Interim Report
Research Project T9903, Task 34
Constructability Review Framework

A FRAMEWORK FOR THE CONSTRUCTABILITY REVIEW OF TRANSPORTATION PROJECTS

by

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16. ABSTRACT

The objective of this project was to recommend to the Washington State Department of Transportation a new process for conducting constructability reviews. In Phase I of the project, the researchers sought to define the problem, identify critical issues, and develop the initial elements of a Constructability Review Process (CRP).

To understand how WSDOT develops its projects, the researchers obtained documents and briefs on a current series of management studies; reviewed WSDOT's manuals, directives, and guides describing the project development process involved; and conducted an extensive round of interviews with WSDOT staff and management, as well as interviews with consultants and others involved with the process. They also reviewed projects on SR 18 in the Northwest Region.

The CRP model was developed concurrently with other studies focusing on other aspects of improving the WSDOT Project Development Process. Although significant changes are being implemented that should result in improvements, the researchers found that issues germane to constructability remain. These include the need for WSDOT to consider constructability in a statewide Project Management Process; to form a multi-disciplinary CRP team at the project scoping phase; for closer communication, coordination, and team building between the Headquarters Structures Service Center and the Regional Design offices; for plans review coordination with the final constructability review; for structured project checklists for use throughout the project development process; and for an accessible record of design decisions made, as well as design and post-contract lessons learned.

The researchers agree that the re-engineering being done to the project development process is making improvements that are consistent with the constructability enhancement provided by the CRP. The main aspects of this new process are as follows: At the draft Project Identification Report (PIR) stage, a project-level Value Engineering study should be considered for projects that are major, costly, or that include complex features to evaluate every possible alternative for the project. A set of up to four constructability reviews should be implemented, with the number depending on the project's type, size and complexity. The general purpose of the constructability review is to assure that constructability issues, including maintainability, are identified and resolved before completion of the PS&E. A system of checklists and a compendium of lessons learned should be developed for use throughout the project.

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DISCLAIMER

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 Washington State Transportation Commission, Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

NOTE TO MAY 1996 DRAFT REVIEWERS

This draft is a substantially revised version of the original draft, prepared by TRAC and distributed for review and comment during the Summer of 1995. Most of the changes reflect major revisions to the WSDOT project development process that have been made or are being made. The WSDOT studies leading to these revisions were under way concurrently with the Phase I CRP study. Because they had not been completed at that time, they were not reflected in the original draft. Phase II proposes development of a statewide CRP Implementation and Training Plan including CRP criteria, CRP guidelines, CRP checklists. This revised draft incorporates comments received from the original and subsequent reviewers to date.

The CRP Study Team acknowledges the valuable assistance in completing this report provided by Pre-Doctoral Candidate John Gambatese, who joined the Team for the Phase II Study.

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1. INTRODUCTION

1.1. INTRODUCTION

This report describes a proposal to implement a constructability review process for the Washington State Department of Transportation (WSDOT). This effort involved a team of researchers from the Civil Engineering Department at the University of Washington and staff and management from the Washington State Department of Transportation (WSDOT) Headquarters Office in Olympia (WSDOT Service Center) and the Northwest Region Office in Seattle.

WSDOT has become increasingly concerned about the constructability and the quality of design plans for its major roadway construction projects. WSDOT management has directed several studies over the past few years intended to upgrade methods and procedures to assure that the processes in place are effective and appropriate for a modern transportation agency. Several of the studies have been conducted in-house. This study was undertaken independently to increase the opportunity for an objective review and to provide a link with the Department's other concurrent procedural studies.

WSDOT, like most transportation agencies throughout the country, is facing increasing technical complexities, increasing regulatory restrictions, and tremendous internal and external (public, private, and political) pressures to deliver quality products on time, within budget, and with unchanged scopes. Furthermore, WSDOT, like many public agencies, periodically has large turnovers of experienced staff. Each of these issues results in or exacerbates problems related to construction.

The issues being addressed are not unique to Washington. The subjects of constructability and quality of design plans have been identified and publicized as significant national issues. The construction industry, as a whole, has expressed concern about the increasing number of projects proposed for construction that appear to be marginally biddable. Several construction industry publications have reported increases in the number of contract change orders, contracts settled through litigation, and construction contracts that exceed the original bid price (Construction Management Committee 1991). There is much speculation about the root causes of constructability problems and the diminishing quality of design plans. The paper "Constructability: a Primer," prepared by the Construction Industry Institute (1986), argues that constructability is a world-wide problem. It also cites examples in which constructability reviews that were applied in real cases throughout the project development process, beginning at the project scoping phase, provided cost and time savings. Of note on the positive side, information received from our contacts in other states indicated that WSDOT, through this effort and study, is viewed as taking a proactive lead in improving the constructability of its projects. These other states have expressed interest in the outcome of this study.

Congress, through the Intermodal Surface Transportation Act of 1991 (ISTEA), made it clear that the transportation industry needs to look for continuous improvements, especially improvements in the quality of transportation products and services. Constructability improvements have been identified as an integral step in achieving quality. The American Association of State Highway and Transportation Officials (AASHTO), Federal Highway Administration (FHWA), and many states have launched programs focusing on initiatives involving continuous quality improvement programs, of which constructability and existing project development process problems are key focal points.

The Associated General Contractors (AGC) has been working with public agencies to expand the concept of "partnering" as one means of improving the construction process (Associated General Contractors 1991). Partnering certainly helps to develop the communication and working relationships that are necessary for the successful conduct of day-to-day business. Partnering is just one of many elements that are being identified with successful improvement programs, most of which were initially concentrated on the construction phase. This team-building is now being considered throughout the project life-cycle, from inception through construction and maintenance.

Use of these concepts of quality in the pre-construction phases of project development is crucial to achieving a high quality end product. WSDOT has been at the forefront in recognizing and developing an awareness of quality. This study is another step the Department has taken to assure quality. WSDOT has been recognized as a leading state agency in the quality movement by the National Quality Steering Committee. Led by the Washington State Secretary of Transportation, representatives from the Washington transportation industry were asked to present their program at the Second National Conference on Quality convened in Arlington, Virginia, in November 1995. This study was included as one of WSDOT's ongoing quality improvement efforts.

1.2. PURPOSE AND OBJECTIVE OF THIS STUDY

The original objective of this study was to recommend to WSDOT a new process for conducting constructability reviews. Since the project's inception, though, the objectives have expanded, as described below. The proposed research project will include three phases, each of which has objectives as follows:

Phase I: 1994-1995	Define the problem; conduct a literature search and interviews; identify critical issues; develop the initial elements of a Constructability Review Process (CRP); undertake initial testing of the model on selected State Route (SR 18) projects.
Phase II: 1995-1996	Evaluate tests using the pilot process model; modify and improve the model; develop initial computer tools to assist in the application of the review process; perform more rigorous tests on the proposed CRP; document the steps of the model; recommend the Phase III completion steps.
Phase III: 1996-1997	Further evaluate and refine the prototype CRP; develop a computer-based CRP database and process; develop and test "smart" CRP proposals; document and write the final report for "Improving Project Constructability."

NOTE: The Proposal for Phase II now combines, modifies, and accelerates completion of the original Phases II and III into a single phase. Phase II will now test and verify the CRP concept and develop a complete Training and Implementation Plan. Phase II is proposed to be completed by late 1996.

1.3. CONSTRUCTABILITY DEFINED

Constructability means different things to different people; in particular, constructability review is often interpreted as a review that occurs at the end of the Plans, Specifications, and Estimate (PS&E) process. A working definition was therefore needed for this study. The researchers adopted the following definition:

> ***Constructability is the property of a project in which errors and omissions on the contract plans and special provisions have been minimized and allow the contractor to construct a high quality project that is biddable, buildable, and maintainable.***
>
> ***Constructability Review is a systematic process to ensure that a project possesses the foregoing attributes.***
>
> ***The process starts at the inception of the project and continues throughout its duration.***

These definitions embody the primary goals for the success of a project. Refinement of the concept suggests two sub-classes of constructability: Programmatic Constructability and Technical Constructability. Both are important, but each assumes different weights at different times during the development of a project. Programmatic Constructability dominates the early phases of project development and evaluates whether the project scope will solve the problem identified by the Department, whether it meets the definition of constructability, and whether it is programmable for construction within the desired time frame. This evaluation also identifies any major environmental, construction, or maintenance issues/concerns germane to the environmental study and/or design of the project.

Technical Constructability addresses the technical details of the engineering solutions to the overall problem. It concerns both the engineering attributes of the finished product and the possible means and methods by which the product can be built. Depending on the size and complexity of the project, Technical Constructability evaluations should occur at key process steps during the PS&E phase of design.

Programmatic and Technical Constructability evaluations also assure that the finished construction meets the Department's current design, construction, and maintenance standards and practices.

Maintainability is also considered an integral part of assuring that a quality facility is provided continuously throughout the operational phase. Maintenance preserves the investment for as long as possible, practicable, and cost effective. Maintainability as conceived within this definition, is ease of maintenance, workability, accessibility, and minimizing, wherever possible, operational conflicts and the exposure of maintenance staff and equipment to moving traffic or other hazardous conditions. Maintainability is a property that each constructed project should possess and is as important as biddability, ease of construction, and structural adequacy.

1.4. EXPECTED BENEFITS

Significant improvement should be realized from the implementation of a Constructability Review Process (CRP). Experiences of those who have implemented a CRP lead to the conclusion that a cost-effective, quality project should result and additional costs and delays should be minimized.

Two features are essential for successful implementation of a CRP: multidisciplinary participation and an early start. Gathering all the disciplines involved in a project provides both the immediate benefit of resolving the problems at hand and the long-term advantage of building teamwork. The goal is that in the future, the majority of the issues will have been discussed and resolved by the multidisciplinary teams during the course of design.

The need for an early start is demonstrated by the fact that opportunities to influence costs diminish as the project progresses. This is illustrated in Figure 1.1. The Construction Industry Institute has determined that the most cost-effective constructability successes are realized when constructability evaluations are initiated at the project scoping phase and conducted at key steps throughout the development of the project before construction.

At present, WSDOT constructability reviews occur when the PS&E process is about 90 percent complete or later and therefore do not follow these principles. Implementation of a structured CRP that is initiated at the beginning of a project and that provides ongoing monitoring of constructability issues should lead to better quality plans and specifications. These in turn should assure fewer scheduling delays, fewer cost overruns, a better ability to avoid the potential for costly conflicts and contract claims, and a higher quality product for its ultimate customers, the transportation user.

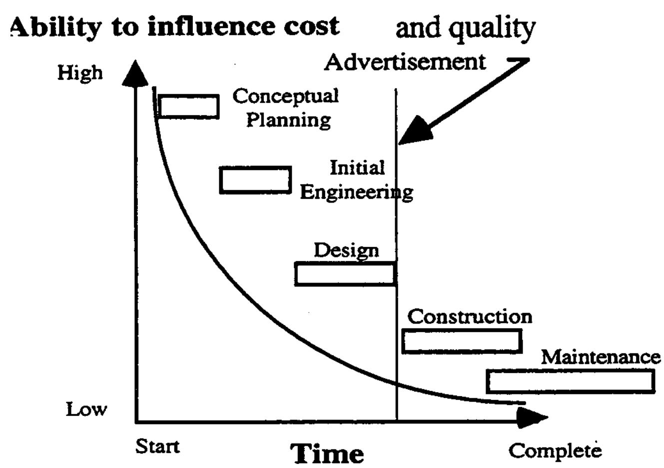


Figure 1.1: Ability to Influence Project Costs and Quality over the Life of the Project.
(Construction Industry Institute 1986)

2. REVIEW OF OTHER ONGOING STUDIES AND EFFORTS

Several studies related to constructability have recently been completed or are currently under way both in Washington and elsewhere in the nation. These are briefly described below and in detail in Appendix A.

- The ongoing National Cooperative Highway Research Program (NCHRP) project 94-10-42 is identifying constructability problems nationwide and recommending methods for correcting them (Texas Transportation Institute, University of Houston).
- The WSDOT study WA-RD 246.1, titled "Constructability Improvement of Highway Projects in Washington," conducted by Washington State University, also addressed constructability. The project recommended development of a computerized tracking system (Highway Constructability Improvement System (HCIS)). The Department deferred implementation because the proposal was to essentially computerize the existing review process, whereas the Department was contemplating making changes to improve the existing process (Lee and Clover 1991).

Six other key efforts related to constructability have been recently completed or are currently under way in Washington State. All of these efforts are compatible and consistent with each other and with this study, even though all were done by independent groups.

- The Washington Quality Initiative (quality improvement program within the state of Washington; on-going effort involving the entire transportation community).
- Design Development and Documentation Study developed by WSDOT. (approved January 1995) (WSDOT 1994)
- Stewardship Agreement (Delegations to WSDOT by FHWA)
- The Technical Development Plan (WSDOT study, CAE Office)
- The WSDOT Scoping Task Force Study (approved September 1995)
- The WSDOT Environmental Organization Study (approved January 1994) and the NEPA/SEPA/404 Merger Agreement (implemented early 1994; fully executed June, 1995).

At the start of this study, the research team contacted transportation departments in Arizona, California, Florida, Idaho, Iowa, Pennsylvania, and Vermont. All were interested in this project and the NCHRP study on constructability. Several offered to host short meetings to assemble key transportation personnel and management from the department and the construction industry to brainstorm constructability issues within their respective states. Although many of the states were attempting to or had tightened their plan review process, they were still very interested in this study and commended the foresight of Washington for taking the lead.

