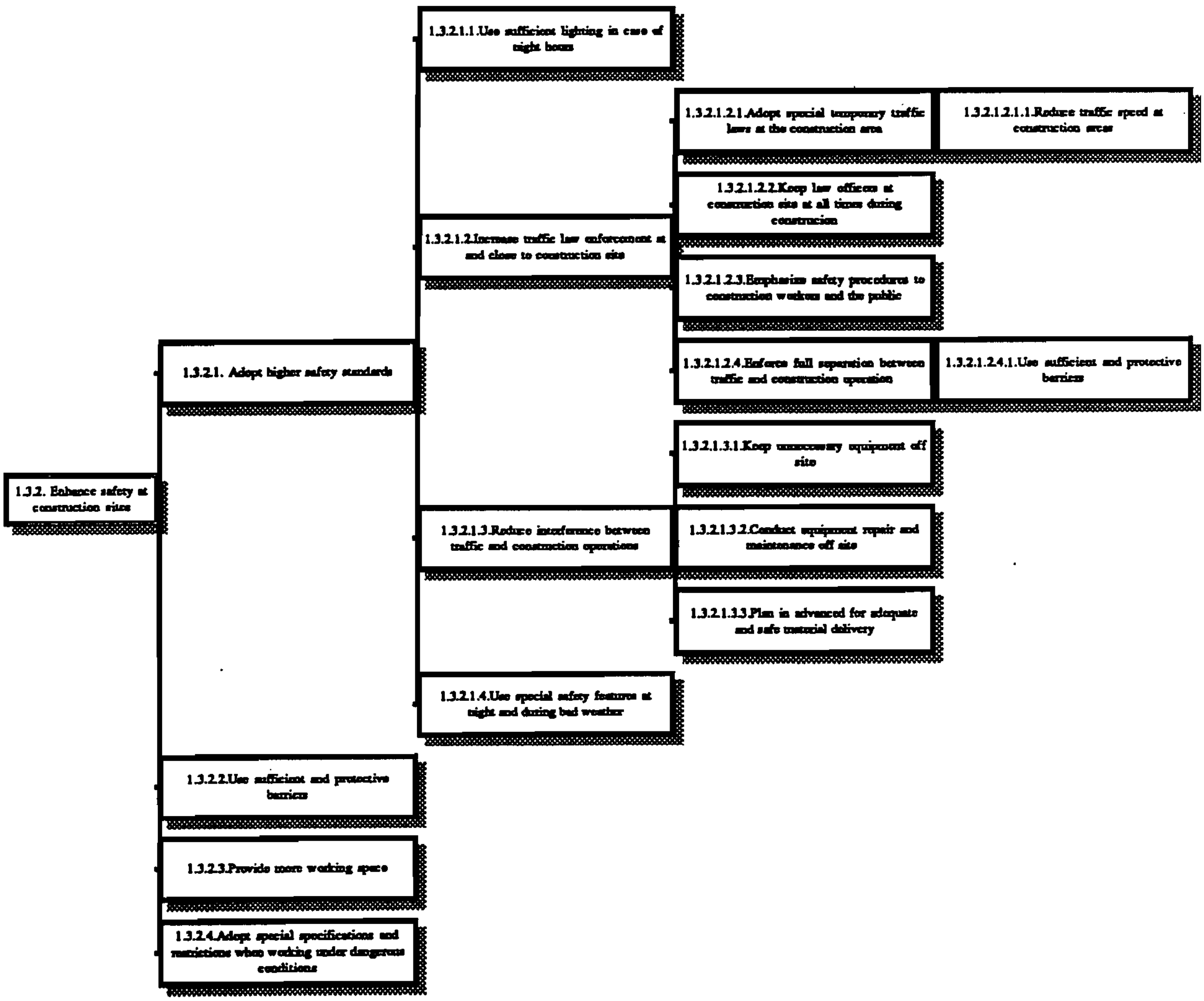


Fig C6. Sample of a sub-tree using the outline given in Fig C5.

Thus, this appendix, appendix D, and appendices F-G present, in HOT outline and diagram form, a comprehensive reference guide for mitigating the adverse impact of urban highway construction — as identified through ideas suggested in the TxDOT survey. These ideas and lessons begin from the main objective, proceed to issues and concerns for meeting this objective, and finally to specific and detailed solutions. The order of these strategies reflect their rank of importance as given in Fig 5.1.

HOT OUTLINE

IDEAS TO MINIMIZE THE ADVERSE EFFECTS OF URBAN HIGHWAY CONSTRUCTION ACCORDING TO SDHPT OFFICIALS

+ **1. Minimizing Adverse Effects of Urban Highway Construction**
    + **1.1. Minimize Time, Phases and Steps Involved in Pavement Construction**
        + 1.1.1.Use high early strength materials
            + 1.1.1.1.Use stabilizers
                - 1.1.1.1.1.Use asphalt stabilizers
                - 1.1.1.1.2.Use lime stabilizers
                - 1.1.1.1.3.Use cement stabilizers
            + 1.1.1.2.Use high early strength concrete
                - 1.1.1.2.1. Use hydraulic cement in critical areas
                - 1.1.1.2.2. Use jet cement when it is economically feasible
                - 1.1.1.2.3. Use fiber reinforced concrete
            - 1.1.1.3.Use thick asphalt pavement when possible
            - 1.1.1.4.Use high cement ratio
            - 1.1.1.5.Reduce curing time of stabilized material
            - 1.1.1.6.Use foam insulated curing blankets for P. C. concrete
            - 1.1.1.7.Apply fly ash to concrete pavements
        + 1.1.2. Minimize number of layers
            + 1.1.2.1. Use high strength materials
                + 1.1.2.1.1.Use stabilized under layers
                    - 1.1.2.1.1.1.Use asphalt stabilizers
                    - 1.1.2.1.1.2.Use lime stabilizers
                    - 1.1.2.1.1.3.Use cement stabilizers
                - 1.1.2.1.2.Use thicker layers with no base
                - 1.1.2.1.3.Use automated and accelerated methods
                - 1.1.2.1.4.Pour concrete directly into grade
                - 1.1.2.1.5.Use Continuous Reinforced Concrete Pavements
                - 1.1.2.1.6. Minimize the time required before joint can be sealed
            + 1.1.2.2.Use full-depth materials
                - 1.1.2.2.1.Minimize number of layers
                + 1.1.2.2.2.Use high strength materials
                    - 1.1.2.2.2.1. Use reinforced concrete pavement
                    - 1.1.2.2.2.2. Use fiber reinforced concrete pavements
                    + 1.1.2.2.2.3. Use full depth asphalt pavements
                        + 1.1.2.2.2.3.1. Eliminate asphalt seasons for hot mix and surface treatments
                            - 1.1.2.2.2.3.1.1. Use additives for hot mix pavements and surface treatments in all weathers
                            - 1.1.2.2.2.3.1.2. Use exotic polymer concrete
            + 1.1.2.3. Use prefabricated members
                - 1.1.2.3.1.Use precast short segments and curbs
                - 1.1.2.3.2.Precast manholes, inlets, and box culverts
            + 1.1.2.4. Encourage and plan for innovation to reduce number of layers
                - 1.1.2.4.1. Organize and coordinate innovative procedures to optimize utilization of time and energy
                - 1.1.2.4.2. Establish and implement advanced procedures, programs, and systems for the planning, designing, and construction of pavements
                - 1.1.2.4.3. Allocate necessary resources for innovation

- 1.1.2.4.4. Monitor and standarize innovation
- 1.1.2.5. Plan for the future in the design, construction, and maintenance of pavements

+ 1.1.3. Implement accelerated and fast track methods
  + 1.1.3.1. Employ advanced and automated equipment and procedures in construction
    - 1.1.3.1.1. Use automated dowel bar inserters
    - 1.1.3.1.2. Use zero clearance paver
    - 1.1.3.1.3. Use slip form paving method
    - 1.1.3.1.4. Employ multi-piece tie bars and dowel bars
    - 1.1.3.1.5. Implement improved accelerated testing procedures
    - 1.1.3.1.6. Use extended width pavers
    - 1.1.3.1.7. Adopt procedures requiring shorter fabrication time
    - 1.1.3.1.8. Use nonreinforced pavements with dowel inserters in congested areas
    - 1.1.3.1.9. Use nuclear gauge
    - 1.1.3.1.10.Use steel fiber in thin bonded concrete overlay and special areas such as intersections
    - 1.1.3.1.11.Use milling machines for shoulder widening
    - 1.1.3.1.12.Employ pavement pulverizers to remove the old pavement
    - 1.1.3.1.13.Use diamond saw in cutting reinforced concrete
    + 1.1.3.1.14.Provide adequate, compatible, and reliable equipment to ensure continuous and uniform operation
      - 1.1.3.1.14.1.Provide central mixer on the project
      - 1.1.3.1.14.2.Ensure adequate number of haul trucks to keep pavers moving
      - 1.1.3.1.14.3.Keep mix uniform to ensure smooth and steady operation
    - 1.1.3.1.15.Provide adequate and qualified manpower to operate the advanced machines
  + 1.1.3.2. Implement fast track materials
    - 1.1.3.2.1. Use hydraulic cement when justifiable
    - 1.1.3.2.2. Use jet cement in critical areas
    - 1.1.3.2.3. Use roller compacted concrete
    - 1.1.3.2.4. Use vacuum treatment of portland cement concrete pavements
    - 1.1.3.2.5. Use accelerators in PCC
    - 1.1.3.2.6. Use exotic polymer concrete
+ 1.1.4. Use properly constructed prefabricated designs
  - 1.1.4.1.Use precast short segments and curbs
  - 1.1.4.2.Precast manholes, inlets, and box culverts
+ 1.1.5. Improve productivity
  - 1.1.5.1.Train and educate workers on the improved construction methods in use
  - 1.1.5.2.Use advanced and automated construction methods and procedures
  - 1.1.5.3.Use concrete designs with thicker layers and less reinforcing steel
  - 1.1.5.4.Use jointed concrete pavements with no steel
  + 1.1.5.5.Use Continuous Reinforced Concrete Pavements
    - 1.1.5.5.1.design reinforced pavement with single matt of reinforcing steel
  + 1.1.5.6.Coordinate between manpower and equipment used
    - 1.1.5.6.1.Provide adequate and qualified manpower to operate the advanced machines
    + 1.1.5.6.2.Provide adequate, compatible, and reliable equipment to ensure continuous and uniform operation
      - 1.1.5.6.2.1 Provide central mixer on the project for concrete products
      - 1.1.5.6.2.2 Ensure an adequate number of haul trucks to keep pavers moving

- 1.1.5.6.2.3 Keep mix uniform to ensure smooth and steady operation
- 1.1.5.6.3.Mobilize necessary equipment, material, and labor forces before beginning work
- 1.1.5.7.Use extended width pavers
- 1.1.6. Encourage and plan for research and innovation
- 1.1.7. Construct reliable, and durable pavements using advanced and less time-consuming methods
+ 1.1.8. Minimize the time required to conducting the follow up activities
- 1.1.8.1. Minimize the time required to seal joints
- 1.1.8.2.Reduce the curing time of the cement-stabilized subbase
- 1.1.9.3.Use concrete cutter instead of conventional saws for-full depth repairs
- 1.1.9. Secure right-of-way (R.O.W.) before beginning construction
+ 1.1.10.Eliminate leave-outs
- 1.1.10.1.Use portable bridges to avoid leave-outs
- 1.1.11.Give adequate time to review plans before construction
+ 1.1.12.Adopt advanced methods for handling the drainage system
- 1.1.12.1. Plan for handling and modifying the drainage affected by construction
- 1.1.12.2.Plan for new construction drainage
- 1.1.12.3.Precast dranage structures
- 1.1.13.Reduce the use of lime-treated subgrade
- 1.1.14.Eliminate the use of cement stabilization on a non-erodable platform
- 1.1.15.Avoid, when possible, block-outs
- 1.1.16.Speed repair of equipment in case of breakdown
- 1.1.17.Employ large contractors with high volume equipment
- 1.1.18.Adopt project sequencing to ensure the most efficient production
- 1.1.19.Speed approvals on field changes as needed
- 1.1.20. Construct reliable frontage roads
- 1.1.21. Enforce cooperation, coordination, and uniformity between SDHPT offices