Although formal meetings were not held in other states, it was possible to discuss constructability by phone and to collect documentation on the subject from Arizona and California. Constructability is a timely and pertinent issue in virtually every state that was contacted, and all those contacted looked at this effort as a potentially important contribution toward solving a major problem.

The references at the end of this report contain a sample of the publications and papers that have been written on this subject. Most discuss the problems with little insight into effective solutions. Most also deal with incremental approaches that add systems or modify systems linked to existing processes without eliminating or even addressing the principal causes of problems in those processes.

3. RESEARCH APPROACH

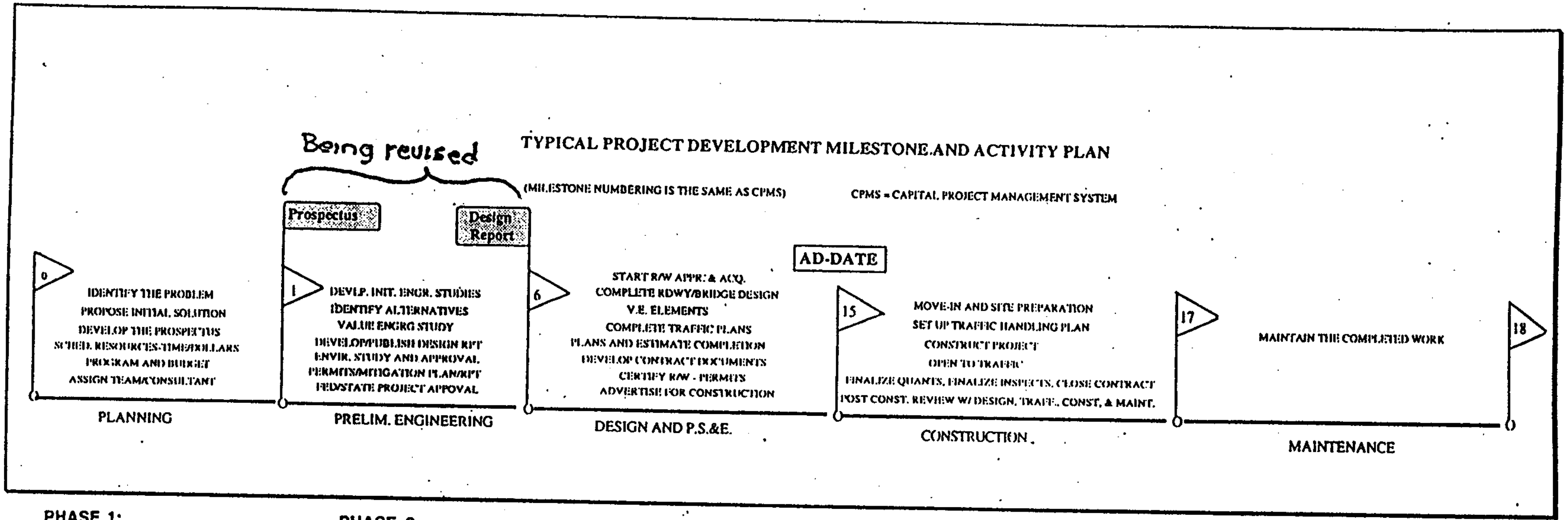
The plan that was established at the outset for this phase was basically to set the goals and objectives for the study, identify the problems, search for information and potential solutions, and develop and offer a solution.

An important part of the plan involved understanding how WSDOT presently conducts and manages the business of developing its projects. This was done by obtaining documentation and briefings on a current series of management studies; reviewing the Department's manuals, directives, and guides describing the processes involved; and conducting an extensive round of interviews with WSDOT staff and management, as well as interviews with consultants and others involved with the process. Projects on SR 18 in the Northwest Region were used as a vehicle for examining the current process, but the problems identified there appear to pervade most large projects.

WSDOT staff went to considerable trouble to help the research team understand the problems and freely provided their insights into the causes. They also provided many valuable suggestions for improvement. This chapter briefly describes the information search and gathering. The problems that were identified during the interviews and document search as most probably constructability related are compiled and discussed in Chapter 4 and were used to formulate recommendations. Part of the difficulty that confronted the research team was to determine the problems that could be addressed by a constructability evaluation (by definition) while recognizing problems that were more process related and therefore being addressed by the other concurrent studies.

3.1. CPMS USED TO GUIDE THE PROJECT DEVELOPMENT FLOW PROCESS

The team used the Capital Project Management System (CPMS) Activity Network as the base definition of department-wide project activities (WSDOT undated). The CPMS milestone schematic, shown in Figure 3.1, is an adaptation of the activity network and served during the study as a base diagram that could be used as a statewide reference.



PHASE 1:
(CPMS MILESTONE 0)

1. INITIAL PLANNING STUDIES TO DETERMINE IF PROB. WARRANTS A PROJ. STUDY FOR POSSIBLE PROGRAMMING
2. MULTIDISCIPLINE TEAM COMPLETES PROJ. STUDY AND PROPOSE SOLUTION, COSTS, AND SCHED. FOR PROGRAMMING - COMPLETE A PROSPECTUS TO DOCUMENT THE CONCEPT TO BE PROGRAMMED.
3. CONCEPT PLACED IN MULTIYEAR PROGRAM AND PRESENTED TO COMMISSION FOR APPROVAL
4. PROJECT ASSIGNED FOR DEVELOPMENT DETERMINE IF PRELIM. OR DESIGN OR BOTH TO BE DONE BY CONSULTANT OR IN-HOUSE STAFF.
5. REQUEST TRAFFIC AND ACCIDENT DATA, GEOTECH. STUDY, AND MAPPING

PHASE 2:
(CPMS MILESTONES 1 THROUGH 6)

1. INITIAL ENGR STUDIES TO CONFIRM CONCEPTS AND ALTERNATIVES AND BEGIN DEVEL. OF DESIGN REPORT.
2. TEAM OF PLAN & ENGR BEGIN DEVEL. OF VALUE ENGINEERING STUDY, PREP. A V.E. REPORT W/ RECOMMENDATIONS
3. OBTAIN BASE MAP FOR ENGR. STUDY
4. DEVEL. DRAFT ENVIR. DOCUMENT AND CIRCULATE FOR APPROVAL TO STUDY
5. COMPLETE DESIGN REPORT AND DEVEL. BRIDGE SITE PLAN(S)
6. COMPLETE ENVIR. STUDY, HOLD PUB. HEARINGS, AND WRITE FINAL ENVIR. DOCUMENT FOR APPROVAL.
7. DEVELOP. ENVIR. MITIGATION PLAN
8. OBTAIN ENVIR. DOC. APPROVAL
9. OBTAIN FED/STATE PROJ. APPROVAL TO PROCEED WITH DEVEL. OF P.S.&E.
10. DETERMINE R/W NEEDS

PHASE 3:
(CPMS MILESTONES 7 THROUGH 15)

1. REQUEST R/W
2. COMPLETE ENGINEERING DESIGN STUDIES FOR DEVELOP. OF ROADWAY AND BRIDGE P.S. & E.
3. FURNISH DESIGN INFO. TO TRAFF. AND REQUEST TRAFFIC PLANS FOR P.S. & E. AND FOR TRAFFIC STAGING DURING CONSTRUCTION
4. APPRAISE, ACQUIRE AND CERTIFY R/W
5. OBTAIN INTERAGENCY PERMITS, DEVEL. UTILITY PLANS AND AGREEMENTS
6. COMPLETE DEVEL. CONTRACT PLANS, SPECS, AND ESTIMATES FOR CONTRACT DOCUMENTS
7. ADVERTISE FOR CONSTRUCTION CONTRACT

PHASE 4:

1. CONTRACTOR AWARDED CONTRACT AND BEGINS CONSTRUCTION OF THE PROJECT
2. CONTRACTOR/STATE FIELD CREW CONDUCT A PARTNERING SESSION TO ESTABLISH AN MUTUAL UNDERSTANDING OF ALL FACETS OF THE CONTRACT AND ESTABLISH THE WORKING RELATIONSHIPS AND COMMUNICATION PLAN FOR THE PROJECT
3. CONTRACTOR COMPLETES THE CONTRACT AND NEGOTIATES CLOSING ALL ADMINISTRATIVE CLAIMS, REMAINING ESTIMATES, ETC.
4. STATE ACCEPTS THE CONTRACT/COMPLETES FINAL QUANTITIES, PROJECT PAY ESTIMATE, CONTRACT REPORT, RECOMMENDS DISPOSITION OF OUTSTANDING CONTRACT ISSUES

PHASE 5:

1. ROAD MAINTENANCE CREW REVIEWS THE COMPLETED PROJECT AND PROJECTS MAINTENANCE BUDGET FOR THE NEW SECTION OF HIGHWAY
2. MAINTAIN THE ROADWAY

Figure 3.1. Typical CPMS Timelines

3.2. DOCUMENT SEARCH

Three reports documenting the progress and status of the ongoing project development process were studied to gain insight into the difficulties faced by WSDOT. Two of the reports, the "Sunshine Report" for the Northwest Region (WSDOT Nov. 1994) and "Milestone Report" for the Eastern Region (WSDOT Dec. 1994), are Project Development Status Reports. The third report, the Change Order Review Report (WSDOT 1986-1993), summarizes the change orders that occurred on projects under construction from 1987 through 1993. These documents revealed measurable differences between the programs as initially defined and the results actually achieved. Documents produced during the project development process, which are currently used as products of the engineering and design project effort, were also reviewed in-depth. Many of the problems encountered by the Department during project development appeared to be procedural, although some affected constructability more directly than others. The team's focus was on identifying the problems that most directly affect constructability .

3.3. INTERVIEWS

To develop a background and to define the parameters for this study, the study team conducted extensive interviews with WSDOT staff and management in Olympia and Seattle. The results of these interviews are reported in this chapter and were instrumental in defining the problems, brainstorming potential solutions, and testing concepts as they began to evolve.

The interviews held at WSDOT can be grouped into three categories. First were interviews to understand how the WSDOT normally proceeds during the development of a project. Second, different offices were interviewed to determine the particular problems they encounter. The selected offices were the Headquarters Project Development functions and, from the Northwest Region, the Project Engineer Office, the Program Management Office, the Environmental Office, the Right of Way Office, the Maintenance Group, the Construction Group, and the Materials Office. Finally, interviews were conducted with one firm of consultants that designed parts of the SR 18 project (Howard Needles Tammen & Bergendoff

(HNTB)) and others that conducted a 90 percent constructability review (HDR Engineering, Inc., John Rex from CONREX).

Interviews were scheduled across the entire spectrum of functions that are directly or indirectly associated with the planning, design, construction, maintenance, program management, and administration of the Department's transportation program. Questionnaires (example attached in Appendix B) were sent to interviewees before each scheduled interview to give them an opportunity to prepare. These questionnaires, although very general in many instances, provided a means to establish topics and key areas crucial to the development of the projects and to meeting program requirements. They were also a way to open discussion about problems associated with processes and products. The interviews were kept informal to allow as much free-form discussion and open dialog as possible to take place.

From the outset of the study, the interview process appeared to be the most crucial and informational aspect of the study and the key to defining the problems and seeking solutions. That perception was not only correct, but the active and open participation of the interviewees in sharing their thoughts on problems and solutions far exceeded expectations. That enthusiasm and willingness to contribute bodes well for the implementation of changes designed to improve the process.

3.4. WSDOT CONSTRUCTABILITY REVIEWS (HDR, CH2MHILL, CONREX)

As part of the investigation of existing processes, the team reviewed the constructability processes WSDOT presently uses. The researchers discussed with both the Northwest Region and Headquarters Plans Review units the process they presently follow for constructability review. The team also observed a constructability review conducted by HDR Consulting on an SR 18 Project (Issaquah-Hobart Interchange and Raging River Bridge). In addition, the researchers interviewed John Rex of CONREX Consulting, who conducts constructability reviews for WSDOT, and recorded his observations about how to improve the process. Reading the HDR and CONREX constructability review reports (CONREX Inc. 1993; HDR Engineering Inc. 1994) also helped in identifying the problems and important items that need to be checked.

A previous CONREX Constructability Review of a WSDOT project was reviewed (included in section 4.3.3.3, "Conducting CRP Reviews and Documentation," is a sample of the types of comments that CONREX made). In addition, a 70 percent PS&E constructability review conducted by HDR for the Northwest Region was observed (see section 4.3.4, "Pilot Evaluation of the CRP").

4. FINDINGS AND DISCUSSION

Over the last 10 to 15 years, WSDOT, like many of the state DOTs across the nation, has experienced increasing pressures because of increased technical complexities, increased regulatory restrictions, and increased public, private, and political pressures to deliver quality projects within scope and budget and on time. These pressures have tended to create a schedule-driven environment during project development, especially during the PS&E phases, that has led to errors, omissions, and constructability problems.

From the start of Phase I of this project, it became clear that some of the problems WSDOT experiences have been strongly influenced by its existing Project Development Process. These problems could not be corrected simply by instituting a new Constructability Review or Evaluation Process, even if reviews were conducted at different times during the process. In recognition of these problems, WSDOT management has concurrently tasked, developed, and is implementing several new/improved project development processes through other study efforts. This Phase I Report contains recommendations for a proposed Constructability Review Process that is both compatible and consistent with the other revisions being made to the Project Development Process.

4.1. EVIDENCE OF DIFFICULTIES AND ISSUES—MOTIVATION FOR A SOLUTION

During an in-depth review of the Department's project development process, all levels interviewed (from project level staff to high level management) expressed considerable and consistent concern that the root of the problem was the schedule-driven environment under which projects are planned, designed, and developed for contract and that this problem does, in fact, create and exacerbate the constructability issues. Other symptoms of the problem with the existing process, and sources of management concern, are the dramatic increases in the number of Contract Change Orders (CCO) and final contract costs during the past few years.

4.1.1. Project Schedules

The study team anticipated that an optimal "constructability evaluation" would require at least some procedural modification(s). To be able to address this probability, it was essential to fully understand the existing scheduling process. To achieve this understanding, a two-tiered approach was undertaken involving 1) interviews with those involved and 2) an independent study of the scheduling reports that were available. We also wanted to try to anticipate any procedural modifications that might be under way because the usual dynamics of change could affect this study. We were aware that other studies were under way, although their effect on this study, especially on the scheduling of project development activities and processes, was unclear at the time.

During the initial interview process, several of those interviewed by the team speculated that the process in place at the time required that projects be defined and programs be committed much too early. Most interviewees in each function felt that under the existing process of concept development, good technical information or details of existing conditions at this early phase were generally lacking. This was presented to us as the primary source of scheduling and cost determination problems. Later information seemed to confirm this finding. Subsequently, a new procedure to develop the project concept was recommended in the "Scoping Task Force Study" (including more engineering analysis, better information, more realistic scheduling of activities, and a better determination of project costs); this was recently adopted and approved for implementation.

As a second part of this study into scheduling problems, a fairly detailed review was performed by the team to further understand and analyze the existing scheduling issues. A detailed review of the Northwest Region Sunshine Report (WSDOT Nov. 1994) and the Eastern Region Milestone Report (WSDOT Dec. 1994) revealed an apparent and consistent slippage of planned dates on many projects. Initially, this fact appeared to be at odds with the admittedly schedule-driven environment, in which some dates, such as the advertising date, were reportedly adhered to dogmatically. In this review, it appeared that the slippage of early dates, such as the

Design Report date, led to compressed dates for the later PS&E activities and made it virtually improbable for a project that had met the initial advertising schedule to be completed on time. This finding seemed consistent with the information from the interviews.

From the various Project Development Status reports, timelines were developed for a few important projects to compare planned and scheduled dates for the various steps in the project development process. A comparison of the planned and actual accomplished dates indicated a tendency to be consistently late and/or quite different than the published plan. The Design Report consistently took longer than planned; therefore, the development of Roadway and Bridge PS&Es frequently started late. With the advertising date apparently fixed, WSDOT appeared to consistently have less time than planned to complete the PS&E steps at a normal pace. The Right of Way work also had a tendency to start later than planned and then would also finish later than planned. It appeared that the timelines for the later activities were often substantially compressed. This time compression was therefore identified as a potential contributor to errors and omissions or, at the least, as the creator of inordinate pressures in completing the project. Timeline graphs have been derived and are available in Appendix D.1.

Our review indicated that the Northwest Region has more delay problems than the Eastern Region. It appeared that the heavier workload, the larger number of complex projects, and more extensive regulatory constraints imposed in the Puget Sound area could be the major causes of the problems. In our sampling of projects, we found an inordinately high average number of late days reported for the actual advertising dates in comparison to planned dates for the same activity. Initially, we thought this to be a bias of the particular sample from the Northwest Region. However, in the Eastern Region, although some projects were also reported as very late, others in the same program period were reported earlier than planned. Subsequently, we found that because of programming and resources changes made during the Biennium Reviews or at other times (because of political decisions, funding constraints, priority changes, regulatory impositions), many projects may have been rescheduled, delayed, or accelerated to meet the changes. However, the planned dates were not modified to reflect these changes. Therefore, and unfortunately, comparisons based on information from the Project Development Status reports of both regions (WSDOT Nov. 1994 and Dec. 1994) could be somewhat misleading. A chart grouping all the numbers is available in Appendix D.2. Nevertheless, we concluded that scheduling issues did and still do exist. This finding or understanding was considered an important factor in developing a procedure that would meet our Constructability definition and that would ensure that a project would **"contain minimal errors and omissions .... and [be] readily biddable, buildable, and maintainable."**

During the analysis of the scheduling issues, it also became clear that the political penalty for missing deadlines is considered paramount, and therefore, completeness of plans may sometimes be sacrificed. This choice can actually increase the cost of the completed projects whenever projects are forced to meet constrained schedules.

A high risk option that has been adopted in some cases involves sending the project out to bid on the official advertising date, even though significant items in the plans may be incomplete, and then to furnish or correct the incomplete items during bid preparation. The bid preparation time has then been extended to permit contractors to incorporate the new information into their bids. The result is that, even though the job may have been put out to advertising on or near the programmed date, the bidding process has become somewhat confused or disrupted as attempts have been made to minimize further delay.

In other contracts the advertising date has slipped, despite the best efforts of WSDOT to complete PS&E on time, often because of involvement of external agencies or other unforseeable changes. Although pushing the project through the advertising steps may possibly save time and costs, the larger potential for missing crucial construction or maintenance elements is very real and can lead to the types of constructability problems we are trying to avoid. This approach further increases the possibility of other changes during construction, the potential for costly claims, and damage to the partnering concepts currently being employed with the construction industry. This high risk procedure appears to have had only very limited success, if any.

These factors have also increased the pressure on the project development team at this crucial point in the development and completion of the project for contract. These types of pressures increase opportunities to miss or omit key items in the final contract documents that may be very important to the construction and maintenance of the project. In addition, the bid closing dates have still slipped, the start of construction has still often been delayed, the potential for subsequent claims has increased, the chance of more change order processing during construction has increased, and the potential for additional costs in the final cost of construction (both engineering and contract costs) has also increased.

While the study team and WSDOT management both agree that realistic schedules are a necessary and important part of managing any major project, it is also an understood premise of project management that unrealistic schedules often create additional pressures that lead to "forced decisions." Many times the results of forced decisions become major constructability issues.

The current procedural changes adopted and being implemented by WSDOT are truly crucial in assuring that a new constructability process will avoid constructability issues that arise from scheduling problems. Although this analysis of project scheduling problems may seem somewhat redundant because procedural revisions have been adopted and implementation is underway, it cannot be overstressed that the contributing factors need to be recognized and minimized because they are critical to the success or failure of a constructability procedure. Therefore, we felt that this discussion needed to be included.

We feel that a constructability evaluation procedure that is scheduled and that occurs at selected milestones throughout the development of projects, especially those with large and/or complex designs, should save time, maintain high quality, and reduce the potential of increased construction costs.

4.1.2. Contract Change Orders

The Team felt that information on Contract Change Orders (CCOs) could provide another possible measure of size, number, and types of constructability issues currently being encountered in the post design phase. The CCO report (WSDOT 1986-1993) produced by the WSDOT Northwest Region Construction Office was an important source for this study. The Region has used the report to analyze its ongoing construction program and to identify contract and constructability problems. The CCO statistics for the most recently available five-year period (1987-1993) are shown in Figures 4.1 a-d, and a detailed breakdown by quarter for 1993 is shown in Figures 4.2 a-d. The numbers from which those figures have been derived are available in Appendix C (with and without the Lacey V. Murrow (I-90) floating bridge numbers because that project was viewed as an anomaly). The figures show the data without the Lacey V. Murrow floating bridge project.

Figure 4.1 (a) shows that during the 1987-92 period, the average number of CCOs was relatively stable at 332, suddenly increased to 967. Figure 4.1 (b) indicates an average additional cost due to CCOs of about $2 million per year for the 1987-92 period, which increased to $25.92 million in 1993. Figure 4.1 (c) indicates that the average number of CCOs per project increased steadily from 5 to 13.6 between 1990 and 1993. Finally, Figure 4.1 (d) shows an increase in the cost of a CCO from an average of $6,000 over the 1987-92 period to $26,805 in 1993.

Figures 4.2 a-d show relatively stable behavior except for the second quarter, in which the additional cost due to CCOs increased to $12.1 million. For each quarter, this number and the cost of a CCO were larger than any preceding year from 1987 to 1992.

1992 was an anomalous year, in that a single project dominated WSDOT's construction efforts. The Lacey V. Murrow (I-90) floating bridge across Lake Washington suffered serious damage, and parts of it sank in a major storm that occurred during renovation. The data for I-90 are thus considered exceptional and have been excluded from the figures. With this modification, the data for 1993 show a disturbing upward trend in almost all measures of contract changes. It is possible to argue that the high level of activity during that time absorbed a significant part of the region's construction capacity and that such an environment inevitably leads to errors and changes. (This phenomenon was clearly demonstrated during the WPPS (Washington Public Power Supply) debacle of the early 1980s). However, knowledge of this

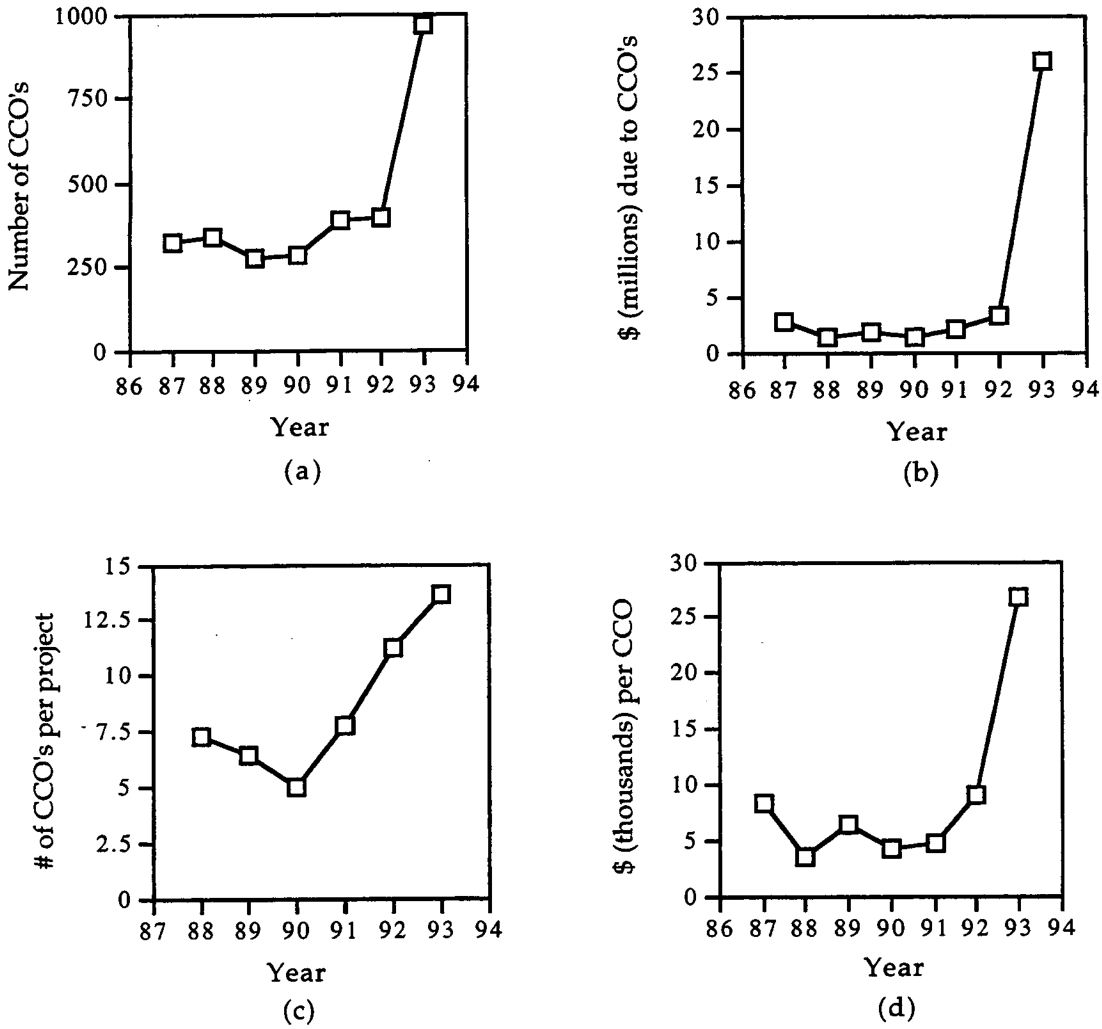
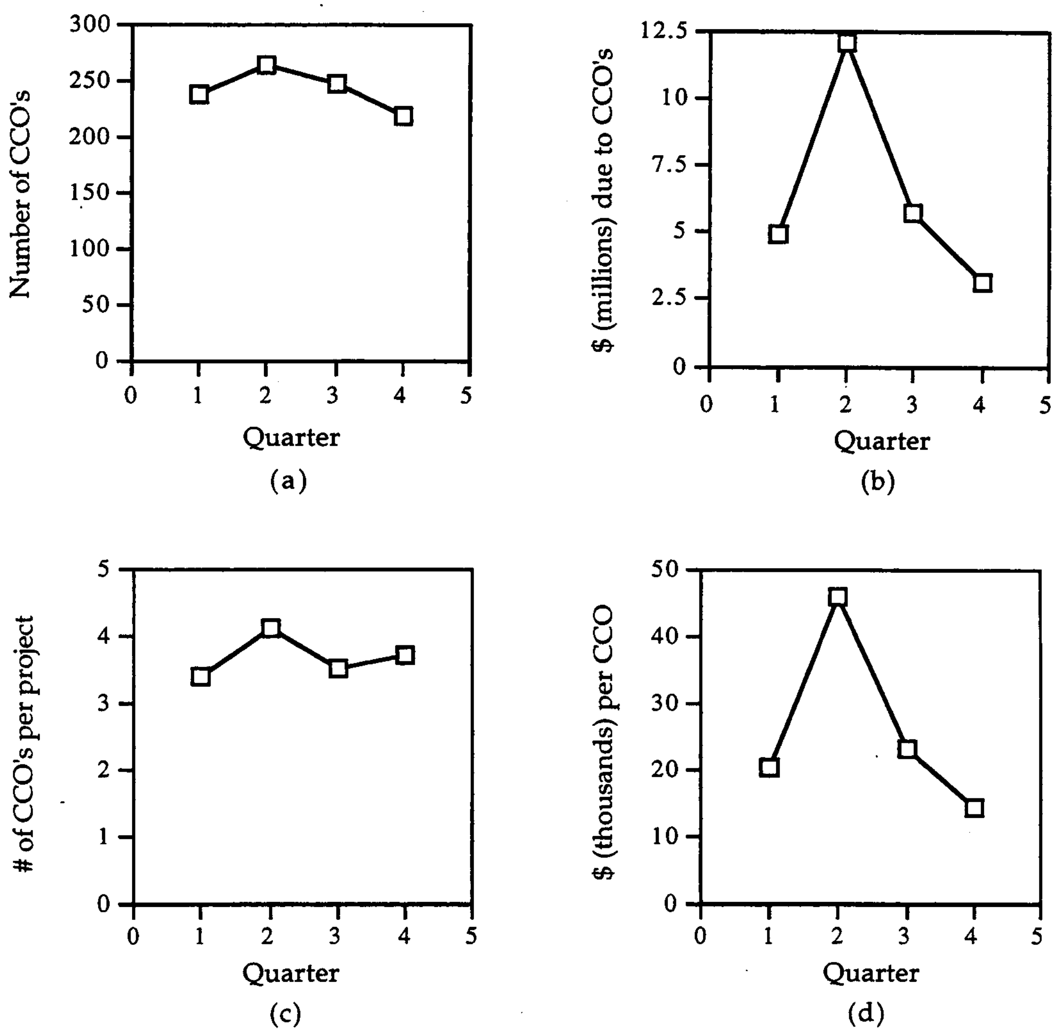


Figure 4.1 a-d: Contract Change Orders Statistics from 1987 to 1993.