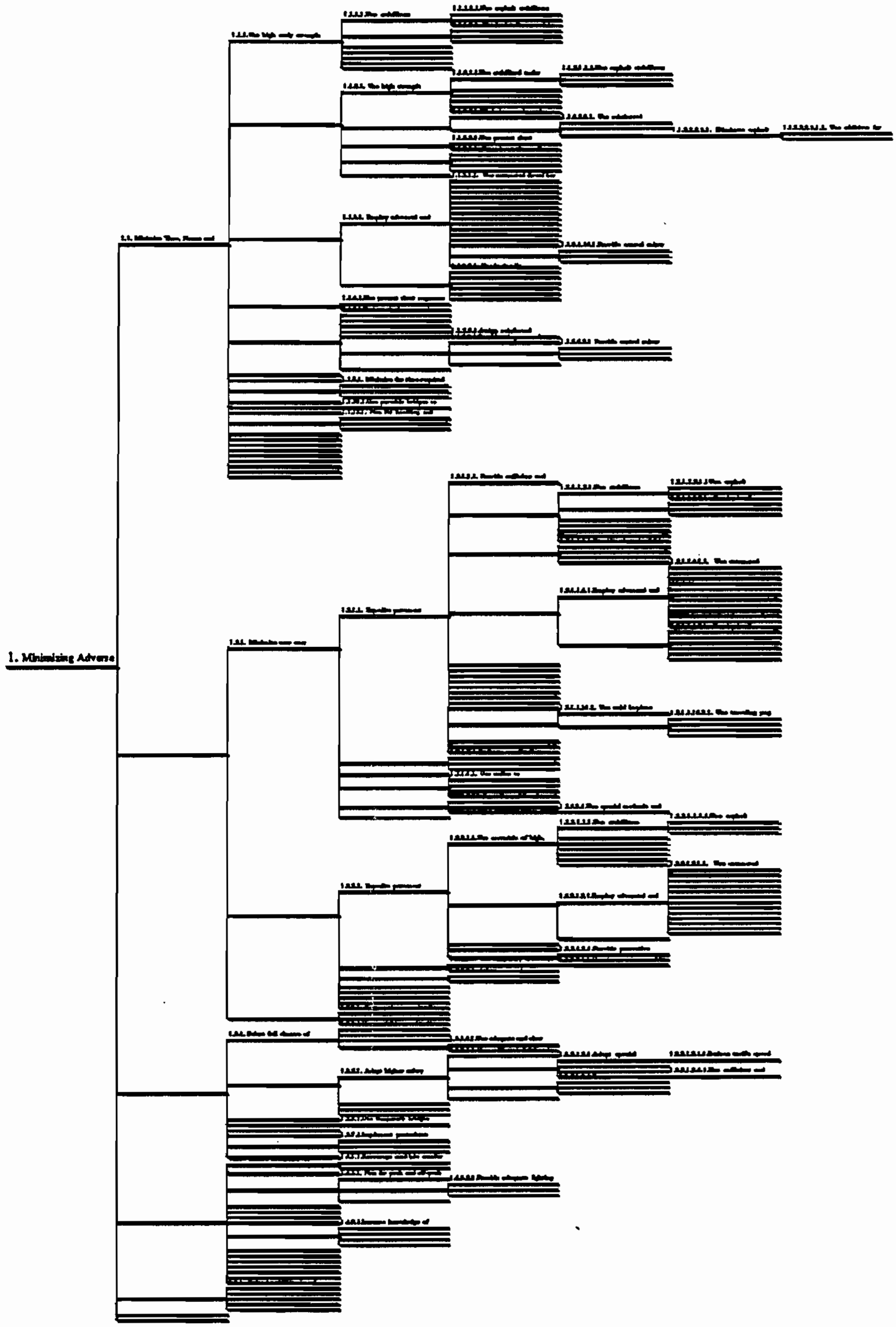
+ **1.2. Improve Public Relations**
+ 1.2.1. Minimize user cost
+ 1.2.1.1. Expedite pavement construction
- 1.2.1.1.1. Provide sufficient and comfortable access detours
+ 1.2.1.1.2.Use materials of high early strength
+ 1.2.1.1.2.1.Use stabilizers
- 1.2.1.1.2.1.1Use asphalt stabilizers
- 1.2.1.1.2.2.Use lime stabilizers
- 1.2.1.1.2.3.Use cement stabilized subbase
+ 1.2.1.1.2.2.Use high early strength concrete
- 1.2.1.1.2.2.1. Use hydraulic cement in critical areas
- 1.2.1.1.2.2.2. Use jet cement when it is economically feasible
- 1.2.1.1.2.2.1. Use fiber reinforced concrete
- 1.2.1.1.2.3.Use thick asphalt pavement as much as possible
- 1.2.1.1.2.4.Use high cement ratio
- 1.2.1.1.2.5.Reduce curing time of stabilizers
- 1.2.1.1.2.6.Use foam-insulated curing blankets
- 1.2.1.1.2.7.Apply fly ash to pavement especially in winter
+ 1.2.1.1.3. Provide safe work area with good signwarning systems
- 1.2.1.1.3.1.Provide adequate light at construction site at night time
- 1.2.1.1.3.2.Reduce interference between road user and construction operation
- 1.2.1.1.3.3.Use effective and protective barriers
- 1.2.1.1.3.4.Eliminate drop-off hazards

+ 1.2.1.1.4 Implement improved-accelerated-construction methods
    + 1.2.1.1.4.1.Employ advanced and automated equipment and procedures in construction
        - 1.2.1.1.4.1.1. Use automated dowel bar inserters
        - 1.2.1.1.4.1.2. Use slip-form paving method
        - 1.2.1.1.4.1.3. Employ multi-piece tie bars and dowel bars
        - 1.2.1.1.4.1.4. Implement improved accelerated testing procedures
        - 1.2.1.1.4.1.5. Use extended width pavers
        - 1.2.1.1.4.1.6. Adopt procedures requiring shorter fabrecation time
        - 1.2.1.1.4.1.7. Use nonreinforced pavements with dowel insertors in congested areas
        - 1.2.1.1.4.1.8. Use nuclear gauge
        - 1.2.1.1.4.1.9. Use steel fiber in thin bonded concrete overlay
        - 1.2.1.1.4.1.10.Use milling machines for shoulder widening
        - 1.2.1.1.4.1.11.Provide compatible equipment to ensure continuous and uniform operation
        - 1.2.1.1.4.1.12.Provide adequate and qualified manpower to operate advanced machines
    + 1.2.1.1.4.2. Implement fast track materials
        - 1.2.1.1.4.2.1. Use hydraulic cement when justifiable
        - 1.2.1.1.4.2.2. Use jet cement in critical areas.
        - 1.2.1.1.4.2.3. Use roller-compacted concrete
        - 1.2.1.1.4.2.4. Use vacuum treatment of PCC pavements
        - 1.2.1.1.4.2.5. Use accelerators in PCC
        - 1.2.1.1.4.2.6. Use exotic polymer concrete
- 1.2.1.1.5. Use temporary driveways to residential and commercial areas
- 1.2.1.1.6. Open road to traffic as soon as pavement strength is assured
- 1.2.1.1.7. Implement procedures and methods that allow early curing time
- 1.2.1.1.8. Use prefabricated designs
- 1.2.1.1.9. Use portable bridges to maintain access across newly placed pavements
- 1.2.1.1.10.Permit all-weather and night working hours
- 1.2.1.1.11.Use steel matts for CRCP
- 1.2.1.1.12.Give adequate time and attention to reviewing construction plans
- 1.2.1.1.13. Eliminate time consuming-incidental construction
+ 1.2.1.1.14. Recycle pavement materials
    - 1.2.1.1.14.1. Use cold in-place recycling of asphalt pavements
    + 1.2.1.1.14.2. Implement advanced methods and procedures in recycling pavement materials
        - 1.2.1.1.14.2.1. Use traveling pug mill for recycling HMAC
        - 1.2.1.1.14.2.2. Adopt uniform procedures and standards when using additives and recycling agents
        - 1.2.1.1.14.2.3.Use diamond saw to cut reinforced concrete
        - 1.2.1.1.14.2.4.Employ pavment pulverizers in recycling
- 1.2.1.1.15. Keep a clean construction site
- 1.2.1.1.16. Reduce construction pollution
- 1.2.1.1.17. Avoid problematic and environmentally sensitive issues

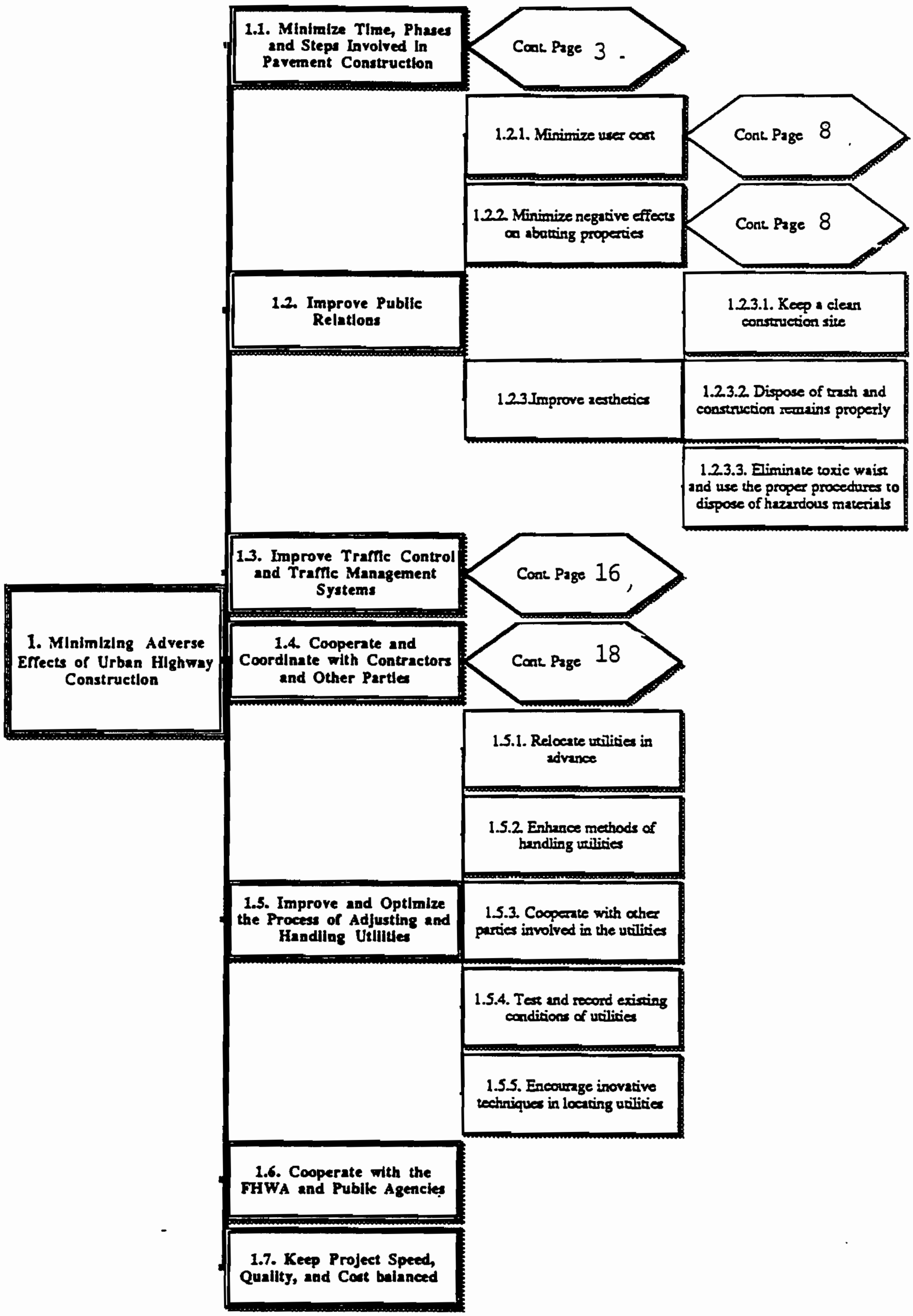
+ 1.2.1.2. Reduce conflict between vehicles and construction equipment
    - 1.2.1.2.1.Perform construction during off-peak hours
    - 1.2.1.2.2.Eliminate critical vehicular conflict
    - 1.2.1.2.3.Prevent interference between traffic and construction operations
- 1.2.1.3. Educate motorists regarding construction activities and long-term benefits
+ 1.2.1.4. Keep the public informed of construction activities and progress at all

APPENDIX D:

Hierarchy of Objectives Technique (HOT) in Tree-Structure Form
Used to Categorize Responses to Questionnaire Prepared for
the Texas Department of Transportation



The Complete Information Tree Formed from the SDHPT Survey


1.1. Minimize Time, Phases and Steps Involved In Pavement Construction
Cont. Page 3
1.2.1. Minimize user cost
Cont. Page 8
1.2.2. Minimize negative effects on abutting properties
Cont. Page 8
1.2. Improve Public Relations
1.2.3.1. Keep a clean construction site
1.2.3.Improve aesthetics
1.2.3.2. Dispose of trash and construction remains properly
1.2.3.3. Eliminate toxic waist and use the proper procedures to dispose of hazardous materials
1.3. Improve Traffic Control and Traffic Management Systems
Cont. Page 16
1. Minimizing Adverse Effects of Urban Highway Construction
1.4. Cooperate and Coordinate with Contractors and Other Parties
Cont. Page 18
1.5.1. Relocate utilities in advance
1.5.2. Enhance methods of handling utilities
1.5. Improve and Optimize the Process of Adjusting and Handling Utilities
1.5.3. Cooperate with other parties involved in the utilities
1.5.4. Test and record existing conditions of utilities
1.5.5. Encourage inovative techniques in locating utilities
1.6. Cooperate with the FHWA and Public Agencies
1.7. Keep Project Speed, Quality, and Cost balanced