Figures 4.2 a-d: Contract Change Orders Statistics for the Four Quarters of 1993.

situation should serve as a warning that either capacity should not be so stretched or that, if such a situation is unavoidable, additional safeguards should be instituted to prevent errors.

If the data for I-90 are included, the number and cost of change orders increase dramatically for 1992.

The data in Figures. 4.1 a-d suggest a fairly stable level of CCOs and costs for 1987-1992, but a significant increase thereafter. The data for 1993, shown in Figures. 4.2 a-d by quarter, show a trend of consistent spending rather than an anomalous surge that could be explained away by exceptional circumstances. The problems are therefore believed to be real.

The Northwest Region's CCO report also provided an analysis and categorization of the reasons for the CCOs. Most of the errors that resulted in change orders were categorized as plan errors made during the design phase that were not corrected before contract award. Some important questions arise. For example, how many of the changes could have been avoided (i.e., discovered through a constructability review) and corrected before the contract was awarded? Or would costs have been substantially lower and construction time shorter if these changes had been incorporated in the design before advertising? The Northwest Region shared a copy of its 1994 CCO Report with the Team. The tabulated data indicated that the level of CCOs and added costs continued at about the same level as 1993. A preliminary review of 1995 performance indicated that this trend continues.

Unfortunately, no comparative report was readily available for the other parts of the state. However, many of the problems that exist in the Northwest Region are reportedly evident in other regions, according to several managers interviewed. Sharp increases elsewhere would probably not be as apparent because of the disparity in average project size, larger numbers of projects, and greater number of complex projects in the Northwest Region. WSDOT's statewide records show that fewer construction claims have been made during the past few years, but both the number of CCOs and final contract costs have increased. We feel strongly that this factor suggests that potential claims are now being resolved through the CCO process rather than being filed. Exchanging claims for CCOs avoids the time, cost, and confrontational atmosphere that inevitably accompany litigation. However, avoiding the problems that lead to the CCOs would be preferable. The fact that fewer claims have been filed is a good sign that WSDOT enjoys generally good working relationships with the construction industry. However, although reducing claims is an important step, the increase in CCOs may eventually strain that relationship unless the increase is corrected and the reported problems with contract documents are improved. The optimal level of design reviews and project plans improvement is a tradeoff between competing cost factors. Errors and changes to correct them incur costs both directly in dollars and indirectly in construction delays, consequential costs, and delay in deploying the project.

Other difficulties, such as loss of political credibility with the Transportation Commission and state legislature, also arise. However, early detection and correction of potential errors also costs money because individuals with appropriate talents must spend the time to familiarize themselves with the project and conduct an in-depth review. The relationship between these costs is illustrated heuristically in Figure 4.3, in which cost is interpreted in the broadest sense and includes such issues as inconvenience to the public. It is unrealistic to expect a contract to proceed with no errors or changes; however, the minimum overall cost cannot be achieved without fewer errors than WSDOT is experiencing now.

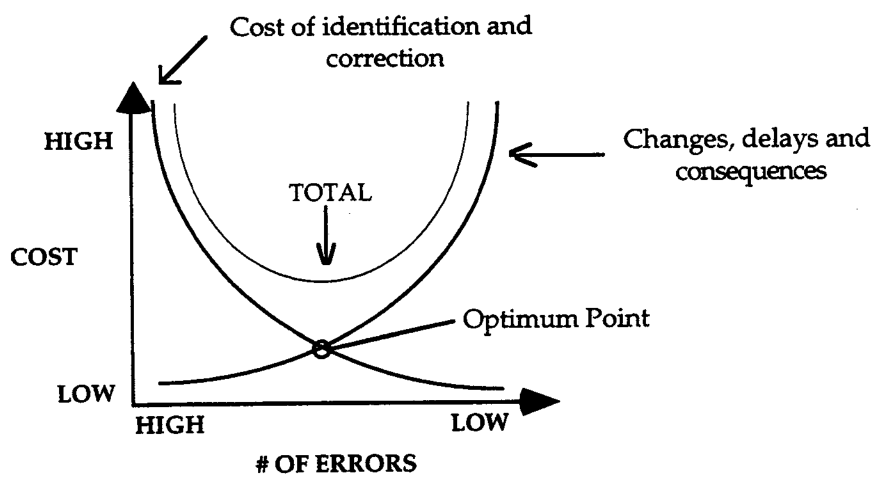


Figure 4.3: Relationship between Cost and Number of Errors for Early and Late Corrections.

Typically, the final reported cost of projects seems to be about 10 percent to 15 percent higher than the bid because of added work and delays caused by change orders. Furthermore, 10 percent of the construction work force reportedly works full time to process change orders, thereby potentially increasing costs for construction engineering. These results suggest that WSDOT has been experiencing problems in this area and that an improved Constructability review process could be beneficial.

4.2. IDENTIFICATION OF OTHER ISSUES

The review of the Project Development Status Reports and the Change Order Review Report, and the many interviews conducted with various WSDOT's offices and consultants, revealed many problems that seem to be occurring during the project development process. Several of the problems not directly involving constructability have subsequently been addressed or are being considered for improvement. The Team has attempted to sort the issues and to focus our study and recommendations on only those elements that most directly affect the Department's constructability performance. To some extent we have also identified and have included some indirect constructability impacts that could be pertinent for the Department. The information the study team collected verified the need for constructability process improvements and further supports the changes to the overall project development procedures that have been adopted and are currently being implemented by the Department.

In this section we describe the critical issues that affect constructability performance and that are considered pertinent to developing an improved process. Below is a discussion of several key categories: project management, formalized internal team building before construction (both internal and external), coordination with bridges and structures, the plans review process, design reviews during PS&E phase, and building the record of decisions and lessons learned.

4.2.1. Need to Consider Constructability in a Statewide Project Management Process

The Department should consider utilizing or revising its existing system for statewide project management to include the constructability process.

During the interviews with WSDOT personnel, subjects consistently commented that the real problem with the process is the initial determination of project schedules. We certainly agree with management that the new Scoping Process should help. Although there is general recognition that schedules are needed, schedules also seem to bear the brunt of all criticism about the lack of time to complete projects in an orderly, reasonable time frame and to check for errors and omissions. Such a schedule-driven environment cannot be expected to operate successfully unless the oversight of projects includes a formal, effective Project Management Process (PMP).

Discussions with several other states, including California, Arizona, Texas, Pennsylvania, and Florida, revealed a consensus that most medium- to large-size transportation departments have also found a need to implement a modern Project Management Process to avoid or mitigate the same types of project schedule problems found here in Washington. These states have found that a formalized Project Management Process has successfully helped to control costs, scopes, and schedules. They have also found a marked improvement in project level accountability, project delivery, and quality control with a PMP. They reported that program credibility improved, higher quality products were delivered on time, and that staff performance was enhanced. Although these other states had not yet (at the time of our contact) implemented an operating constructability procedure, that was reported to be a "next step in improving their processes."

WSDOT does conduct project status and project schedule reviews on a periodic basis. These reviews seem to be conducted independently in each region and appear to be basically "failure review and reporting" rather than true Project Management.

True Project Management, when implemented, includes formal assignment of responsibility, authority, and accountability. It includes full empowerment to make project decisions at the project manager level. The project manager, as used in this scenario, is the lowest level lead person actually directing the day-to-day development of the project. This management issue is an essential part of PMP.

Empowering and holding staff directly responsible and accountable has been shown to be a successful strategy and is consistent with quality improvement programs. The team's WSDOT interviews suggested that the project level staff feel neither empowered nor held accountable for many of their actions. When a project involves consultants, ownership at the staff level and effective liaison and oversight of the consultants' activities is even more necessary. It is very important that those assigned responsibility are able to continuously weigh consequences and alternatives that keep the project on schedule and within budget and scope, and to schedule, monitor, and manage the constructability reviews or checkpoints. These appear to be major WSDOT management considerations.

CPMS is the Department's formal Program Management System. It is the existing hierarchical database system that contains the project schedules used for programming and determining multi-year resources. CPMS appears to have the basic capability to include project activity scheduling and to provide a basis for a project management process. However, it is not currently interfaced with an operating, defined, statewide, project management process (PMP) that we could identify. If management adopts and implements a formal PMP, a more in-depth investigation could be made in-house to better determine whether CPMS would actually need any modifications or changes. However, the Team feels that CPMS is a viable base for early implementation of a PMP, especially because it is a key project-specific source for the Department's multi-year program. We suggest that with all of the other procedural changes being implemented, implementing a modern PMP at the same time would further improve the management of projects and would definitely support the Constructability proposal.

4.2.2. Need to Form a Multi-Disciplinary CRP Team at the Project Scoping Stage

A multi-disciplinary team created at the beginning of a project would support the partnering and team building concept and would directly improve constructability results.

Another issue has been the lack of or inconsistent involvement of an identified multi-disciplinary team assigned to each appropriate project throughout the project development process. There was general consensus during our interviews that more in-house partnering is definitely needed, particularly the early development phases to strengthen, confirm, and get all parties' approval of the concepts and proposed scope. This requires the creation of an internal multi-disciplinary team committed to working together from the inception to the completion of the project PS&E. The creation of a multi-disciplinary team would also allow the disciplines (or functions) to be more knowledgeable about each other's involvement and would provide some of the cross-training and formal communication needed throughout the process. In addition, short cross-training classes could be provided when they were deemed necessary (or maybe on a regular basis, especially for new staff), and an on-site tour could be required for every discipline/function involved on the project. Team Building is not a new concept to the Department, and it has been employed successfully in many areas. Constructability is another area in which success is dependent upon this concept. The following definition was borrowed from the Houston Business Roundtable regarding constructability team building (Houston Business Roundtable 1995):

Team Building

Very few Constructability concepts are single discipline activities. The team environment is essential to ensure that each concept is reviewed for inter-discipline impact before being endorsed for implementation. Constructability is a project team process and that is where the greatest gains are made.

Multi-disciplinary teamwork is needed from the beginning. Other industries have also found that the greatest constructability benefits are derived when a multi-disciplinary team is involved from the scoping phase of project development. The interviewees contended that, in general, "not enough offices have been involved during the scoping period." This has led to the oversight of important considerations, which could have been avoided or at least detected much earlier with consistent internal teamwork.

Interviewees observed that important disciplines such as Maintenance, Environmental, Bridge, or Construction are not always invited or involved as assigned members at the Project Scoping stage. However, the new Scoping process is addressing this problem.

Consistent teamwork is especially needed between Construction and Design. More consistent teamwork appears to also be needed between Bridge Design and Roadway Design (see section 4.2.6, “Bridge and Structures—Need for Timely Delivery”). Most often, Environmental is another critical team member needed at the early stages. Experience has shown that late design changes may often be required late as a result of environmental procedures, issues, and permits that have not been considered early enough. Early involvement and input from Maintenance has also been often missed. Maintenance involvement from the start of the project can ensure greater maintainability (which is one of the key objectives of the Constructability definition). During interviews connected with this study and in other external studies conducted by members of the Team, Maintenance identified several cost-effective opportunities and examples in which maintainability could have been improved if it had been addressed during the design phase. Finally, we also found examples in which early involvement of Right of Way, in many instances, could have helped Design identify missed opportunities and options that may have avoided costly accesses, easements, and/or existing or future real estate issues.

External partnering should also be considered with several of the Resource Agencies. Currently, many of the resource and local agencies have told WSDOT staff that they do not have enough staff to permit consistent partnering with WSDOT. Although this area has been addressed by Department management and some successes have been attained, it is probably a critical area that requires continued attention and oversight. Lack of good teamwork has often meant that WSDOT has received its requirements and permits late, and it has led to major redesigns and subsequent project delays. The Environmental Office in the Northwest Region is focusing on developing partnering agreements with these agencies. It is a crucial effort that continues to need strong management support and attention. Partnering with external resource and local agencies would allow the complex and critical permitting process to proceed more smoothly.

Finally, closer partnering with consultants who are selected by WSDOT to design its projects should also be provided to avoid any major communication problems. Although administrative liaison and coordination appear to exist today, better coordination could be achieved by having the consultants meet with the technical personnel from the multi-disciplinary team responsible for the project during review sessions. These would also help keep the work done by the consultants on track from the beginning to the end of the contract. Although this problem may seem to have only an indirect impact on Constructability, some national studies about managing consultants have cited examples in which expensive and time consuming rework could have been avoided if better communications and oversight had been maintained during the course of the consultant contract. This issue, if uncorrected, can only be further exacerbated if or when the use of private sector designs increases.

Another item found in the Houston Business Roundtable's guide on successful constructability is the need to recognize that team building may have to address barriers. The Roundtable cited the importance of recognizing and overcoming major impediments to successful Constructability team building. Crucial to success is breaking business, cultural, traditional, and internal functional turf barriers. The HBR stated the following (Houston Business Roundtable 1995):

Breaking Barriers

Barriers can be broken by educating team members on the Constructability Process and by Team Building. This will substantially improve communication and reduce adversarial relationships. Making teams, not individuals, the focus for improved performance enhances the ability of the team to execute projects efficiently.

Barriers are reduced significantly if players with several competencies are encouraged as team members rather than specialists.

The need to develop team building skills in young project managers from each project development function should continue to be a priority training activity for the Department. Good team building skills at this level may, in some instances, be almost as important as technical skills.

4.2.3. Need for Closer Communication, Coordination, and Team Building between the Headquarters Structures Service Center and the Regional Design Offices

There is a need for closer communication and partnering between the Headquarters Structures Service Center and the Regional Design Offices to assure better and more timely integration of the structural elements into the project design.

This issue is an important example of the need for internal team building described in section 4.2.2. At the time of our reviews, information did not appear to flow in a timely manner between the Project Design Offices and the Headquarters Structures Service Center. For example, at the 70 percent PS&E review of the SR 18 project (304th to Covington Rd.) conducted by HDR Engineering and attended by the research team, the bridge plans were found to be far from complete. The major problem was that the project construction sequence had been significantly changed as a result of a decision requiring a major redesign of bridge foundations. The "domino effect" had changed earlier design assumptions (made without the benefit of bridge information), resulting in some roadway redesign, incurring more consultant cost and time, and further constraining an already tight timeline. Although this is an isolated example, it is a problem that probably could have been avoided with better and earlier coordination. It is a problem that occurs often enough to warrant instituting an improved partnering procedure. The "domino effect," as mentioned earlier, can and does often lead to Constructability problems. The seriousness of correcting this problem cannot be overstressed. Recently, the final PS&E for a project already scheduled for advertisement was sent to the construction field office for a final review. However, no bridge or retaining wall plans (a major item on the project), special provisions, or structural items were included.

Early in the PS&E phase, the Project Design Office needs, at a minimum, information about the final alignment of a bridge, pier location(s), foundation types, and materials and construction methods to be used in order to proceed with the design of the other roadway elements. Under present procedures, this information still appears to be lacking in many cases.

To keep this team concept in perspective, we also found that the Structures Unit is under pressure to operate efficiently. Structures is understandably reluctant to commit staff to a project until all of the information that it needs is decided and available from the roadway designer. It had found that it frequently must rework a design to accommodate late design changes, resulting in more bridge engineering time than planned. The staff reported to us that they have also experienced difficulties in obtaining all the information that they need, such as geotechnical borehole data, because of difficulties in obtaining drilling permits.

These dichotomies are but a few examples of the need for better and more frequent team contacts. Designer checklists should call for periodic contacts with the Structures design group, and vice versa, to keep each function fully apprised of the status of roadway designs, bridge designs, and any other functional involvement that might impact structures or roadways.

The recommended closer coordination could also possibly be better facilitated by the Project Management Process (PMP) suggested earlier. Formal and timely communication and timely delivery of needed information by each involved function is necessary if costly redesigns and missing data or design elements are to be avoided or minimized. This is also very important if schedules are to be maintained.

4.2.4. Need for Plans Review Coordination with the Final Constructability Review

Before the new process was implemented, most plans reviews were conducted much too late in the process.

The Plans, Specifications and Estimates are the final product in the design effort and, as such, are the key reference documents and information used in preparing the contract documents. They represent the basis of engineering data for the construction phase of the project. Any errors or omissions in them have a negative impact on the biddability, buildability, quality, and cost of the project.

As previously covered in this report, PS&Es are frequently prepared on very tight schedules. As a result, PS&Es have sometimes been incomplete when a project has been initially advertised. Changes may continue to be made during the bid preparation time, and in many cases, changes are incorporated into the contract by means of a contract addendum. Frequently, these addendum changes escape any review, either formal or informal. Resultant errors or omissions are then manifested into change orders, delays, and potential claims.

Until recently, three plan review approaches were used within WSDOT. All took place near the plans completion stage of project design, as follows. 1) On about 25 percent of the projects, In-house Design or Plans Review staff performed a Constructability Review, usually at about the 90 percent stage of PS&E completion. 2) In about 75 percent of the cases, the Constructability Review was scheduled to be conducted by in-house Construction staff when they were available during winter months. 3) In the remaining cases, the Constructability Review was conducted by outside consultants such as CONREX or HDR Engineering.

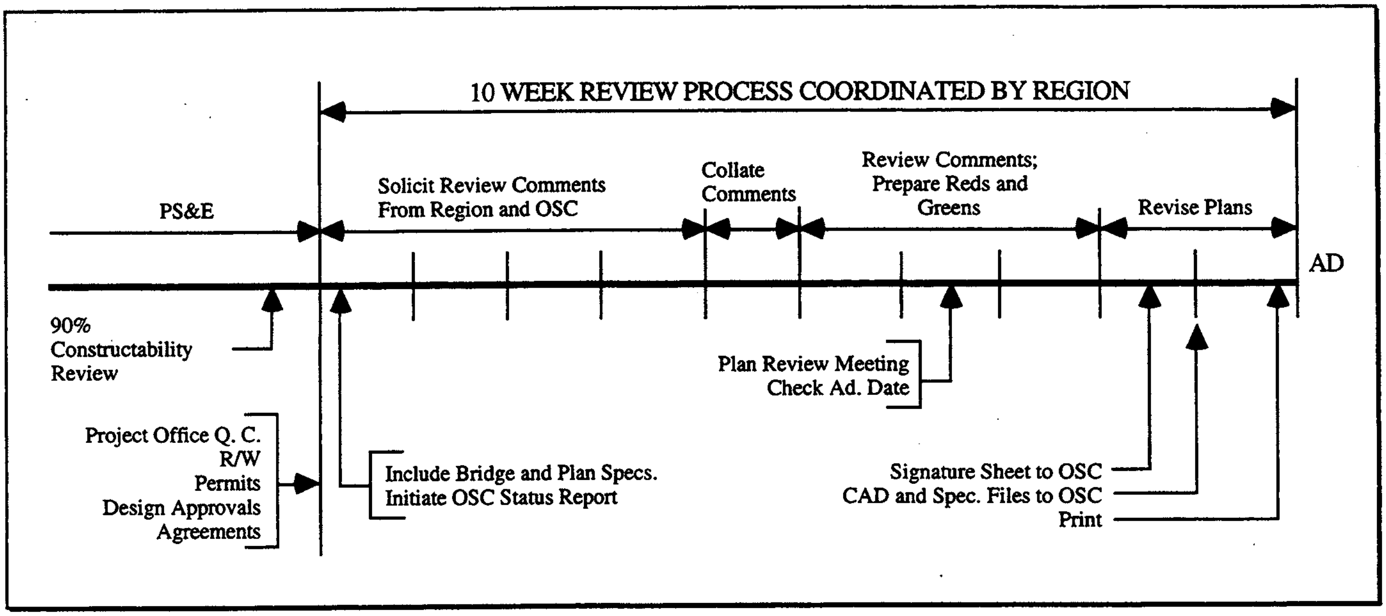
While these have been genuine Constructability Reviews, interviews with WSDOT staff suggested that they were done much too late to avoid or minimize many of the constructability issues. They were also limited to only what could be done at the very last stage of design. With the pressures to advertise almost immediately, significant problems often could only be patch repaired (CONREX Inc. 1993; HDR Engineering Inc. 1994). Many of the problems identified were omissions or inconsistencies in the plans, while others represented potential problems in building the job as specified. Some of the recommendations could not be or were not corrected in the time remaining before the advertisement date.

During the latter stages of this portion of the study, the Department revised the "plans review" process. In our opinion the revised, and now current, procedure will improve the final phase reviews. This process is consistent with our proposal, however, it only addresses the 90 percent constructability review. Figure 4.4 illustrates the new and current process.

The overall impression gained from the interviews with WSDOT staff is that the Constructability Reviews, when done, are useful, but that they would be more useful if they occurred earlier. The Plans Reviews were seen to be of limited value because they overlap to some extent and because their thoroughness is limited by the short time available.

4.2.5. Need for Structured Project Checklists for Use throughout the Project Development Process

Use of systematic and structured checklists during each phase of Project Development would help avoid omissions or errors being discovered too late in the process.



ROLES:

OSC Plans Office:	Distribute review copies to OSC offices; review standards; track final approvals; print; prepare addendum.
Region Plans Office:	Coordinate printing and distribution of review sets; review format and standards; input specs and estimate; prepare addendum for Region AD and Award.
Project Office:	Gather and respond to comments; schedule review meeting when ready; make plan revisions; document comment resolution.

Figure 4.4 WSDOT's Current 10-Week Plans Review Process

Projects are being developed today without a consistent system of checklists to minimize the number of errors, inconsistencies, or omissions. Checklists can never take the place of experience or good engineering, but they are valuable as a means of minimizing oversights, particularly for less experienced staff.

We did find that some checklists were used during the late plans review process. This was clearly an excellent start as far as they went. However, because most of the reviews were occurring so late, little time remained for acting on many of the errors discovered during these reviews. The use of checklists throughout the development process itself should help reduce the number of errors and would avoid the difficulties of last-minute fixes.

Appendix E of this report provides a skeleton for some checklists that could be used. Because such lists should carry over from one stage of design and plans preparation to the next, they should preferably incorporate different levels of detail that can be activated at the appropriate stage. Such a "zoom" or "tree" feature is well suited to computer storage, and we encourage the Department to develop computer-based checklist. Electronic storage and retrieval also offers the benefit of ease of expansion and modification, both of which are essential if the process is to "learn" with accumulated experience. Furthermore, the use of electronic media raises the possibility of integrating the Project Management Process, the Checklists, and the Decision database described in the next section. We urge management to consider these possibilities with any future system changes that may be undertaken.

4.2.6. Need for an Accessible Record of Design Decisions Made as Well as Design and Post-Contract Lessons Learned

Important decisions made and lessons learned during the design process are not adequately recorded, nor is there a link between change order findings and lessons learned. This information should be maintained, at least for major projects.

Decisions are made every day during the design process. The final PS&E in some sense represent the aggregate of those decisions translated into procedures and physical components. However, the reason for each decision is not now recorded, and the findings of post-contract review are often not completely documented. In a large, complex project that involves a number of disciplines, reasons can be lost because the Project Engineer cannot be expected to have an active role in all decisions. As the design is developed under the present system, new decisions may be inconsistent with the reasoning on which previous ones were based. This scenario is particularly likely if there is a turnover in staff and new engineers are brought on-line part way through the project. The problem leads to the potential for inconsistencies in the design and consequent problems.

Records of decisions would provide at least two benefits. First, they would form an (electronic) history of the project in question, so that any member of the design team could access the rationale underlying an earlier step in the design. This would improve the quality of immediate decisions by facilitating the transfer of information among different disciplines of the design team. Records would also simplify the task of mid-stage reviews (say, at the 30 percent and 60 percent stages) by maximizing the amount of study of the project that could be done remotely and minimizing the need for large group meetings, which are notoriously difficult to schedule among busy staff members.

The second benefit would pertain to future projects. A database of lessons learned could be used to guide other projects and to serve as an expert system to help train new staff. The usefulness of such a system would depend very much on its accessibility because it would not be used if access were difficult. Again, electronic storage appears to be the obvious answer. WSDOT staff mentioned a paper file of lessons learned that exists today, but it appears to enjoy little use because it is seldom updated and is then circulated in hard copy form. Paper documents seldom arrive on an engineer's desk at the same time that (s)he has the time to read them.

4.2.7. Other Related Procedural Problems Addressed by WSDOT Process Revisions

In the original draft of this report (Summer 1995), the Study Team had identified several items that they felt needed to be addressed if the Department were to fully benefit from an improved constructability procedure. They also realized that separate study teams had been commissioned by management and were looking into many of these items. However, the full extent of potential change was not fully identified until after the draft had been prepared and distributed. The Design Development Study, Stewardship Agreement, Technical Development Plan, Scoping Study, and the Environmental Organization Study were the major studies completed or under way, and all recommended significant process changes to improve the development of future projects (see also Sections 2 and 4.3).

The Study Team also felt that although some of the changes would have only indirectly affected the constructability process, others could have been significant. Now that the several changes have been or are presently being made, the constructability proposal as visualized can, we feel, be more effectively integrated into the Department's Revised Project Development Process. We have subsequently modified this Section to reflect those changes.