1.1. Minimize Time, Phases and Steps Involved in Pavement Construction

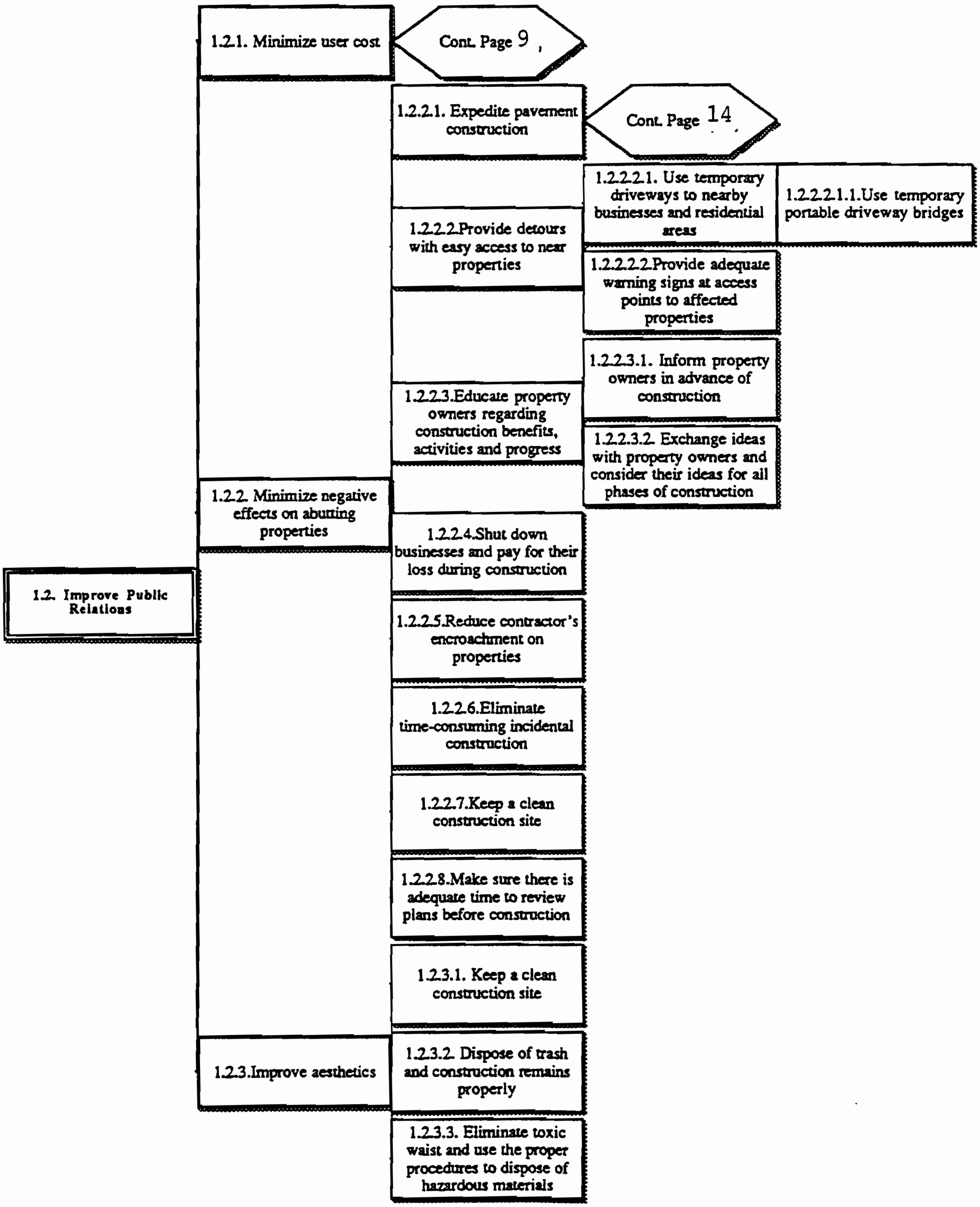
- 1.1.1.Use high early strength materials Cont. Page 4
- 1.1.2. Minimize number of layers Cont. Page 5
- 1.1.3. Implement accelerated and fast track methods
  - 1.1.3.1. Employ advanced and automated equipment and procedures in construction Cont. Page 6
  - 1.1.3.2. Implement fast track materials Cont. Page 6
- 1.1.4. Use properly constructed prefabricated designs
  - 1.1.4.1.Use precast short segments and curbs
  - 1.1.4.2.Precast manholes, inlets, and box culverts
- 1.1.5. Improve productivity Cont. Page 7
- 1.1.6. Encourage and plan for research and innovation
- 1.1.7. Construct reliable, and durable pavements using advanced and less
- 1.1.8. Minimize the time required to conducting the follow up activities
  - 1.1.8.1. Minimize the time required to seal joints
  - 1.1.8.2.Reduce the curing time of the cement-stabilized subbase
  - 1.1.9.3.Use concrete cutter instead of conventional saws for-full depth repairs
- 1.1.9. Secure right-of-way (R.O.W.) before beginning construction
- 1.1.10.Eliminate leave-outs
  - 1.1.10.1.Use portable bridges to avoid leave-outs
- 1.1.11.Give adequate time to review plans before construction
- 1.1.12.Adopt advanced methods for handling the drainage system
  - 1.1.12.1. Plan for handling and modifying the drainage affected by construction
  - 1.1.12.2.Plan for new construction drainage
  - 1.1.12.3.Precast dranage structures
- 1.1.13.Reduce the use of lime-treated subgrade
- 1.1.14.Eliminate the use of cement stabilization on a non-erodable platform
- 1.1.15.Avoid, when possible, block-outs
- 1.1.16.Speed repair of equipment in case of breakdown
- 1.1.17.Employ large contractors with high volume equipment
- 1.1.18.Adopt project sequencing to ensure the most efficient production
- 1.1.19.Speed approvals on field changes as needed
- 1.1.20. Construct reliable frontage roads
- 1.1.21. Enforce cooperation, coordination, and uniformity between SDHPT offices

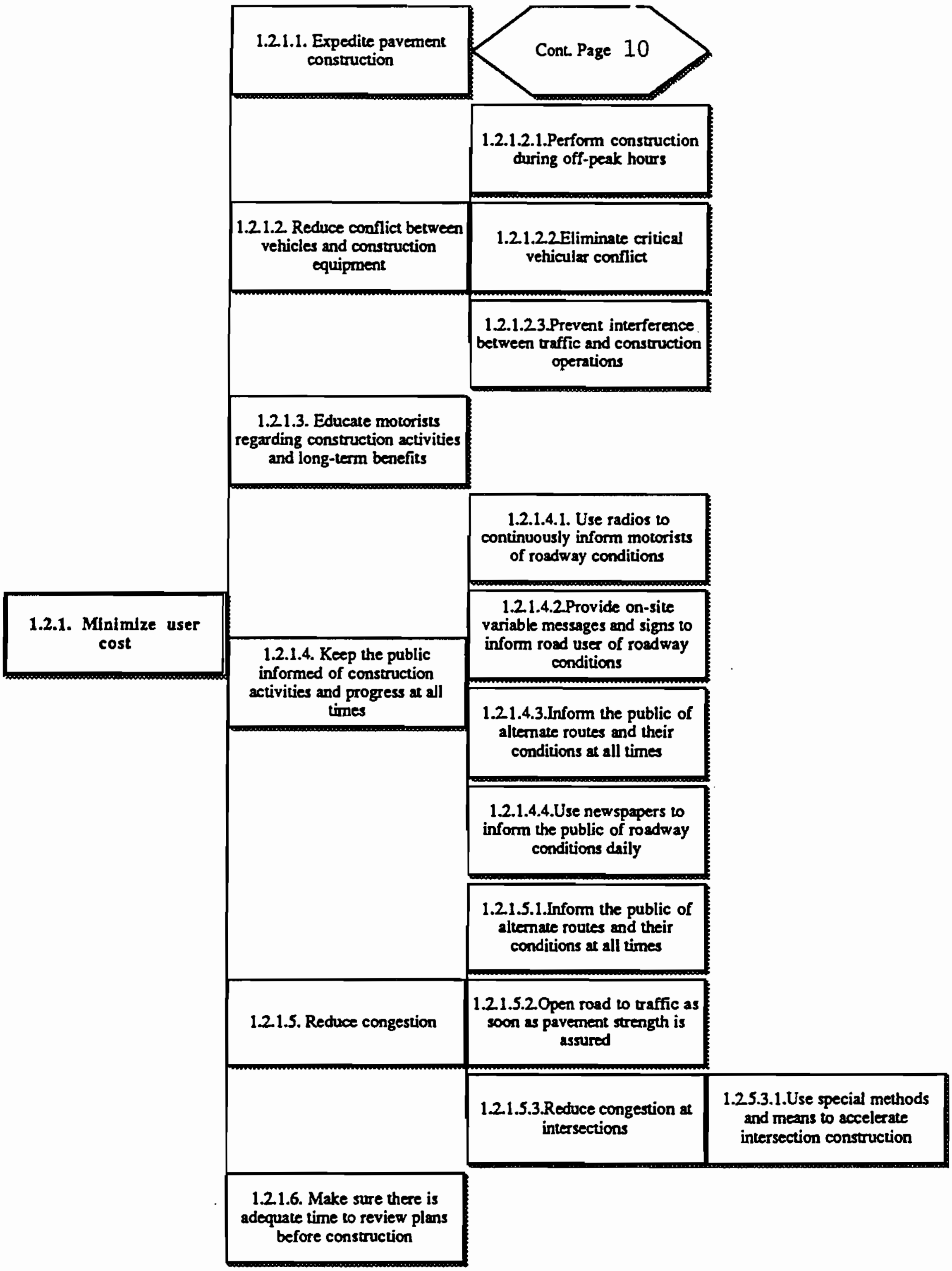
- **1.1.1.Use high early strength materials**
  - 1.1.1.1.Use stabilizers
    - 1.1.1.1.1.Use asphalt stabilizers
    - 1.1.1.1.2.Use lime stabilizers
    - 1.1.1.1.3.Use cement stabilizers
  - 1.1.1.2.Use high early strength concrete
    - 1.1.1.2.1. Use hydraulic cement in critical areas
    - 1.1.1.2.2. Use jet cement when it is economically feasible
    - 1.1.1.2.3. Use fiber reinforced concrete
  - 1.1.1.3.Use thick asphalt pavement when possible
  - 1.1.1.4.Use high cement ratio
  - 1.1.1.5.Reduce curing time of stabilized material
  - 1.1.1.6.Use foam insulated curing blankets for P. C. concrete
  - 1.1.1.7.Apply fly ash to concrete pavements

- 1.1.2. Minimize number of layers
  - 1.1.2.1. Use high strength materials
    - 1.1.2.1.1.Use stabilized under layers
      - 1.1.2.1.1.1.Use asphalt stabilizers
      - 1.1.2.1.1.2.Use lime stabilizers
      - 1.1.2.1.1.3.Use cement stabilizers
    - 1.1.2.1.2.Use thicker layers with no base
    - 1.1.2.1.3.Use automated and accelerated methods
    - 1.1.2.1.4.Pour concrete directly into grade
    - 1.1.2.1.5.Use Continuous Reinforced Concrete Pavements
    - 1.1.2.1.6. Minimize the time required before joint can be sealed
  - 1.1.2.2.Use full-depth materials
    - 1.1.2.2.1.Minimize number of layers
    - 1.1.2.2.2.Use high strength materials
      - 1.1.2.2.2.1. Use reinforced concrete pavement
      - 1.1.2.2.2.2. Use fiber reinforced concrete pavements
      - 1.1.2.2.2.3. Use full depth asphalt pavements
        - 1.1.2.2.2.3.1. Eliminate asphalt seasons for hot mix and surface treatments
          - 1.1.2.2.2.3.1.1. Use additives for hot mix pavements and surface treatments in all weathers
          - 1.1.2.2.2.3.1.2. Use exotic polymer concrete
  - 1.1.2.3. Use prefabricated members
    - 1.1.2.3.1.Use precast short segments and curbs
    - 1.1.2.3.2.Precast manholes, inlets, and box culverts
  - 1.1.2.4. Encourage and plan for innovation to reduce number of layers
    - 1.1.2.4.1. Organize and coordinate innovative procedures to optimize utilization of time and energy
    - 1.1.2.4.2. Establish and implement advanced procedures, programs, and systems for the planning, designing, and construction of pavements
    - 1.1.2.4.3. Allocate necessary resources for innovation
    - 1.1.2.4.4. Monitor and standarize innovation
  - 1.1.2.5. Plan for the future in the design, construction, and maintenance of pavements

- 1.1.3. Implement accelerated and fast track methods
  - 1.1.3.1. Employ advanced and automated equipment and procedures in construction
    - 1.1.3.1.1. Use automated dowel bar inserters
    - 1.1.3.1.2. Use zero clearance paver
    - 1.1.3.1.3. Use slip form paving method
    - 1.1.3.1.4. Employ multi-piece tie bars and dowel bars
    - 1.1.3.1.5. Implement improved accelerated testing procedures
    - 1.1.3.1.6. Use extended width pavers
    - 1.1.3.1.7. Adopt procedures requiring shorter fabrication time
    - 1.1.3.1.8. Use nonreinforced pavements with dowel inserters in congested areas
    - 1.1.3.1.9. Use nuclear gauge
    - 1.1.3.1.10.Use steel fiber in thin bonded concrete overlay and special areas such as intersections
    - 1.1.3.1.11.Use milling machines for shoulder widening
    - 1.1.3.1.12.Employ pavement pulverizers to remove the old
    - 1.1.3.1.13.Use diamond saw in cutting reinforced concrete
    - 1.1.3.1.14.Provide adequate, compatible, and reliable equipment to ensure continuous and uniform operation
      - 1.1.3.1.14.1.Provide central mixer on the project
      - 1.1.3.1.14.2.Ensure adequate number of haul trucks to keep
      - 1.1.3.1.14.3.Keep mix uniform to ensure smooth and steady
    - 1.1.3.1.15.Provide adequate and qualified manpower to operate the advanced machines
  - 1.1.3.2. Implement fast track materials
    - 1.1.3.2.1. Use hydraulic cement when justifiable
    - 1.1.3.2.2. Use jet cement in critical areas
    - 1.1.3.2.3. Use roller compacted concrete
    - 1.1.3.2.4. Use vacuum treatment of portland cement concrete pavements
    - 1.1.3.2.5. Use accelerators in PCC
    - 1.1.3.2.6. Use exotic polymer concrete