4.2.8. Summary of Problems

In our view, the primary motivations for a CRP are to reduce the number of CCOs, better control the final costs of construction, and consistently deliver quality projects that are biddable, buildable, on time, and within budget. Although WSDOT has made some significant improvements toward meeting schedules and project budgets, addressing the issues described in this section is also very important to ensure success with the CRP:

1) consider constructability in a statewide Project Management Process
2) form a multi-disciplinary CRP team at the project scoping stage
3) create closer communication, coordination, and team building between the Headquarters Structures Service Center and the Regional Design Offices
4) provide plans review coordination with the final constructability review
5) provide structured project checklists for use throughout the project development process
6) provide an accessible record of design decisions made, as well as design and post-contract lessons learned.

4.3. PROCEDURES TO IMPROVE THE PROJECT DEVELOPMENT PROCESS

The goals of the foregoing part of the research project were to identify problems in the project development process that may conflict with or reduce the effectiveness of a CRP and to then offer recommendations to improve or avoid the problems. The intent of the recommendations is to provide programmatic and technical solutions that will improve the constructability results on each project.

During the problem identification phase of this project, we realized that providing a meaningful process to improve the "Constructability of WSDOT Projects" would require more than just developing additional checklists or instituting more procedures. Other procedural changes were probably needed as well. It was during this time, as described in Section 4.2.7, that WSDOT conducted separate in-house studies to review the existing project development procedures.

The authors of the WSDOT Design Development and Documentation Study (DDDS) (WSDOT Dec. 1994) and the Scoping Task Force identified many of the same issues and problems that the research team found initially. A revised procedure to "Scope" projects was designed by a WSDOT Team and approved for implementation by WSDOT management. The facts that each of these studies were conducted independently and each found many of the same problems and issues, and reached similar conclusions added weight to these common findings (and further supports the corrective actions taken). The revised processes proposed for implementation, including the CRP being recommended here, should result in full attainment of the purpose and objectives of this research.

4.3.1. Building a Project Team Early

The most important benefits expected from these modifications are the achievement of an efficient project development process and the realization of a cost-effective, constructable and maintainable project.

Starting the first "Constructability Assessment" just before completion and submission of the Project Identification Report (PIR) should assist WSDOT in realizing some important benefits. Overall, engineering effort should be reduced through a more orderly project development process and less rework, especially in response to late-breaking changes. The political benefits would be realized from an improved ability to maintain the commitments made to the Transportation Commission and the legislature.

The utilization of the Value Engineering (VE) methodology before completion of the PIR, in our opinion, should initiate partnering between several project functions at an early stage and should assist in developing a team approach for the life of the project. Long-term savings to the project as a whole are to be expected by applying these methods early. The combination of VE and early partnering should also provide greater certainty about the basic project concept proposed, produce more consistent PS&Es, and reduce the number of changes, which should recoup many times over any additional funds expended to do a VE study and conduct a CRP at this stage.

4.3.1.1. Early Value Engineering Study

- ISTEA (Intermodal Surface Transportation Act) Section 1091 emphasized the use and application of Value Engineering as a means of reducing costs and achieving consistent quality. VE is also an important element in constructability.

- The purpose of Value Engineering (VE) studies is to ensure that the most cost-effective methods are used to reach the project goals. VE is defined as the "systematic application of recognized techniques by multidisciplinary teams to identify the function of a product or service, to establish a worth for the function, to generate alternatives through the use of creative thinking, and to provide the needed function at the lowest overall life-cycle cost. The VE team also evaluates the alternatives and makes recommendations to the design office" (WSDOT 1988). Therefore, VE can be a very effective tool to use during the alternative analysis phase of the Scoping stage of project development and could be used by the team to actually determine and justify the alternative recommended. This concept will be explored further in the discussion about VE.

- Value Engineering is a valuable tool that, unfortunately, is seldom implemented at the most effective time. The beneficial effects of systematically reviewing alternatives are greatest near the start of a project and diminish with time thereafter (Figure 4.5). The places where the research team feels that VE should be applied in the proposed process for the most effective results are shown on the timeline in Figure 4.6 .

- The purpose of having such a study before the PIR is to investigate the major alternative solutions for the project early in the process, before the concepts are locked in and change becomes disruptive and expensive. This VE study should involve every necessary discipline, such as Construction, Maintenance, Traffic, Structures, Environmental, Hydraulics, and Geotechnical. The Department should also consider including the Public and Regulatory Agencies as appropriate for the problem at hand. It is highly recommended that the Environmental function be included to consider environmental issues early in the development of the concept and that the participants be trained in VE.

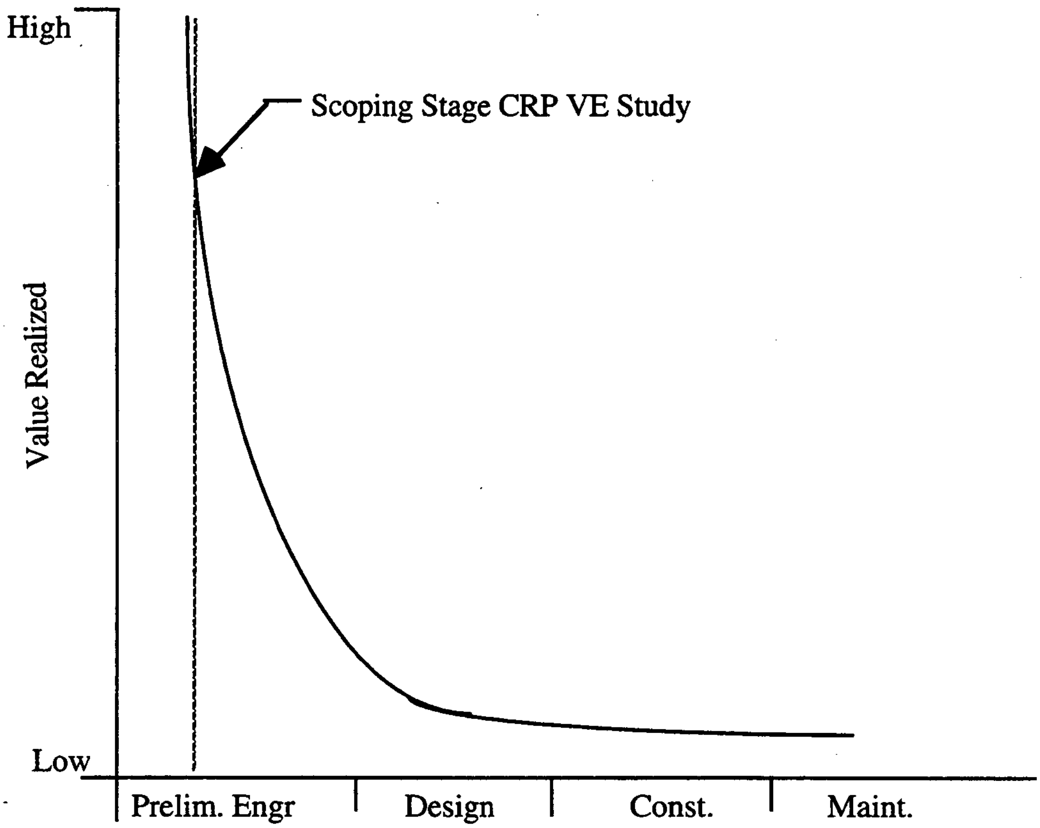
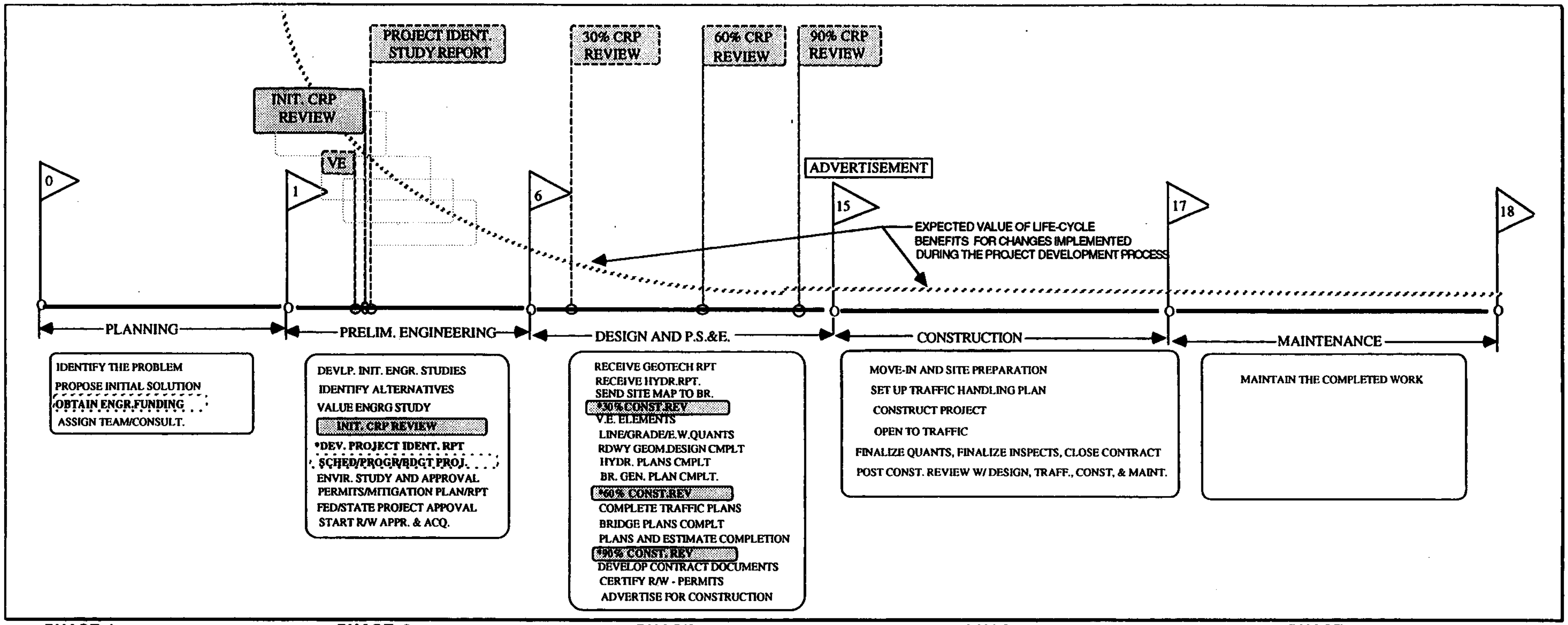


Figure 4.5 Pareto Indication of Expected Value from Early VE Study

- VE done at this stage should also be used as the tool to analyze all proposed alternatives and to evaluate the environmental draft. The objective of the VE study should be to determine the "favored alternative" to recommend in the final PIR and to use in the programming and scheduling plan. This VE study represents an additional opportunity for partnering and customer involvement. VE applied after this point should only be used to evaluate and determine the best solution or proposal for selected elements in the design, i.e., complex designs, high cost structures.

TYPICAL PROJECT DEVELOPMENT MILESTONE PLAN
(MILESTONE NUMBERING IS THE SAME AS CPMS)



PHASE 1:
(CPMS MILESTONE 0)

1. INITIAL PLANNING STUDIES TO DETERMINE IF PROB. WARRANTS A PROJ. STUDY FOR POSSIBLE PROGRAMMING
2. SCHED. FOR STUDY AND CIRCULATE FOR APPROVAL TO STUDY
3. PROJECT ASSIGNED FOR DEVELOPMENT OF PROJ.IDENT.STUDY BY IN-HOUSE OR CONSULTANTS
4. REQUEST TRAFFIC AND ACCIDENT DATA, GEOTECH. STUDY, AND MAPPING

PHASE 2:
(CPMS MILESTONES 1 THROUGH 6)

1. INITIAL ENGR STUDIES TO CONFIRM CONCEPTS AND ALTERNATIVES AND DEVEL. PROJ. IDENT. REPORT.
2. OBTAIN BASE MAP FOR ENGR. STUDY
3. MULTIDISCIPLINE TEAM COMPLETE. DEVELOPMENT OF PROJ. IDENT. STUDY, CONDUCT VALUE ENGINEERING STUDY, AND CONDUCT INIT. CRP REVIEW
4. PREPARE AND SUBMIT PROJECT IDENT. STUDY AND RECOMMENDATIONS INCL. PROJ.SCHED. AND ESTIMATE.
5. PROJ IDENT. CONCEPT PLACED IN MULTI-YEAR PROGRAM AND PRESENTED TO COMMISSION FOR APPROVAL
6. DEVEL. DRAFT ENVIR. DOCUMENT
7. COMPLETE ENVIR. STUDY, HOLD PUB. HEARINGS, AND WRITE FINAL ENVIR. DOCUMENT FOR APPROVAL
7. DEVELOP. ENVIR. MITIGATION PLAN OBTAIN ENVIR. DOC. APPROVAL
8. OBTAIN FED/STATE PROJ. APPROVAL TO PROCEED WITH DEVEL. OF P.S.&E.