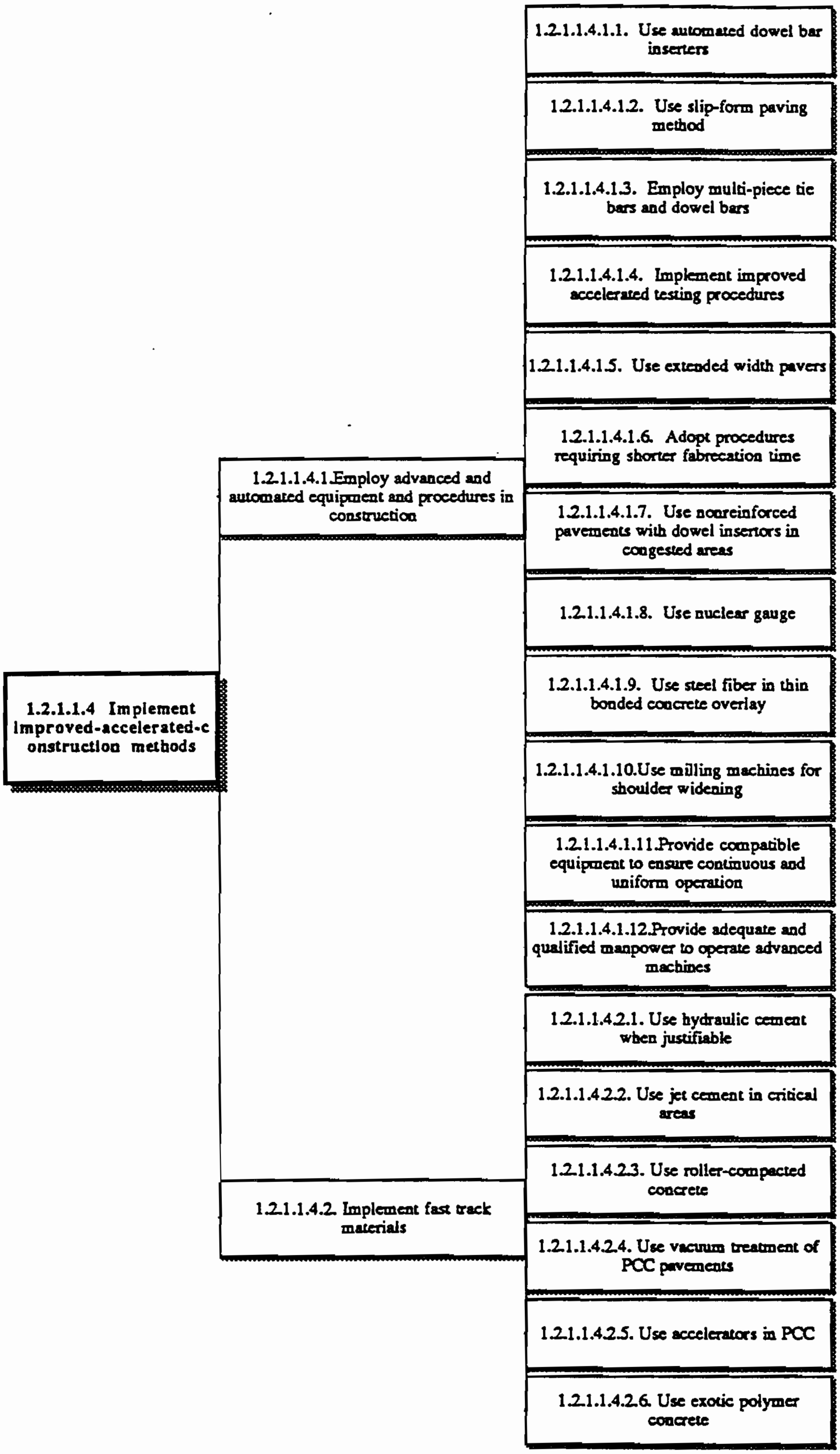
- **1.1.5. Improve productivity**
  - 1.1.5.1. Train and educate workers on the improved construction methods in use
  - 1.1.5.2. Use advanced and automated construction methods and procedures
  - 1.1.5.3. Use concrete designs with thicker layers and less reinforcing steel
  - 1.1.5.4. Use jointed-concrete pavements with no steel
  - 1.1.5.5. Use Continuous Reinforced Concrete Pavements
    - 1.1.5.5.1. design reinforced pavement with single matt of reinforcing steel
  - 1.1.5.6. Coordinate between manpower and equipment used
    - 1.1.5.6.1. Provide adequate and qualified manpower to operate the advanced machines
    - 1.1.5.6.2. Provide adequate, compatible, and reliable equipment to ensure continuous and uniform operation
      - 1.1.5.6.2.1 Provide central mixer on the project for concrete products
      - 1.1.5.6.2.2 Ensure an adequate number of haul trucks to keep pavers moving
      - 1.1.5.6.2.3 Keep mix uniform to ensure smooth and steady operation
    - 1.1.5.6.3. Mobilize necessary equipment, material, and labor forces before beginning work
  - 1.1.5.7. Use extended width pavers

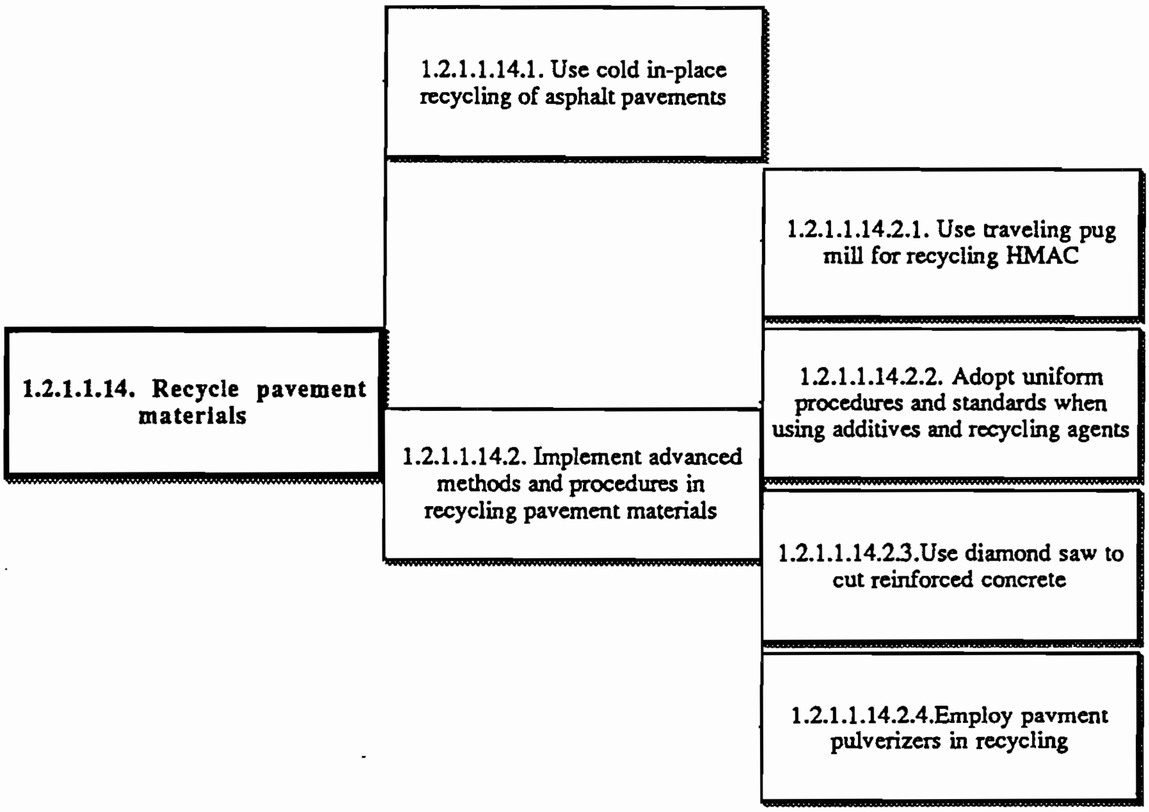

1.2.1. Minimize user cost
Cont. Page 9
1.2.2.1. Expedite pavement construction
Cont. Page 14
1.2.2.2.1. Use temporary driveways to nearby businesses and residential areas
1.2.2.2.1.1.Use temporary portable driveway bridges
1.2.2.2.Provide detours with easy access to near properties
1.2.2.2.2.Provide adequate warning signs at access points to affected properties
1.2.2.3.1. Inform property owners in advance of construction
1.2.2.3.Educate property owners regarding construction benefits, activities and progress
1.2.2.3.2. Exchange ideas with property owners and consider their ideas for all phases of construction
1.2.2. Minimize negative effects on abutting properties
1.2.2.4.Shut down businesses and pay for their loss during construction
1.2. Improve Public Relations
1.2.2.5.Reduce contractor's encroachment on properties
1.2.2.6.Eliminate time-consuming incidental construction
1.2.2.7.Keep a clean construction site
1.2.2.8.Make sure there is adequate time to review plans before construction
1.2.3.1. Keep a clean construction site
1.2.3.Improve aesthetics
1.2.3.2. Dispose of trash and construction remains properly
1.2.3.3. Eliminate toxic waist and use the proper procedures to dispose of hazardous materials

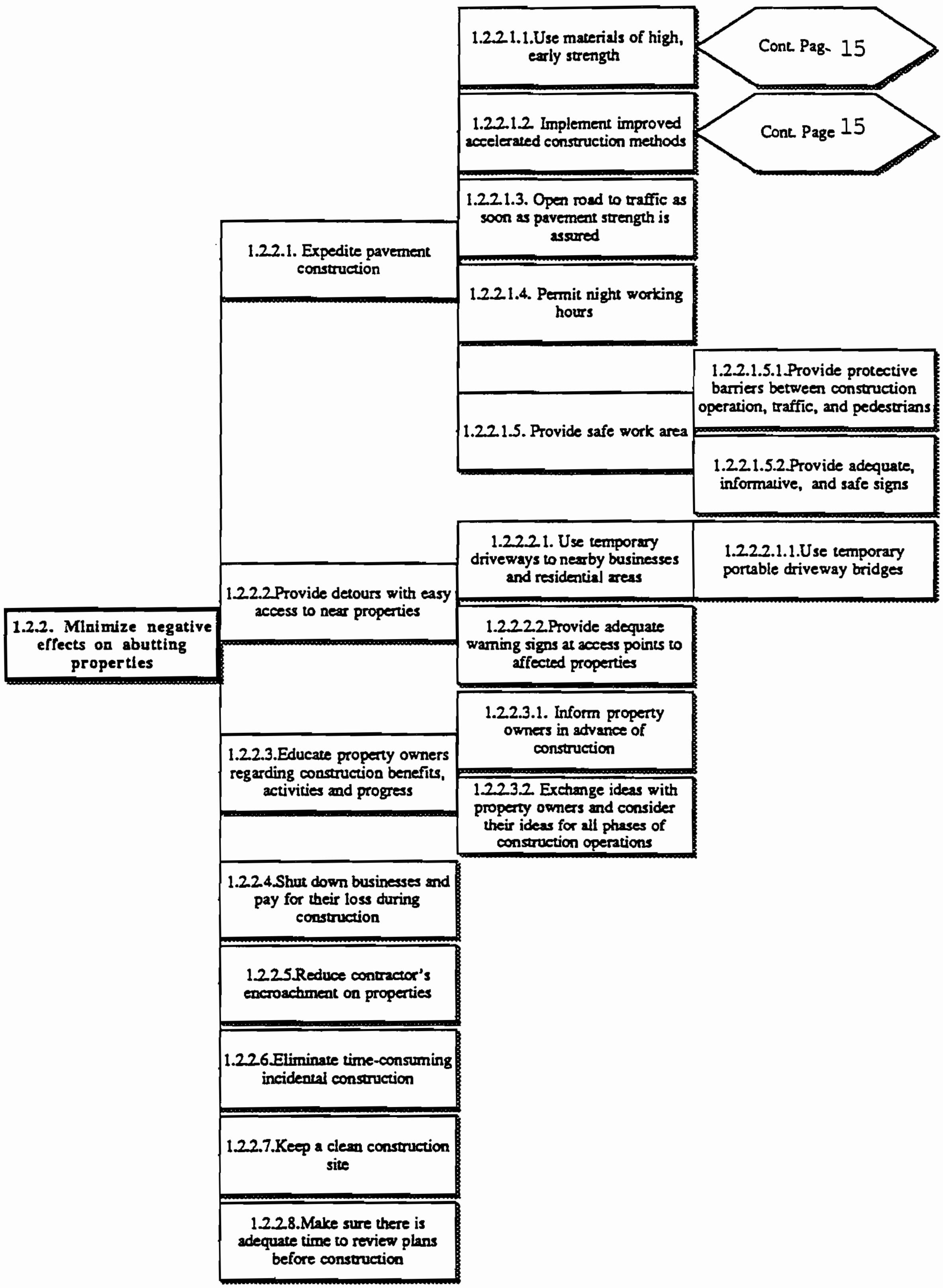

1.2.1.1. Expedite pavement construction
Cont. Page 10
1.2.1.2.1.Perform construction during off-peak hours
1.2.1.2. Reduce conflict between vehicles and construction equipment
1.2.1.2.2.Eliminate critical vehicular conflict
1.2.1.2.3.Prevent interference between traffic and construction operations
1.2.1.3. Educate motorists regarding construction activities and long-term benefits
1.2.1.4.1. Use radios to continuously inform motorists of roadway conditions
1.2.1. Minimize user cost
1.2.1.4.2.Provide on-site variable messages and signs to inform road user of roadway conditions
1.2.1.4. Keep the public informed of construction activities and progress at all times
1.2.1.4.3.Inform the public of alternate routes and their conditions at all times
1.2.1.4.4.Use newspapers to inform the public of roadway conditions daily
1.2.1.5.1.Inform the public of alternate routes and their conditions at all times
1.2.1.5. Reduce congestion
1.2.1.5.2.Open road to traffic as soon as pavement strength is assured
1.2.1.5.3.Reduce congestion at intersections
1.2.5.3.1.Use special methods and means to accelerate intersection construction
1.2.1.6. Make sure there is adequate time to review plans before construction

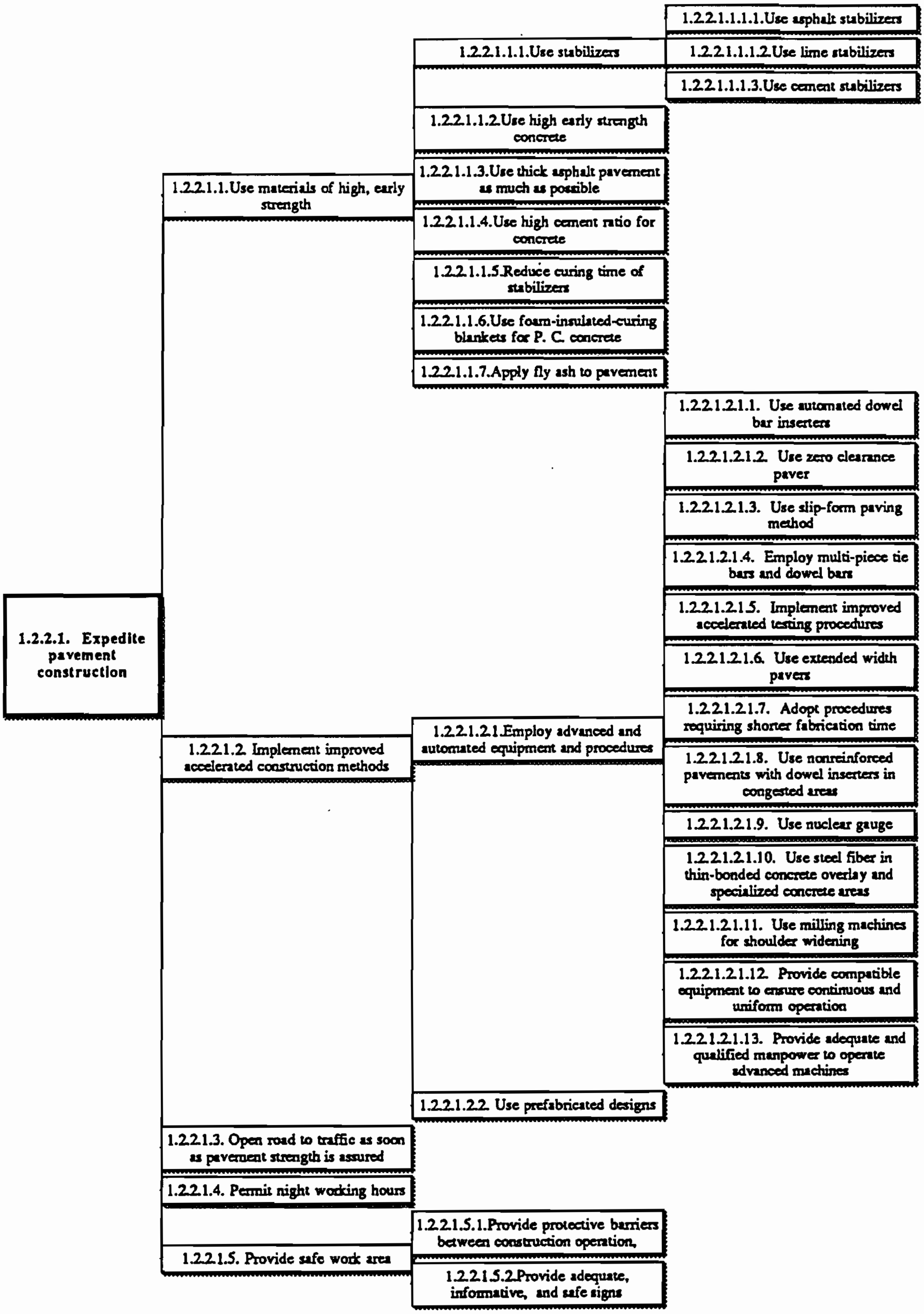
- 1.2.1.1. Expedite pavement construction
  - 1.2.1.1.1. Provide sufficient and comfortable access detours
  - 1.2.1.1.2.Use materials of high early strength Cont. Page 11
  - 1.2.1.1.3. Provide safe work area with good sign/warning systems
    - 1.2.1.1.3.1.Provide adequate light at construction site at night time
    - 1.2.1.1.3.2.Reduce interference between road user and construction operation
    - 1.2.1.1.3.3.Use effective and protective barriers
    - 1.2.1.1.3.4.Eliminate drop-off hazards
  - 1.2.1.1.4 Implement improved-accelerated-construction methods Cont. Page 12
  - 1.2.1.1.5. Use temporary driveways to residential and commercial areas
  - 1.2.1.1.6. Open road to traffic as soon as pavement strength is assured
  - 1.2.1.1.7. Implement procedures and methods that allow early curing time
  - 1.2.1.1.8. Use prefabricated designs
  - 1.2.1.1.9. Use portable bridges to maintain access across newly placed pavements
  - 1.2.1.1.10.Permit all-weather and night working hours
  - 1.2.1.1.11.Use steel matts for CRCP
  - 1.2.1.1.12.Give adequate time and attention to reviewing construction plans
  - 1.2.1.1.13. Eliminate time consuming-incidental construction
  - 1.2.1.1.14. Recycle pavement materials Cont. Page 13
  - 1.2.1.1.15. Keep a clean construction site
  - 1.2.1.1.16. Reduce construction pollution
  - 1.2.1.1.17. Avoid problematic and environmentally sensitive issues

- **1.2.1.1.2.Use materials of high early strength**
  - 1.2.1.1.2.1.Use stabilizers
    - 1.2.1.1.2.1.1Use asphalt stabilizers
    - 1.2.1.1.2.2.Use lime stabilizers
    - 1.2.1.1.2.3.Use cement stabilized subbase
  - 1.2.1.1.2.2.Use high early strength concrete
    - 1.2.1.1.2.2.1. Use hydraulic cement in critical areas
    - 1.2.1.1.2.2.2. Use jet cement when it is economically feasible
    - 1.2.1.1.2.2.1. Use fiber reinforced concrete
  - 1.2.1.1.2.3.Use thick asphalt pavement as much as possible
  - 1.2.1.1.2.4.Use high cement ratio
  - 1.2.1.1.2.5.Reduce curing time of stabilizers
  - 1.2.1.1.2.6.Use foam-insulated curing blankets
  - 1.2.1.1.2.7.Apply fly ash to pavement especially in winter

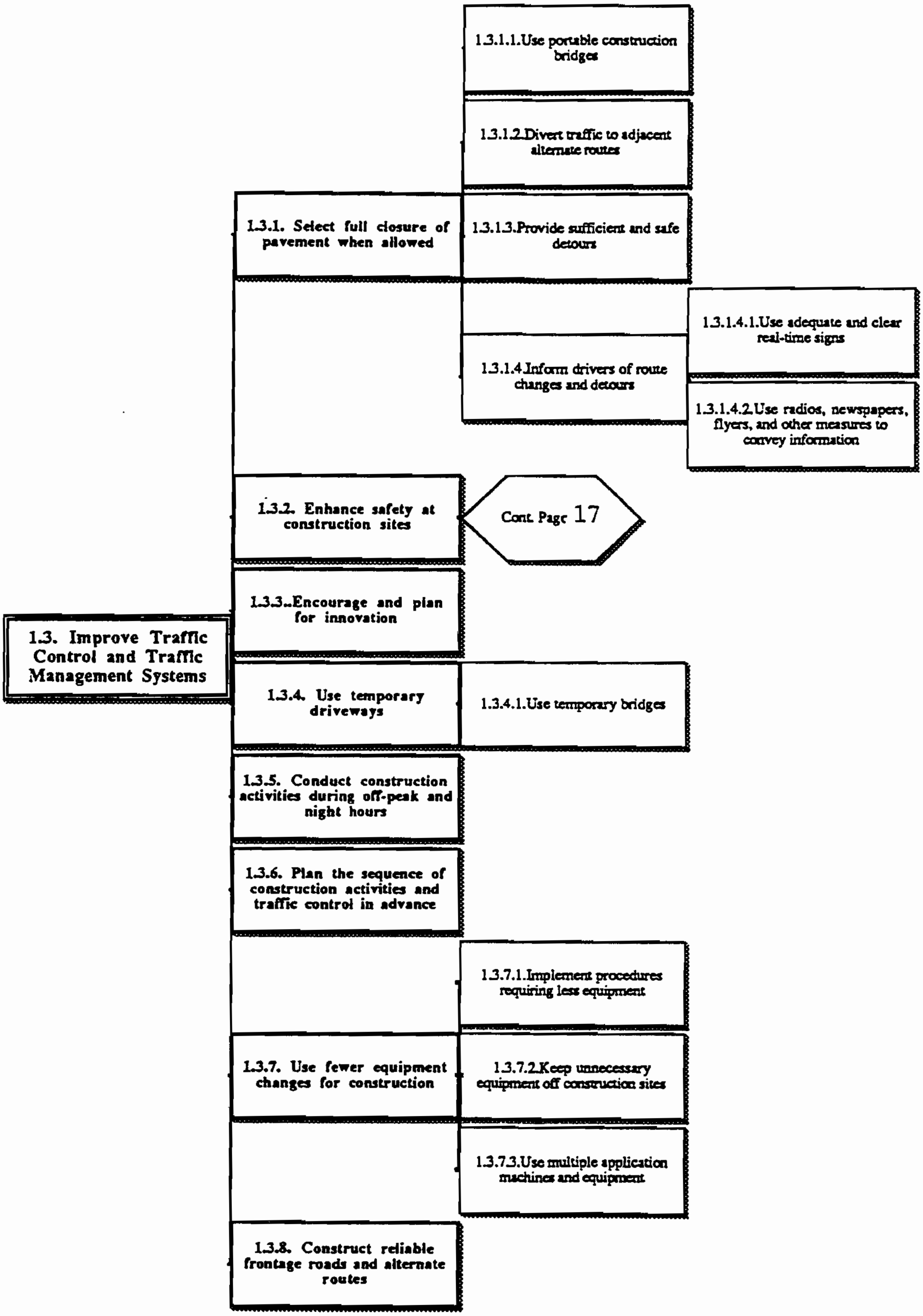

1.2.1.1.4 Implement improved-accelerated-construction methods
1.2.1.1.4.1.Employ advanced and automated equipment and procedures in construction
1.2.1.1.4.2. Implement fast track materials
1.2.1.1.4.1.1. Use automated dowel bar inserters
1.2.1.1.4.1.2. Use slip-form paving method
1.2.1.1.4.1.3. Employ multi-piece tie bars and dowel bars
1.2.1.1.4.1.4. Implement improved accelerated testing procedures
1.2.1.1.4.1.5. Use extended width pavers
1.2.1.1.4.1.6. Adopt procedures requiring shorter fabrecation time
1.2.1.1.4.1.7. Use nonreinforced pavements with dowel insertors in congested areas
1.2.1.1.4.1.8. Use nuclear gauge
1.2.1.1.4.1.9. Use steel fiber in thin bonded concrete overlay
1.2.1.1.4.1.10.Use milling machines for shoulder widening
1.2.1.1.4.1.11.Provide compatible equipment to ensure continuous and uniform operation
1.2.1.1.4.1.12.Provide adequate and qualified manpower to operate advanced machines
1.2.1.1.4.2.1. Use hydraulic cement when justifiable
1.2.1.1.4.2.2. Use jet cement in critical areas
1.2.1.1.4.2.3. Use roller-compacted concrete
1.2.1.1.4.2.4. Use vacuum treatment of PCC pavements
1.2.1.1.4.2.5. Use accelerators in PCC
1.2.1.1.4.2.6. Use exotic polymer concrete


1.2.1.1.14. Recycle pavement materials
1.2.1.1.14.1. Use cold in-place recycling of asphalt pavements
1.2.1.1.14.2. Implement advanced methods and procedures in recycling pavement materials
1.2.1.1.14.2.1. Use traveling pug mill for recycling HMAC
1.2.1.1.14.2.2. Adopt uniform procedures and standards when using additives and recycling agents
1.2.1.1.14.2.3.Use diamond saw to cut reinforced concrete
1.2.1.1.14.2.4.Employ pavment pulverizers in recycling