PHASE 3:
(CPMS MILESTONES 7 THROUGH 15)

1. DETERMINE R/W NEEDS AND REQUEST R/W
2. COMPLETE INITIAL ENGINEERING DESIGN STUDIES FOR DEVELOP. OF ROADWAY GEOM. AND BRIDGE SITE, AND GENERAL PLANS
3. FURNISH DESIGN INFO. TO TRAFF. AND REQUEST TRAFFIC PLANS FOR P.S. & E. AND FOR TRAFFIC STAGING DURING CONSTRUCTION
4. COMPLETE ROAD AND BRIDGE PS&E
5. APPRAISE, ACQUIRE AND CERTIFY R/W
6. OBTAIN INTERAGENCY PERMITS, DEVEL. UTILITY PLANS AND AGREEMENTS
7. COMPLETE DEVEL. CONTRACT PLANS, SPECS, AND ESTIMATES FOR CONTRACT DOCUMENTS
8. ADVERTISE FOR CONSTRUCTION CONTRACT

PHASE 4:
(CPMS MILESTONE 15 THROUGH 17)

1. CONSTRUCT THE PROJECT

PHASE 5:
(CPMS MILESTONE 17 TO 18)

1. MAINTAIN THE ROADWAY

Figure 4.6 Timeline of the Proposed Process
Constructability Review Project

4.3.2. Establishing the CRP Process

Implementation of constructability reviews at key points during project development should be extremely beneficial. CRP meetings appear necessary when many disciplines, functions, and special expertise are needed and are involved as a part of the project team. This type of review procedure is most important on large and complex projects, or where complex structures are being designed, traffic handling is a major item during construction, complex or difficult drainage features may be encountered, or required design elements are new or seldom used. These are but a few of the types of features that can create constructability and maintainability problems that can be best resolved in a team environment.

A maximum of four CRP meetings is conceptualized. The first review would occur at the completion of the draft Project Identification Report, the second review at the 30 percent point in PS&E completion, the third at the 60 percent point in PS&E completion, and the fourth at 90 percent of PS&E completion. These reviews are shown on the timeline diagram in Figure 4.6.

The purposes of these meetings would be to raise issues, resolve problems, recommend modifications, suggest any actions required with dates of expected accomplishment, and to provide direction and/or any guidance that is endorsed by the team before going further with the PS&E development. Agreements should be reached and firm commitment to schedules and actions should be given by the end of each meeting. Any modified design directions or guidance that is needed to complete the next phase of the project development process should be provided. The issues raised at one CRP meeting would be resolved before the next meeting were held. If not, a mutual decision should be made by the involved project and functional management on expediting resolution of any outstanding problems that affect PS&E progress and rescheduling the CRP review, if necessary.

Constructability Review Process checklists have been developed for various functions and review types (PIR, 30 percent, 60 percent or 90 percent) and are shown in Appendix E. The CRP checklists include the items considered most pertinent and would be the basis for the CRP reviews and meeting. If any checklist item identified problems whose resolution required direct input from other functions (i.e., Structures, Traffic, Hydraulics, Construction), then those functions would need to attend, and their items would have to be specifically addressed at the CRP meeting by the responsible discipline(s). The primary objective of the CRP meetings is to make sure that the items described in the checklists have been completed to ensure that design concepts and considerations are complete to that stage and that further design can proceed with development toward PS&E completion.

Each meeting should fulfill a specific objective, and for every review, specific documents should be ready and specific functions be involved. Tables 4.1a-d present the main features and objectives of the PIR, 30 percent, 60 percent, and 90 percent CRP meetings, i.e., Programmatic review, Geometric review, and others.

The Project Identification Report (PIR) CRP meeting should be primarily a programmatic review. The review at this stage would ensure that the engineering study had been adequate, including a VE analysis, and that the information generated and available in the PIR was adequate and sufficient to schedule and program the project (see Table 4.1a). A further objective would be to end up with a viable and constructable project for the State Multi-Year Program that fulfills and meets the transportation need and can be programmed.

The 30 percent CRP meeting would be mainly concerned with a constructability assessment following development of the project's primary geometric features (see Table 4.1b). Geometric details would be checked, and guidelines/directions would be given to Right of Way, Structures, Traffic, Hydraulics, and others so that they could perform their studies and provide the required/ultimate design details for the PS&E.

The 60 percent CRP meeting would probably be at the most critical stage of design and PS&E development. The focus would be on several design features and details and would address all items that were or would be critical to the completion of a constructable and maintainable project. Reviews should be made and discussions held on such items as the bridge general plans; costs and structural requirements, including any special foundation considerations or materials involved; a review of all traffic requirements for the project, including the initial plan for handling traffic during construction, and the details of hydraulics requirements, along with any special drainage structures and/or special designs (see Table 4.1c). This stage CRP would also be critical in ensuring that the design team, including all involved functions, had the necessary guidance and direction to proceed into the final detailed design stage and that any major changes, revisions, or other special considerations had been identified, and assignment for resolution had been made and scheduled.

The 90 percent CRP review (replacing the Regional Plans Review) would be the review of the contract plans and the special provisions as the project design stage was being completed and advertisement for construction was being readied (see Table 4.1d). It is anticipated and assumed that all major decisions would have been met and that the proposed PS&E for a project meeting the programmed item in the Department's Multi-Year Program had been completed. Only minor details, omissions, or design problems not previously addressed should materialize or be identified at this stage CRP review. If successful, then no further check would be needed after this review. If no other changes or revisions were needed, the final plans, proposed specifications, and final estimate could be shipped to Olympia for the Headquarters review, completion of contract plans and documents, and advertising of the project for construction.

Although the entire CRP includes four steps, all four reviews should only apply, for the most part, to major or very complex projects. For smaller and/or less complex projects, we recommend a modified CRP process with fewer reviews. Section 4.3.3.1 "Guidelines for Selecting Projects for CRP," provides the initial criteria recommended for selecting the number of CRP meetings appropriate for a particular type, size, and complexity of project. Approximately 30 to 40 percent of all projects, whose combined value is over 80 percent of the annual program dollars, are expected to require the four CRP meetings. Further study during Phase II may reduce or modify this assumption.

Table 4.1(a) The Project Identification Report CRP Meeting

Objective	Offices involved	Documents
Scoping Phase Review (Programmatic)	• Management • Design • Construction • Environmental • Maintenance • Traffic • Right of Way • Regulatory Agencies • Local (counties, cities) and public (citizens groups) agencies. • Structures and Bridges	• Early VE study • Planning document (i.e., 20 year Plan) • Draft PIR with estimate of costs, items used, documentation of the concept used and any issues regarding potential complexities or major engineering complications. • Preliminary draft environmental information • Mapping used in study • Preliminary studies (structures, geotech, hydraulic) • Modifications from the standard specifications discussed • PIR and other studies or information avail-able for adjacent projects.

Table 4.1(b) The 30 percent CRP Meeting

Objective	Offices involved	Documents
Geometric Review	• Management • Design • Construction • Environmental • Environmental Agencies • Maintenance • Traffic • Geotech • Hydraulics/Drainage • Right of Way • Structures and Bridges	• Project Identification Report (PIR) • Environmental Summary • Description of all permits needed • Design level Mapping • Federal/State project approval • Start R/W appraisal and acquisition • Received Geotech report • Firm line/grade/geometric layout (including interchanges and intersections) • Prelim. earthwork and grading completed • Received Traffic Prelim. Design Recom. • Received Hydraulics report • Sent Site Data to Bridge • Sent Site Map to Bridge • Value Engineering study for any complex items for Structures or Hydraulics • Bridge Preliminary Report/Plan (schematic). • List of any modifications since the preceding CRP meeting (at the PIR stage)

Table 4.1(c) The 60 percent CRP Meeting

Objective	Offices involved	Documents
General Plans Review	• Management • Design • Construction • Maintenance • Environmental • Permits • Traffic • Structures/Bridge (if involved) • Geotech • Hydraulics/Drainage • Right of Way	• Geotech and Soils Reports • Bridge General Plan with schedules, costs, concepts, and preliminary quantities for all bridges. • Draft Traffic Control Plan/Recommendation • Hydraulics Report/Plan including drainage layout and preliminary quantities • Environmental re-evaluation (every 12 months) • Approved Right of Way Plan with any recommended mitigation or design and construction commitments. • Completed earthwork and grading plan • A list of recommendations and commitments for permits requirements including schedules and commitments provided by the permitting agencies. • Alternatives recommended to meet the approved schedule, scope and budget. • List of any design modifications or variations from the agreements reached at the 30% CRP meeting, or other recommendations

Table 4.1(d) The 90 percent CRP Meeting

Objective	Offices involved	Documents
Contract Plans Review	• Management • Maintenance • Right of Way • Design • Construction • Permits • Traffic • Structures/Bridge (if involved) • Environmental, Hydraulics and Geotech if necessary)	• Traffic Plans complete • Bridge Plans complete • Plans and Estimates completion • List of any design modifications or variations from the agreements reached at the 60% CRP meeting

4.3.3. Tentative Guidelines for Conducting CRP Reviews

This section presents an initial set of guidelines for conducting constructability reviews. These guidelines are the result of Phase I of the project; however, through further study during Phase II of this research effort, firmer directions and modifications may be developed.

4.3.3.1. Guidelines for Selecting Projects for CRP

Although CRP reviews are believed to be effective over a broad range of project types and have the benefit of allowing multiple functions to view the overall project as it develops, the effort and cost of conducting reviews and documenting their results are significant. Therefore, the decision about the number of reviews is a tradeoff between the expected benefits and the expected cost of these reviews. Because of the variability in size, complexity, and timelines in the program, selection should be keyed to modifying the number of CRP steps and reviews for each project.

Table 4.2 shows the different types of projects and their corresponding CRP levels.

Table 4.2. Recommended CRP Review Level by Project Type

CRP LEVEL	TYPE OF PROJECT
LEVEL 1 Full CRP processing including all four listed reviews	• Major roadway/facility improvements • Major, complex interchanges • Major structures with complex or very high cost features • Major preservation projects that include widening, replacement of existing structures/drainage features, etc.
LEVEL 2 CRP reviews at PIR, 30% and 90%	• All other roadway/facility improvements • Major, less complex, structures and interchanges • Preservation projects that involve widening, structure rehabilitation, new R/W, or safety improvements, including roadside features
LEVEL 3 CRP reviews at PIR and 90%	All others

4.3.3.2. Organizing the Project Review Team

Selecting the Project Review Team would probably be just as critical as conducting the CRP Reviews. This would be a major internal partnering opportunity and crucial to the success and accomplishment of the objectives of the CRP.

The CRP Review Team should be made up of a mix of reviewers and managers most familiar with the project and others who bring to the task objectivity and independence. The team should have the authority to make on-site decisions regarding issues that arise during the review. Each team member should be able to commit, if necessary, a full day for the review. However, for the PIR review, one whole day might not be necessary. Multiple projects might be reviewed in the same day to maximize the efficiency of assembling the group. The Project Engineer for the project would be the Team Leader and would be responsible for coordinating the schedule and location for the review with the Team. The Team should include, at the minimum, Design, Construction, Maintenance, Environmental, Traffic, Right of Way, and Bridge (whenever bridges or structures are included in the project). When needed, the Team should include also a Geotechnical, Hydraulics, and Permits representative, and any other function pertinent to the complete review of issues that need to be addressed to complete the PS&E. If the particular stage of the project were being done by a consultant, the consultant team should also be involved.

4.3.3.3. Conducting CRP Reviews and Documentation

The CRP meetings should follow the structured format described below:

- The Project Designer establishes the actual review point in the development phase and the calendar date and location where that point will occur. If the project was being designed by a consultant, the Project Designer should coordinate and mutually agree on the date for the CRP Review.
- The Project Designer develops the approximate agenda and times for each segment of the review so that the review can be accomplished in one day.
- The Project Designer should schedule the major functions involved for the entire day (Design, Construction, Maintenance, and Traffic) and time the agenda to add or involve other members (Environmental, Hydraulics, Permits, R/W, Geotechnical, outside agencies, i.e., Feds/locals/DOE) as needed to cover every phase or element. Bridge should be viewed as an important member of the Team, and where significant structures are involved on a project should be scheduled appropriately. If some of the work had been done under contract by private vendors outside WSDOT (Geotechnical, Bridge, Hydraulics) then representatives from those firms should be available at or during the Review.
- The Project Designer should provide or have the consultant provide or have available all documentation related to the project that might be needed for reference during the Review by the Review Team.

- Prior to the review, the Project Designer has to ensure that all disciplines involved had checked the applicable documents and plans and have completed the applicable review forms (checklists).

- During the CRP meetings, interactions should be primarily inter- rather than intra-disciplinary, to make the best use of time. It is assumed that issues within a discipline will have been largely resolved before the meeting, so that the time can be used to explore problems that will only become visible when different disciplines discuss the design.

- The Project Engineer should conduct the review in accordance with the agenda, allowing adequate time for questions, explanations, and discussions regarding any pertinent item or issue that could impact schedules, costs, scope, biddability, and buildability. It is critical that the meeting be controlled for timing, completeness, and resolution of any issue raised or problem identified. It is important to periodically remind all attendees that the goal is to complete the review in one day. At the conclusion of the meeting and if possible, an approximate date for the next CRP Review should be discussed and agreed to by the Team.

- The Review should be recorded either by a designated note keeper or by tape recorder. At a minimum, all decisions and agreements and all directions and scheduling must be documented. It is beneficial if every issue and corresponding action is written on a display board so that decisions are unambiguous. Individuals should be made clearly responsible for addressing any unresolved issues.

- A brief report should be developed by a designated person, outlining the results of the meeting (issues raised, decisions or solutions) and documenting the directions discussed and agreed to for the next phase of project development.

- If any unresolved issues remain at the conclusion of the review and an impasse has obviously occurred, the Appeal and Resolution process described in section 4.3.3.4, "Follow-up, Reporting, Appeals," should be implemented immediately.

- In addition, a WSDOT regional staff member at the Project Development Management level should be permanently assigned as responsible for the constructability issues. That individual will assure that the CRP meetings are conducted; that the CRP checklists are kept applicable, up-to-date and complete; and that recommendations are implemented. Any positive or negative feedback from these CRP meetings will come to this person so that monitoring can be conducted and future improvements can be made. A designated statewide CRP manager will also be assigned as the statewide monitor, coordinator, and focal point for process updating and improvements. This person will also be responsible for expediting any appeals or issue resolutions elevated beyond the regional level.