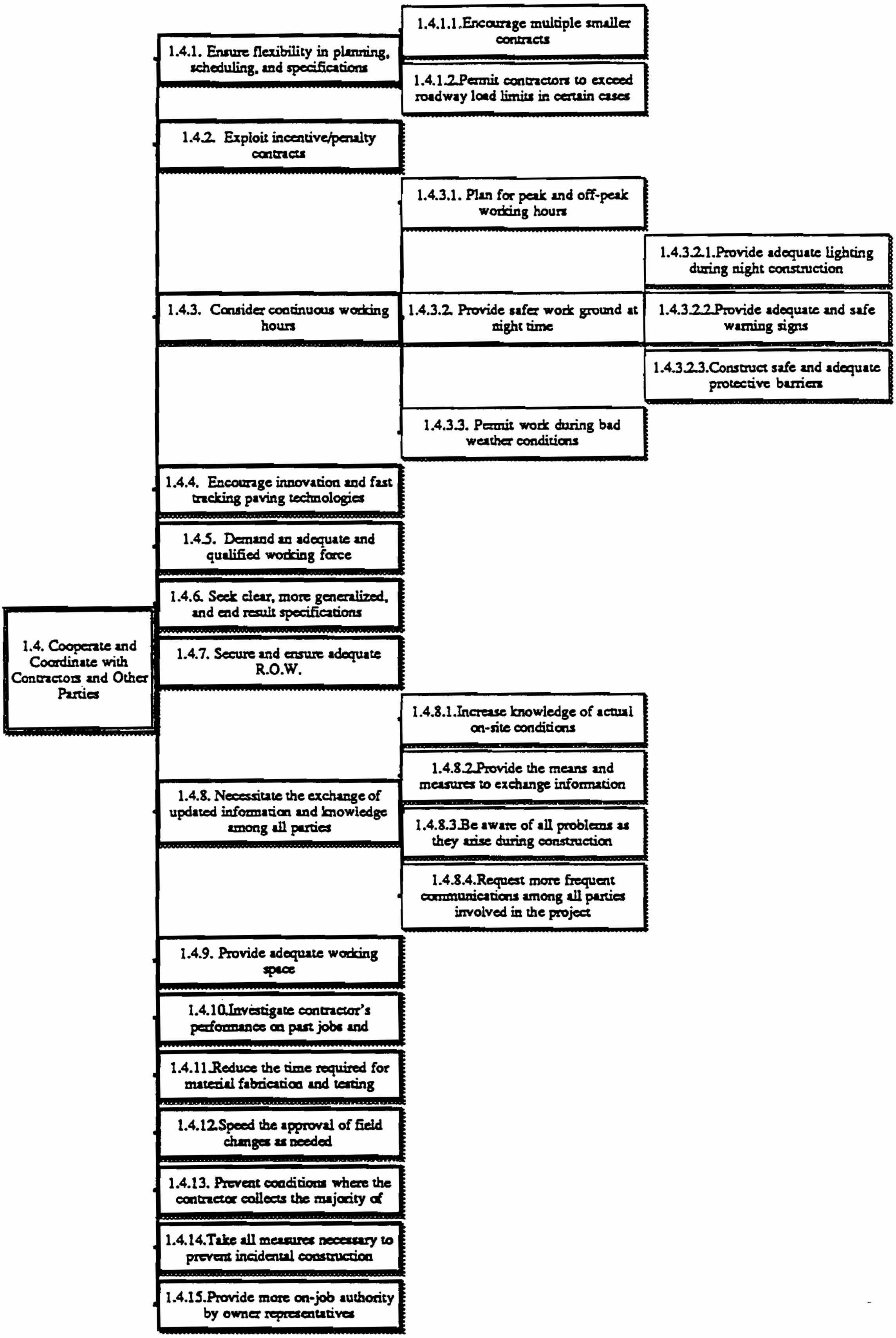

1.2.2. Minimize negative effects on abutting properties
1.2.2.1. Expedite pavement construction
1.2.2.1.1.Use materials of high, early strength
Cont. Pag. 15
1.2.2.1.2. Implement improved accelerated construction methods
Cont. Page 15
1.2.2.1.3. Open road to traffic as soon as pavement strength is assured
1.2.2.1.4. Permit night working hours
1.2.2.1.5. Provide safe work area
1.2.2.1.5.1.Provide protective barriers between construction operation, traffic, and pedestrians
1.2.2.1.5.2.Provide adequate, informative, and safe signs
1.2.2.2.Provide detours with easy access to near properties
1.2.2.2.1. Use temporary driveways to nearby businesses and residential areas
1.2.2.2.1.1.Use temporary portable driveway bridges
1.2.2.2.2.Provide adequate warning signs at access points to affected properties
1.2.2.3.Educate property owners regarding construction benefits, activities and progress
1.2.2.3.1. Inform property owners in advance of construction
1.2.2.3.2. Exchange ideas with property owners and consider their ideas for all phases of construction operations
1.2.2.4.Shut down businesses and pay for their loss during construction
1.2.2.5.Reduce contractor's encroachment on properties
1.2.2.6.Eliminate time-consuming incidental construction
1.2.2.7.Keep a clean construction site
1.2.2.8.Make sure there is adequate time to review plans before construction



1.2.2.1. Expedite pavement construction
1.2.2.1.1. Use materials of high, early strength
1.2.2.1.1.1. Use stabilizers
1.2.2.1.1.1.1. Use asphalt stabilizers
1.2.2.1.1.1.2. Use lime stabilizers
1.2.2.1.1.1.3. Use cement stabilizers
1.2.2.1.1.2. Use high early strength concrete
1.2.2.1.1.3. Use thick asphalt pavement as much as possible
1.2.2.1.1.4. Use high cement ratio for concrete
1.2.2.1.1.5. Reduce curing time of stabilizers
1.2.2.1.1.6. Use foam-insulated-curing blankets for P. C. concrete
1.2.2.1.1.7. Apply fly ash to pavement
1.2.2.1.2. Implement improved accelerated construction methods
1.2.2.1.2.1. Employ advanced and automated equipment and procedures
1.2.2.1.2.1.1. Use automated dowel bar inserters
1.2.2.1.2.1.2. Use zero clearance paver
1.2.2.1.2.1.3. Use slip-form paving method
1.2.2.1.2.1.4. Employ multi-piece tie bars and dowel bars
1.2.2.1.2.1.5. Implement improved accelerated testing procedures
1.2.2.1.2.1.6. Use extended width pavers
1.2.2.1.2.1.7. Adopt procedures requiring shorter fabrication time
1.2.2.1.2.1.8. Use nonreinforced pavements with dowel inserters in congested areas
1.2.2.1.2.1.9. Use nuclear gauge
1.2.2.1.2.1.10. Use steel fiber in thin-bonded concrete overlay and specialized concrete areas
1.2.2.1.2.1.11. Use milling machines for shoulder widening
1.2.2.1.2.1.12. Provide compatible equipment to ensure continuous and uniform operation
1.2.2.1.2.1.13. Provide adequate and qualified manpower to operate advanced machines
1.2.2.1.2.2. Use prefabricated designs
1.2.2.1.3. Open road to traffic as soon as pavement strength is assured
1.2.2.1.4. Permit night working hours
1.2.2.1.5. Provide safe work area
1.2.2.1.5.1. Provide protective barriers between construction operation,
1.2.2.1.5.2. Provide adequate, informative, and safe signs


1.3.1.1.Use portable construction bridges
1.3.1.2.Divert traffic to adjacent alternate routes
1.3.1. Select full closure of pavement when allowed
1.3.1.3.Provide sufficient and safe detours
1.3.1.4.1.Use adequate and clear real-time signs
1.3.1.4.Inform drivers of route changes and detours
1.3.1.4.2.Use radios, newspapers, flyers, and other measures to convey information
1.3.2. Enhance safety at construction sites
Cont. Page 17
1.3.3..Encourage and plan for innovation
1.3. Improve Traffic Control and Traffic Management Systems
1.3.4. Use temporary driveways
1.3.4.1.Use temporary bridges
1.3.5. Conduct construction activities during off-peak and night hours
1.3.6. Plan the sequence of construction activities and traffic control in advance
1.3.7.1.Implement procedures requiring less equipment
1.3.7. Use fewer equipment changes for construction
1.3.7.2.Keep unnecessary equipment off construction sites
1.3.7.3.Use multiple application machines and equipment
1.3.8. Construct reliable frontage roads and alternate routes

- 1.3.2. Enhance safety at construction sites
  - 1.3.2.1. Adopt higher safety standards
    - 1.3.2.1.1.Use sufficient lighting in case of night hours
    - 1.3.2.1.2.Increase traffic law enforcement at and close to construction site
      - 1.3.2.1.2.1.Adopt special temporary traffic laws at the construction area
        - 1.3.2.1.2.1.1.Reduce traffic speed at construction areas
      - 1.3.2.1.2.2.Keep law officers at construction site at all times during construcion
      - 1.3.2.1.2.3.Emphasize safety procedures to construction workers and the public
      - 1.3.2.1.2.4.Enforce full separation between traffic and construction operation
        - 1.3.2.1.2.4.1.Use sufficient and protective barriers
    - 1.3.2.1.3.Reduce interference between traffic and construction operations
      - 1.3.2.1.3.1.Keep unnecessary equipment off site
      - 1.3.2.1.3.2.Conduct equipment repair and maintenance off site
      - 1.3.2.1.3.3.Plan in advanced for adequate and safe material delivery
    - 1.3.2.1.4.Use special safety features at night and during bad weather
  - 1.3.2.2.Use sufficient and protective barriers
  - 1.3.2.3.Provide more working space
  - 1.3.2.4.Adopt special specifications and restrictions when working under dangerous conditions


1.4. Cooperate and Coordinate with Contractors and Other Parties
1.4.1. Ensure flexibility in planning, scheduling, and specifications
1.4.1.1.Encourage multiple smaller contracts
1.4.1.2.Permit contractors to exceed roadway load limits in certain cases
1.4.2. Exploit incentive/penalty contracts
1.4.3. Consider continuous working hours
1.4.3.1. Plan for peak and off-peak working hours
1.4.3.2. Provide safer work ground at night time
1.4.3.2.1.Provide adequate lighting during night construction
1.4.3.2.2.Provide adequate and safe warning signs
1.4.3.2.3.Construct safe and adequate protective barriers
1.4.3.3. Permit work during bad weather conditions
1.4.4. Encourage innovation and fast tracking paving technologies
1.4.5. Demand an adequate and qualified working force
1.4.6. Seek clear, more generalized, and end result specifications
1.4.7. Secure and ensure adequate R.O.W.
1.4.8. Necessitate the exchange of updated information and knowledge among all parties
1.4.8.1.Increase knowledge of actual on-site conditions
1.4.8.2.Provide the means and measures to exchange information
1.4.8.3.Be aware of all problems as they arise during construction
1.4.8.4.Request more frequent communications among all parties involved in the project
1.4.9. Provide adequate working space
1.4.10.Investigate contractor's performance on past jobs and
1.4.11.Reduce the time required for material fabrication and testing
1.4.12.Speed the approval of field changes as needed
1.4.13. Prevent conditions where the contractor collects the majority of
1.4.14.Take all measures necessary to prevent incidental construction
1.4.15.Provide more on-job authority by owner representatives

APPENDIX E:

Questionnaire Prepared for
Texas Contractors

TEXAS STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

EXPEDITING PAVEMENT CONSTRUCTION SURVEY

INSTRUCTIONS

1) Please answer all questions fully and to the best of your knowledge.

2) When complete, please send the entire survey to the Center for Transportation Research using the attached self-addressed envelope. No postage is required.

3) Should you have any questions in completing this form, feel free to contact either Bruce Long, Bill Ward or Ken Hankins at (512) 472-8875.

4) Please complete and return by November 9, 1990.

The purpose of this research study is to discover ways to expedite urban pavement construction. By achieving this objective, highway projects will be completed faster with less disruption to the public user creating a winning situation for everyone involved. There are two ideologies to expediting pavement construction. The first method is to modify or eliminate current construction practices or specifications which impede timely execution of the work. The second way is to identify innovative techniques, exotic materials, etc. which would enhance pavement construction.

It is desired that these surveys will provide a wealth of construction knowledge, experience and ideas. Through full cooperation and open discussion, information should be discovered which will lead to better, more efficient construction projects.

All answers will be kept confidential and only a summary of the information received will be published. If available, please provide a business card for future reference. This will be useful if additional information or clarification is required. If a business card is not available, please provide your name and phone number below. Your time and participation in this study is greatly appreciated.

NAME :____________________________________

PHONE :____________________________________

TEXAS STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

EXPEDITING PAVEMENT CONSTRUCTION SURVEY

1) Identify the top five construction items, procedures and specifications which severely impede progress.

2) List the top five construction practices, ideas and solutions which will speed the pavement construction process.

3) What improvements can be made at critical intersection locations to quicken the construction process?

4) Discuss the benefits and disadvantages of the following items concerning expediting pavement construction. Include any personal experiences and whether or not you would recommend the item as an useful solution to speed construction.

a) nighttime construction

b) precast pavement elements

c) multiple smaller contracts instead of a single large contract

d) exotic materials such as high-early strength cements, fiber-reinforced concrete, etc.

e) improved public relations with the highway user

5) Identify innovative construction equipment (automated dowel bar inserters, zero clearance pavers, etc.) currently available which will improve efficiency.

6) Would the use of incentive/penalty specifications provide earlier completion dates? On what bidding basis should the contract be awarded? Identify any advantages and disadvantages.

7) Is there a preference towards pavement materials type and/or pavement structure design which will allow for faster and easier construction?

8) Describe problems encountered with traffic control plans and traffic handling. What would be practical solutions.

9) Would changes or greater flexibility in the project plans and specifications expedite construction? Provide examples.

10) What problems are encountered with abutting property owners on construction sites which severely impedes operations? What solutions would you recommend?

11) Would moving all traffic off of the construction site to a nearby detour have a significant impact on expediting construction? Provide any anticipated problems and advantages with this traffic management suggestion.

12) Please identify construction project sites, past and present, which can serve as case studies. Suggested sites should have used some method to expedite pavement construction (successful or not) or have been a location where expediting pavement construction would have greatly enhanced the project.

13) Provide any additional comments, suggestions and recommendations which would expedite pavement construction.

Thank you for participating in this study. Your time and effort is greatly appreciated.

APPENDIX F:

Hierarchy of Objectives Technique (HOT) Outline Used to Categorize Responses to Questionnaire Prepared for Texas Contractors

HOT OUTLINE

TACTICS TO MINIMIZE THE ADVERSE EFFECTS OF URBAN HIGHWAY CONSTRUCTION ACCORDING TO CONTRACTORS

+ 1. Minimizing Adverse Effects of Urban Highway Construction

  + **1.1. Minimize Phases Involved**
    + 1.1.1. Minimize number of layers
      + 1.1.1.1. Use high early strength materials
        - 1.1.1.1.1.Use lime under layers
        - 1.1.1.1.2. Decrease the time required to seal joints in concrete and to open pavement to traffic
      + 1.1.1.2. Use full-depth materials
        - 1.1.1.2.1. Use high early strength materials
        - 1.1.1.2.2.Use advanced techniques and equipment
      - 1.1.1.3. Use prefabricated members
      - 1.1.1.4. Encourage and plan for innovation
    - 1.1.2. Implement accelerated construction and testing methods
    - 1.1.3. Use prefabricated designs
    - 1.1.4. Allow contractor to lay base in thicker layers
    - 1.1.5. Construct reliable frontage roads
    + 1.1.6. Improve productivity
      + 1.1.6.1. Provide reliable and advanced equipment for construction
        - 1.1.6.1.1. Use full-width paving train
        - 1.1.6.1.2.Use multipurpose equipment
      - 1.1.6.2. Provide sufficient well trained man-power
      - 1.1.6.3. Provide sufficient R.O.W.
      - 1.1.7.4. Recycle existing pavements in place
    - 1.1.7. Train and educate workers on the use of accelerated methods
    - 1.1.8. Encourage and plan for innovation
    - 1.1.9. Keep constructability in mind during the design stage
    - 1.1.10. Use uniform pavement width as much as possible
    - 1.1.11. Recycle pavements using in-place recycling

  + **1.2. Optimize Traffic Control and Management Systems**
    + 1.2.1. Select full closure of pavement when allowed
      - 1.2.1.1. Provide sufficient detours
      - 1.2.1.2. Divert traffic to adjacent routes
    + 1.2.2. Use fewer equipment changes for construction
      - 1.2.2.1. Use multiple application machines and equipment
      - 1.2.2.2. Implement procedures requiring less equipment
      - 1.2.2.3. Remove unnecessary equipment from the site
    - 1.2.3. Use temporary driveways
    - 1.2.4. Construct reliable frontage roads
    + 1.2.5. Enhance safety at construction sites
      - 1.2.5.1. Provide more working space
      - 1.2.5.2. Adopt higher safety standards
      - 1.2.5.3. Have sufficient lighting for night hours
      - 1.2.5.4. Use special safety features at night time and during bad weather

  + **1.3. Improve Utility Adjustment Processes**
    - 1.3.1. Relocate utilities in advance

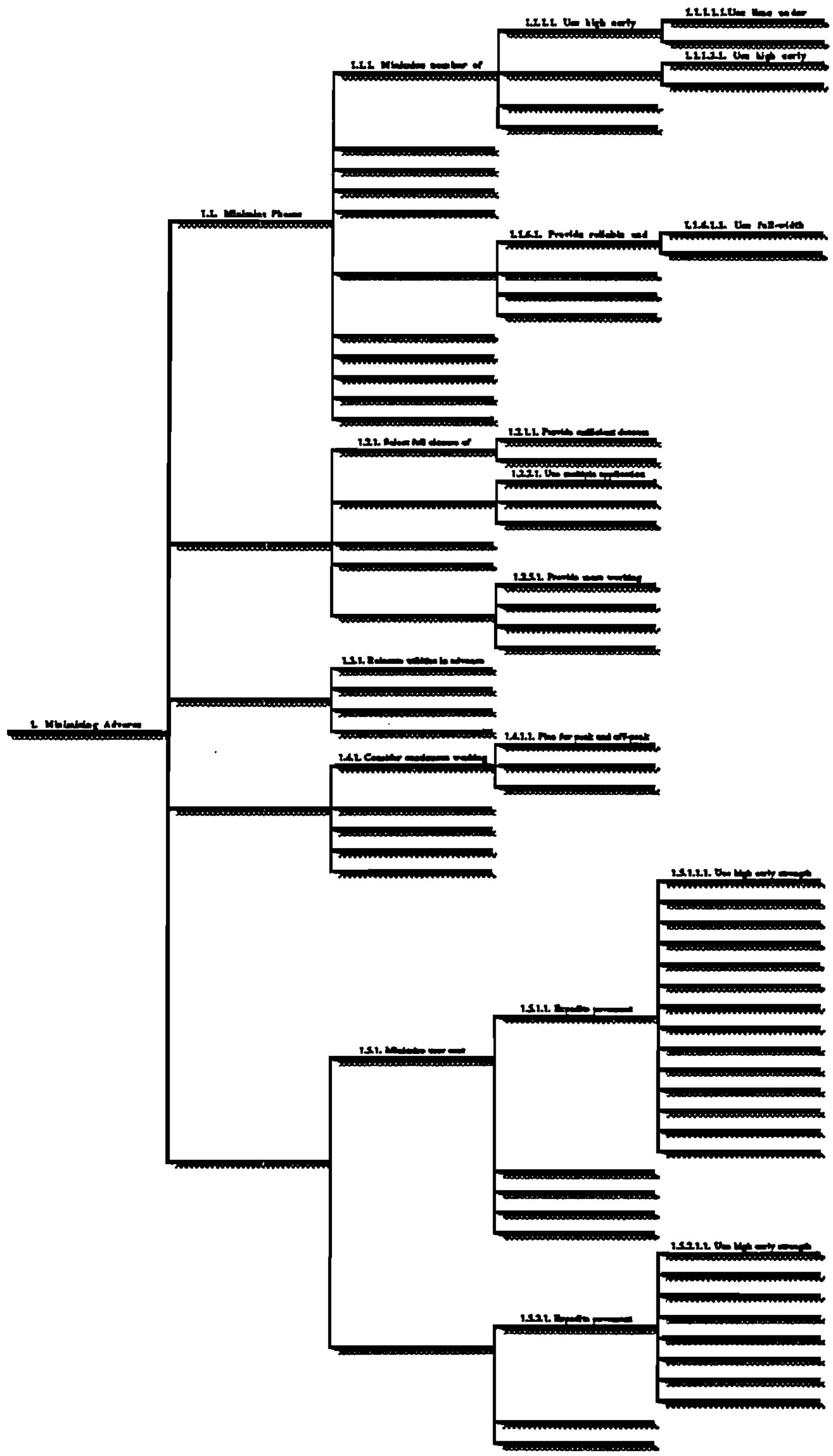
- 1.3.2. Enhance of utility handling methods
- 1.3.3. Cooperate with other parties involved in the utilities
- 1.3.3. Encourage inovative techniques in locating and relocating utilities

+ **1.4. Cooperate with the Highway Department**
  + 1.4.1. Consider continuous working hours
    - 1.4.1.1. Plan for peak and off-peak working hours
    - 1.4.1.2. Provide safe zone for night construction
    - 1.4.1.3. Allow work during bad weather conditions
  - 1.4.2. Allow flexibility in scheduling
  - 1.4.3. Seek more generalized and end result specifications
  - 1.4.4. Exploit incentive/penalty contracts
  - 1.4.5. Provide more on-job authority by owner representatives

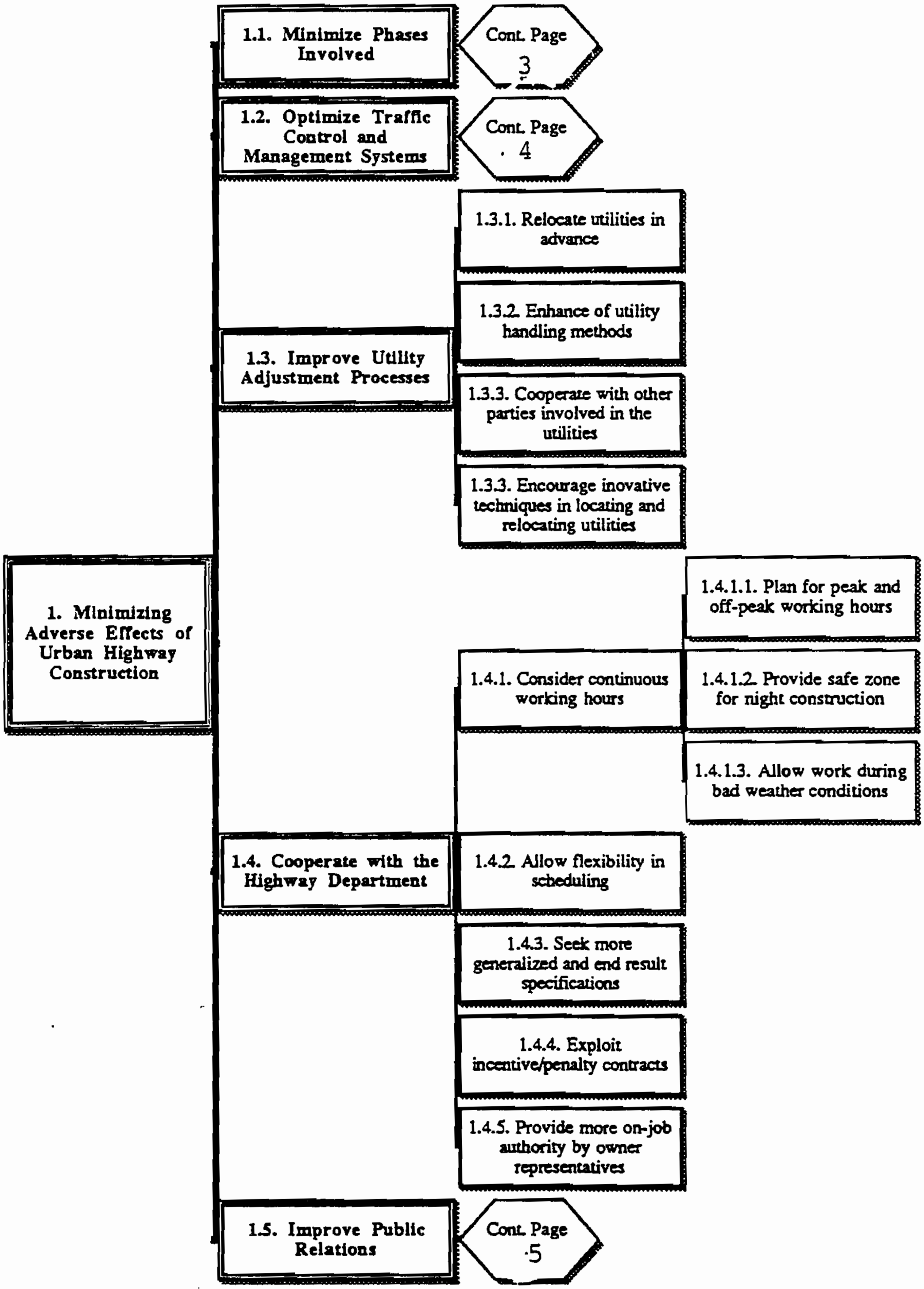
+ **1.5. Improve Public Relations**
  + 1.5.1. Minimize user cost
    + 1.5.1.1. Expedite pavement construction
      - 1.5.1.1.1. Use high early strength materials
      - 1.5.1.1.2. Provide sufficient and comfortable detours
      - 1.5.1.1.3. Use accelerated methods
      - 1.5.1.1.4. Use temporary driveways to residential and shopping areas
      - 1.5.1.1.5. Permit all-weather and night working hours
      - 1.5.1.1.6. Use prefabricated designs
      - 1.5.1.1.7. Open road to traffic as soon as pavement strength is assured
      - 1.5.1.1.8. Provide safe work area with good signing
      - 1.5.1.1.9. Recycle materials
      - 1.5.1.1.10. Keep a clean construction site
      - 1.5.1.1.11. Reduce construction pollution
      - 1.5.1.1.12. Avoid problematic and environmentally sensitive issues
      - 1.5.1.1.11. Reduce curing times between layer applications
      - 1.5.1.1.12. Eliminate time-consuming incidental construction
    - 1.5.1.2. Educate motorists regarding construction activities and progress
    - 1.5.1.3. Keep the public informed at all times
    - 1.5.1.4. Reduce conflict
    - 1.5.1.5. Reduce congestion
  + 1.5.2. Minimize negative effects on abutting properties
    + 1.5.2.1. Expedite pavement construction
      - 1.5.2.1.1. Use high early strength materials
      - 1.5.2.1.2. Open road to traffic as soon as pavement strength is assured
      - 1.5.2.1.3. Allow night working hours
      - 1.5.2.1.4. Use prefabricated designs
      - 1.5.2.1.5. Use accelerated methods
      - 1.5.2.1.6. Provide safe work area with good signing
      - 1.5.2.1.7. Keep a clean construction site
      - 1.5.2.1.8. Eliminate time-consuming incidental construction
    - 1.5.2.2. Use temporary driveways near businesses
    - 1.5.2.3. Keep property owners informed of construction activities and progress

APPENDIX G:

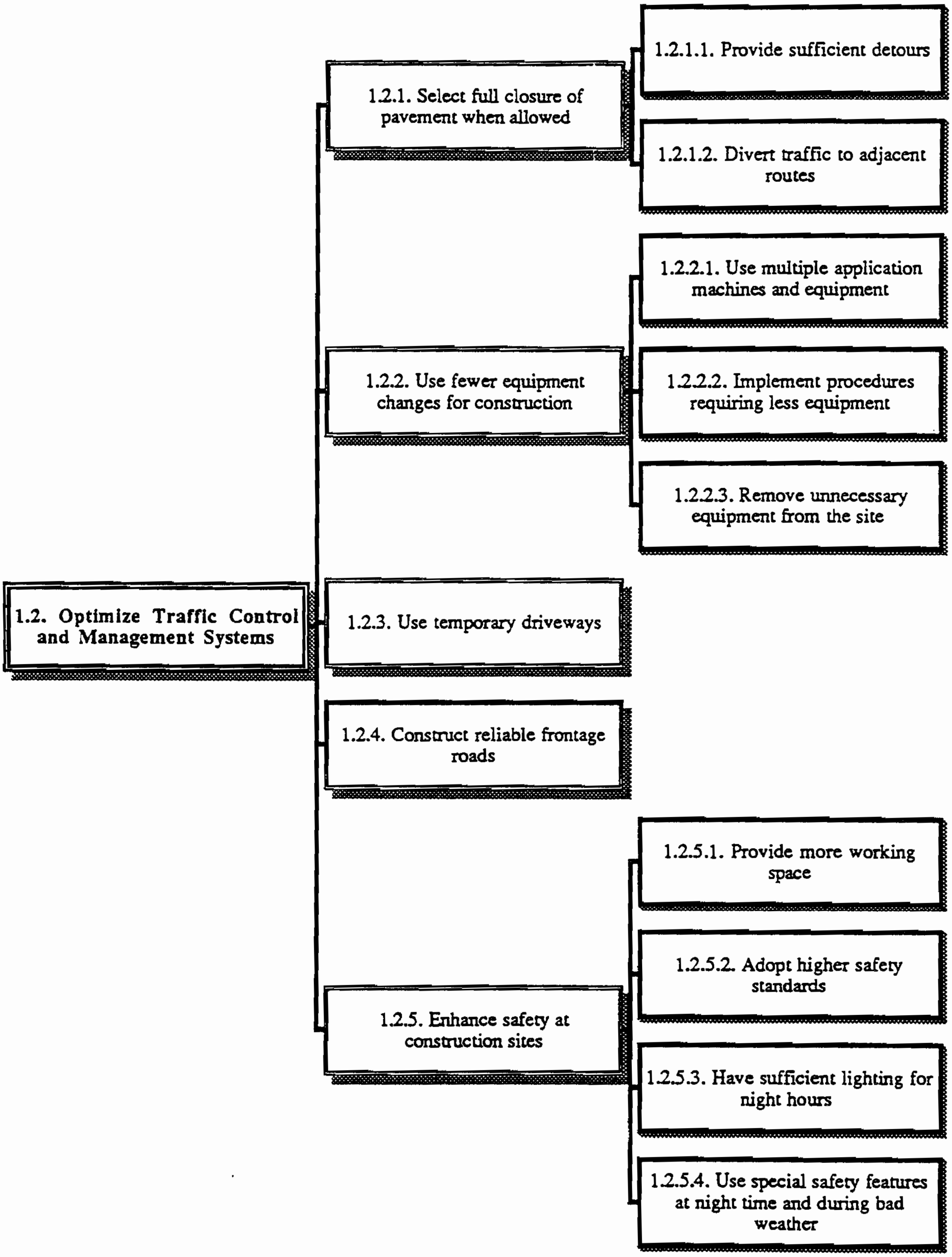
Hierarchy of Objectives Technique (HOT) in Tree-Structure Form
Used to Categorize Responses to Questionnaire Prepared for
Texas Contractors

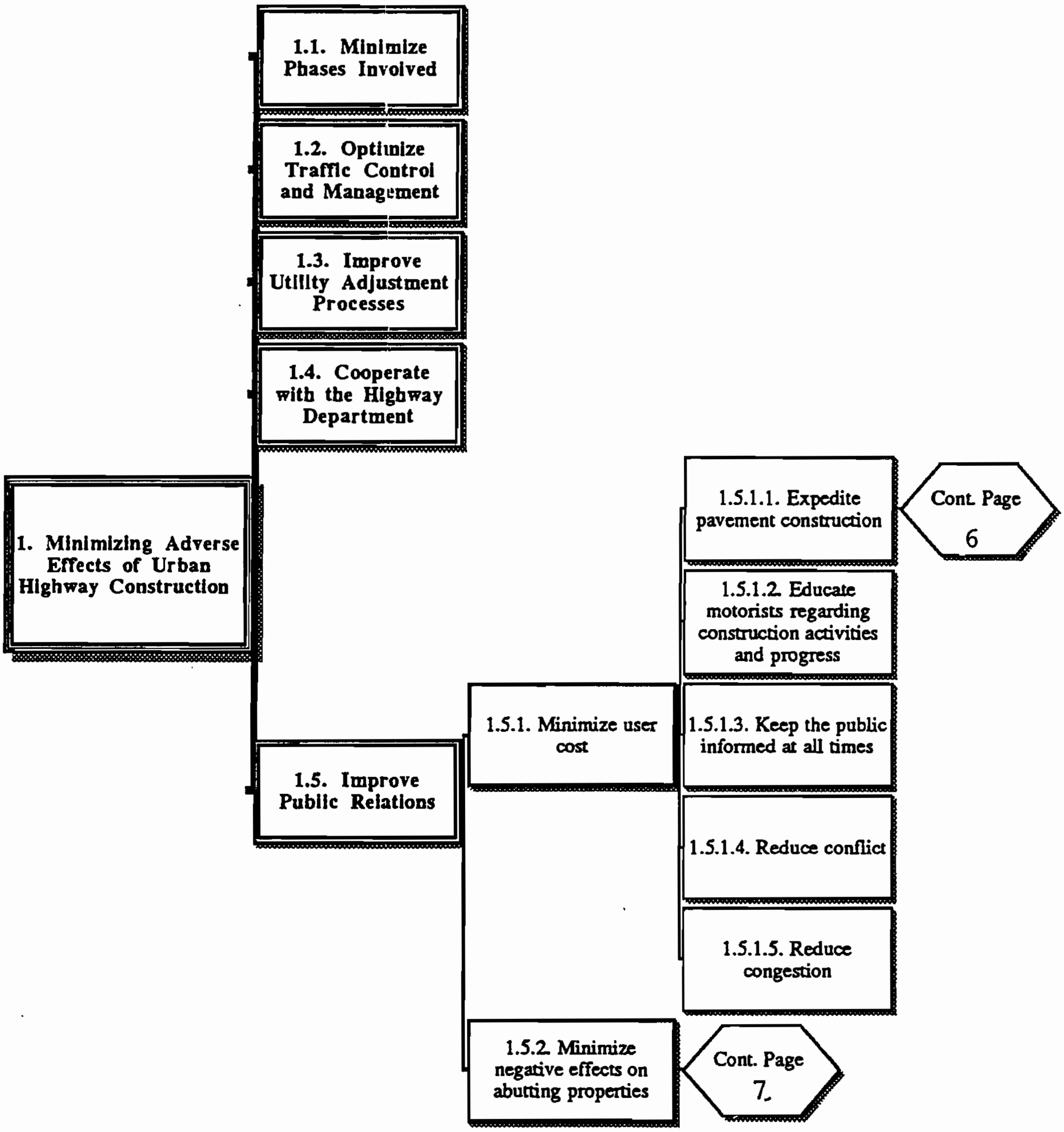


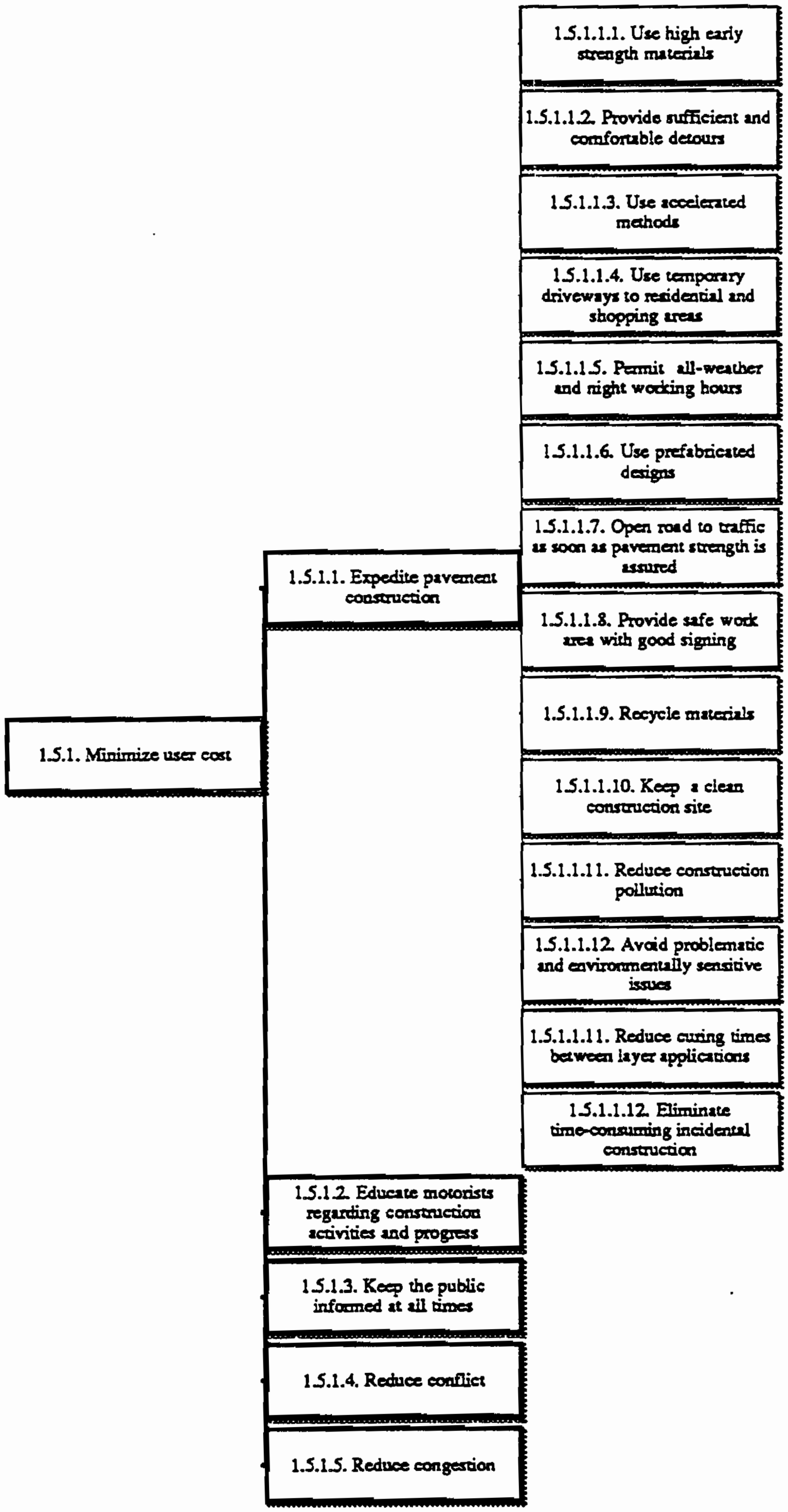
Information Tree Formed from the Contractors' Survey


1.1. Minimize Phases Involved
Cont. Page 3
1.2. Optimize Traffic Control and Management Systems
Cont. Page 4
1.3.1. Relocate utilities in advance
1.3.2. Enhance of utility handling methods
1.3. Improve Utility Adjustment Processes
1.3.3. Cooperate with other parties involved in the utilities
1.3.3. Encourage inovative techniques in locating and relocating utilities
1. Minimizing Adverse Effects of Urban Highway Construction
1.4.1.1. Plan for peak and off-peak working hours
1.4.1. Consider continuous working hours
1.4.1.2. Provide safe zone for night construction
1.4.1.3. Allow work during bad weather conditions
1.4. Cooperate with the Highway Department
1.4.2. Allow flexibility in scheduling
1.4.3. Seek more generalized and end result specifications
1.4.4. Exploit incentive/penalty contracts
1.4.5. Provide more on-job authority by owner representatives
1.5. Improve Public Relations
Cont. Page 5

- **1.1. Minimize Phases Involved**
  - **1.1.1. Minimize number of layers**
    - **1.1.1.1. Use high early strength materials**
      - **1.1.1.1.1.Use lime under layers**
      - **1.1.1.1.2. Decrease the time required to seal joints in concrete and to open**
    - **1.1.1.2. Use full-depth materials**
      - **1.1.1.2.1. Use high early strength materials**
      - **1.1.1.2.2.Use advanced techniques and equipment**
    - **1.1.1.3. Use prefabricated members**
    - **1.1.1.4. Encourage and plan for innovation**
  - **1.1.2. Implement accelerated construction and testing methods**
  - **1.1.3. Use prefabricated designs**
  - **1.1.4. Allow contractor to lay base in thicker layers**
  - **1.1.5. Construct reliable frontage roads**
  - **1.1.6. Improve productivity**
    - **1.1.6.1. Provide reliable and advanced equipment for construction**
      - **1.1.6.1.1. Use full-width paving train**
      - **1.1.6.1.2.Use multipurpose equipment**
    - **1.1.6.2. Provide sufficient well trained man-power**
    - **1.1.6.3. Provide sufficient R.O.W.**
    - **1.1.7.4. Recycle existing pavements in place**
  - **1.1.7. Train and educate workers on the use of accelerated methods**
  - **1.1.8. Encourage and plan for innovation**
  - **1.1.9. Keep constructability in mind during the design stage**
  - **1.1.10. Use uniform pavement width as much as possible**
  - **1.1.11. Recycle pavements using in-place recycling**


1.2. Optimize Traffic Control and Management Systems
1.2.1. Select full closure of pavement when allowed
1.2.1.1. Provide sufficient detours
1.2.1.2. Divert traffic to adjacent routes
1.2.2. Use fewer equipment changes for construction
1.2.2.1. Use multiple application machines and equipment
1.2.2.2. Implement procedures requiring less equipment
1.2.2.3. Remove unnecessary equipment from the site
1.2.3. Use temporary driveways
1.2.4. Construct reliable frontage roads
1.2.5. Enhance safety at construction sites
1.2.5.1. Provide more working space
1.2.5.2. Adopt higher safety standards
1.2.5.3. Have sufficient lighting for night hours
1.2.5.4. Use special safety features at night time and during bad weather


1.1. Minimize Phases Involved
1.2. Optimize Traffic Control and Management
1.3. Improve Utility Adjustment Processes
1.4. Cooperate with the Highway Department
1. Minimizing Adverse Effects of Urban Highway Construction
1.5.1.1. Expedite pavement construction
Cont. Page 6
1.5.1.2. Educate motorists regarding construction activities and progress
1.5.1. Minimize user cost
1.5.1.3. Keep the public informed at all times
1.5. Improve Public Relations
1.5.1.4. Reduce conflict
1.5.1.5. Reduce congestion
1.5.2. Minimize negative effects on abutting properties
Cont. Page 7


1.5.1. Minimize user cost
1.5.1.1. Expedite pavement construction
1.5.1.1.1. Use high early strength materials
1.5.1.1.2. Provide sufficient and comfortable detours
1.5.1.1.3. Use accelerated methods
1.5.1.1.4. Use temporary driveways to residential and shopping areas
1.5.1.1.5. Permit all-weather and night working hours
1.5.1.1.6. Use prefabricated designs
1.5.1.1.7. Open road to traffic as soon as pavement strength is assured
1.5.1.1.8. Provide safe work area with good signing
1.5.1.1.9. Recycle materials
1.5.1.1.10. Keep a clean construction site
1.5.1.1.11. Reduce construction pollution
1.5.1.1.12. Avoid problematic and environmentally sensitive issues
1.5.1.1.11. Reduce curing times between layer applications
1.5.1.1.12. Eliminate time-consuming incidental construction
1.5.1.2. Educate motorists regarding construction activities and progress
1.5.1.3. Keep the public informed at all times
1.5.1.4. Reduce conflict
1.5.1.5. Reduce congestion