Currently WSDOT does conduct constructability reviews on some projects. However, these reviews are often done at a late stage in the process (at 90+ percent PS&E on the contract documents). In our review of some of the CRP reports, we noticed that many of the review comments involved the format, specificity, conciseness, inconsistencies, incompleteness, and clarity of the documents (55 percent of the comments in the CONREX review [ref. 2]), and clarity between the Special Provisions and the Plans. These problems were found in most areas such as construction sequencing, traffic management, order of work, geotechnical work (excavation, embankments, ground water problems), design details, illumination, and others. Systematic review checklists might potentially help in reducing these problems.

We have developed a set of checklists that include items from various domains, including drainage, traffic, roadway surface, landscaping, environmental mitigation, hearings, permits, geotechnical/earthwork, structures, utilities, right-of-way and access control, construction, maintenance, and contract documents. These checklists are hierarchical and add elements and details at successive phases. They could be integrated into or with the existing checklist that has been developed by the Plans Review Unit for the 90 percent point. Where some items might be repeated in the PIR, 30 percent, 60 percent, and 90 percent CRP checklists, we envision that different levels of detail would be checked for some items at the later stages of the design development. The difference between the four CRP checklists would be the information and documentation that had to be available at each review stage. The percentage of contingencies that accounts for the unpredictable or unknown would also be variable by stage; it would diminish as more work was done and known. The 90 percent PS&E review should in addition verify completeness, accuracy, clarity, and conformance to policy. A separate checklist might be used for these checks concurrently with the first 90 percent CRP checklist as the last review of the contract documents. (The PIR, 30 percent, 60 percent, and the two 90 percent checklists are shown in Appendix E.)

In addition, we envision that these checklists would be implemented in a computerized process that would become the database for these reviews and would incorporate additional project information (see section 4.4, "Computer Aids for Assisting in Constructability Reviews").

4.3.3.4. Follow-up, Reporting, Appeals

Follow-up and reporting would consist of recording the decisions taken during the CRP meetings in order to track and monitor schedules, progress, and documents produced between meetings. A structured system to store these elements in an efficient and readily accessible way is needed. The implementation of a computerized database would make it simpler to review the history of projects and CRP meetings. It would also provide a single source of information or references in which information could be located about design decisions for every element and function involved in the project. In addition, these files could be accessed to produce reports about lessons learned. Section 4.4 describes computer aids that could be used for assisting in the follow-up and reporting process (see section 4.4, "Computer Aids for Assisting in Constructability Reviews").

Assuming that some items or issues might remain unresolved at the conclusion of a review meeting, an appeal describing them would be prepared by the Team Leader and submitted to the Region Arbitration Committee comprising the Assistant Administrators for Project Development, Construction, Traffic and Maintenance, and, if a bridge issue were involved, an appropriate level of Bridge Management, for a decision. A Headquarters appeal process would be available in the very rare event that the issue were statewide or could not be finalized by the regions. If resolution still could not be attained, the issue should be submitted by FAX to the State Design Engineer, who would promptly process the resolution.

4.3.4. Pilot Evaluation of the CRP

To start evaluating the effectiveness of constructability reviews, a 70 percent CRP meeting was tested on January 10, 1995, to review the 70 percent PS&E documents for a project on SR 18—SE 312th St. to 304th St.—whose advertising date was scheduled for June 26, 1995. The project was beyond the 60 percent completion point; however, it did provide all of the elements for review of a major project and further verified the issues and problems that WSDOT is facing during development of PS&Es.

The objective of this meeting was to find out in a one-day session the problems and inconsistencies that existed in the plans at this stage and to possibly reach a consensus among offices when they needed to be solved. Attending the meeting were various WSDOT functional offices and CH2MHill, which developed major portions of the design under WSDOT direction. The team included Maintenance, Project Staging, Traffic Control, Geotechnical, Structures, Drainage/Hydraulics, Environmental, Right of Way, Landscape, and Utilities. Only the major disciplines such as Maintenance, Design, and Construction were present throughout the day; others appeared at specific times when their particular function was scheduled for review and discussion. Many issues were brought up, including the following:

- traffic control (traffic speed, advisory speed, noise variance permit)
- geotechnical aspects and earthwork (detention ponds, stockpiling sites, excavation and embankment quantities)
- structures (walls and bridges; foundation type, settlement, girder depth)
- drainage and hydraulics (erosion control, access roads, detention pond outfall, sewage systems, energy dissipater, modes of payment)
- environmental aspects (water pollution control)
- permits (temporary water quality modification permit, hydraulic project approval permit)
- landscape (seeding mix, access roads)
- utilities (wells and septics).

For a first attempt, the meeting was successful. The number of personnel present for each office was adequate, and the meeting and schedule worked well. However, some changes should be considered. The plans and other review documents needed to be examined thoroughly by each function before the meeting. Checklists would probably help assure that the reviewers have read and checked the plans. These checklists would also make sure that every office was at the same stage (i.e., 70 percent for this review). Some reviewers had prepared several issues involving the project that they presented to discuss and resolve during the meeting. These discussions are an excellent way to reach resolution at these meetings.

The usage of time needs to be optimized. Items that do not involve different disciplines should be discussed before or after the meeting, and only items that need consulting or approval of different offices should be presented. During this test meeting, one office of WSDOT and the consultants started a long discussion about a specific difference of opinion. The other disciplines present were not involved at all in this discussion, and several could not understand the discussion. While it was apparent that this difference needed to be resolved, it was an example of the issues that should be avoided in order to use the allocated time most effectively.

The meeting was recorded with a tape recorder supplemented with personal notes. However, all issues discussed should also be written on an appropriate display board, including subsequent action steps. This would reduce the chance of people missing issues that were brought up and would also allow everyone to follow the discussion as issues were presented.

An added success factor noted at the meeting was partnering between functions and between the Department and the consultants. The primary product of the meeting was the identification of major issues and an action plan to solve the problems. In addition, all involved persons reiterated their commitment to keeping the project on schedule.

4.4. COMPUTER AIDS FOR FUTURE CONSIDERATION AND DEVELOPMENT TO ASSIST IN PERFORMING CONSTRUCTABILITY REVIEWS

As described in earlier sections, there are acknowledged needs for more communication and cooperation among the multidisciplinary project team members (both within WSDOT and with consultants and Regulatory Agencies) and for earlier feedback on design decisions and proposals in order to improve constructability in the schedule-driven climate.

In this section we describe several computer tools that appear to have significant potential for improving the constructability review process. This discussion, like the need for program management and improvements to the project development process, is being provided here as possible changes that WSDOT management could make after implementing the approved process improvements, including the CRP process. The set of computer tools discussed here may be divided roughly into two categories. The first category is related to the communication and sharing of ideas, reviews, comments, design justifications and rationales, and lessons learned among the members of a project development team in a timely manner during the design process. These tools are, by necessity, network-based and have become technologically feasible because of the recent fusion of computing and communications and the emergence of standard protocols for encoding hypermedia documents (Hyper Text Markup Language (HTML)) and distributing them conveniently on the World-Wide Web.

The second category of tools involves three-dimensional visualization programs that allow the interactive display of a planned facility, and more importantly, the animation of the sequence of construction operations required. Designers, planners, right-of-way personnel, construction engineers, maintenance personnel, regulatory agencies, and prospective contractors can take “animated tours” of computer models and experiment quickly with various alternatives. Such tools may allow more substantive input from various parties at earlier stages in the development process, particularly regarding the sequence of construction operations and the constraints on various construction activities. Although three-dimensional visualization technology has been around for a number of years in university laboratories, the dramatic reduction in the cost of building such 3-D models (both for the graphics software needed to build the models and for the hardware required to run them) makes these tools effective candidates for improving constructability reviews.

Note that technology alone does not solve problems. Even the use of the most sophisticated computer tools cannot be a substitute for a structured framework for overall project management, plans development, and a viability test procedure as that offered by the CRP. However, when properly implemented, computer programs can provide significant assistance in the communication and early review of project plans and specifications and a means to store and retrieve important data whenever needed.

4.4.1. Network Based Tools for Sharing and Storing Project Design Information

Modern computer-based communication and information dissemination has significant potential to achieve the desired levels of closer collaboration among project members at all stages of project development. Computer-based communication is fast, less intrusive than the telephone, more flexible than paper-based communications, and easily retrievable for later use, and it incurs virtually no cost for distributing information to a wide range of people. Today, networks permit close and continuous cooperation among team members who may not be in physical proximity, and better coordination among various offices in a region and between Headquarters and the regions. They also allow documents to be updated in one location, then become immediately accessible to the whole organization. WSDOT has and is utilizing, quite extensively, the capability afforded by e-mail networks.

Numerous studies have shown (Sproull and Kiesler, 1991) that electronic communications significantly change the structure of organizations and the patterns of information sharing among project personnel. Even the simplest text-only electronic mail, of the kind WSDOT already deploys in many offices, can make offices become more flexible and less hierarchical. Much of the information that consists of personal experience and never appears in official manuals (war stories, individual local expertise) becomes available to many people independent of physical proximity and social constraints. The "Does anybody know...?" kind of question that appears so frequently on many electronic forums reach many more people and, because the cost of responding is extremely low in time and effort, is likely to be answered more quickly (even if the answer consists of pointing somebody in the right direction). Moreover, the set of answers can be redistributed and placed in a public file on the network. Archiving these answers from many offices incurs very little overhead and generates an invaluable repository of personal experience and technical knowledge that is always accessible, even when personnel are unavailable, change offices, or leave the organization.

For project development and constructability review purposes, text-only e-mail and file sharing are insufficient to cover all the complexities and subtleties of technical design and construction operations. Diagrams, maps, tables, engineering drawings, and video clips of relevant portions of a site are often necessary to convey sufficient background information about a given topic. Moreover, all participants in the design often need access to these common documents. The World Wide Web opens such possibilities. Anybody with a personal computer or work station and the proper access privileges may be able to browse, search, and comment on a particular aspect of a design after reviewing the relevant graphical and textual information associated with it.

WSDOT already has experience with providing information on the Web. Traffic information, including delays, congestion, and rerouting, is being made available in almost real time to the public. There is no technical reason that project design information cannot be made available to WSDOT engineers, planners, managers, and possibly regulatory agencies. The Web also allows two-way communication so that users not only can view information but can also comment on it, fill out forms about it, add links to it, and send it back to become visible by all users with the proper access privileges. We have identified three classes of documents that are good candidates for network-sharing: on-line documentation tools, project-specific design information, and lessons-learned documents.

4.4.1.1. On-Line Documentation Tools

WSDOT has developed a large set of comprehensive documents, including design manuals, standard specifications, accepted design details, training aids, and others, that are available to design teams. Unfortunately, it takes years, particularly for entry-level engineers, to become familiar with and to use effectively the wealth of information available. However, many delays, redesigns, and constructability problems can be attributed to less-than-optimal use of these documents. In addition, because of the cost of updating and redistributing these documents to all offices, some useful (but possibly ephemeral information) is often left out. For example, special "problems" or "concerns" associated with a design detail may be omitted. Information about people to contact to obtain additional information or procedures to follow may also be omitted because of the dynamic nature of the WSDOT project development process and the variability of this information.

On-line hypertext versions of these documents, with embedded graphics and hyperlinks to appropriate databases, could provide an effective alternative. These Web documents might even have richer content than their paper counterparts because of the possibilities of incorporating color, interactive 3-D details, and more convenient user-interface mechanisms (e.g., clickable maps). They could also be readily searched, could be easily customized with region-specific notes and data, and would only need to be updated in one location. Statistics describing the documents, standard plans, and others that are accessed most frequently could be generated and used to focus resources on improving these topics.

The availability of this information might allow designers to take on more responsibilities. Consider, for example, an entry-level engineer with the task of designing a retaining wall, and suppose that a drainage question were raised. A quick search on the Web for "drainage and retaining wall" could generate the sections in various manuals where this topic is covered, as well as standard geometry, special recommendations, and possibly examples from previous projects, without the designer having to leave her/his desk. Or consider a designer designing a bridge pier foundation and worried about scour. An on-line retrieval of the appropriate documents might reveal that a piece of data was missing and needed (say maximum local pier scour in the 100-year flood) to move ahead. The Web document would be linked to the person or office that might be able to provide this information, and a quick e-mail note to that contact could be sent immediately. Linked electronic documents would allow engineers to quickly identify the necessary information needed and to ask for it from the appropriate offices without the overhead of paper memos, telephone tags, and unnecessary delays. By allowing faster access to relevant information, a shorter turn-around time for design could be realized, and more time would become available for design reviews and critique.

Putting this information in HTML form on the Web all at once would be prohibitive. However, at a cost of one to two hours per page, a set of key documents (especially the ones outlining development steps and complex design details) might be a good nucleus for beginning the process. Moreover, experience suggests that once a base set of documents is in place and users start seeing its benefits, they will have incentives to keep the database as up-to-date as possible.

4.4.1.2. Project-Specific Design Information

Another set of documents that could also be beneficial if shared on the network involves project-specific design information. We envision a database that would act as a central repository not only of design information but also of design intent, history of modifications, and various design constraints. Such a database would be initiated in the early stages of a project and would be expanded regularly to finer levels as the design progressed. The dynamic and fast changing nature of a design project makes electronic media ideal for storing the evolving design documentation about a project and for providing all participants in the design process access to information.

This database of project information would contain text, maps, drawings, and possibly relevant photographs about the site of a proposed facility. Users from various functional disciplines could query the database and examine its contents, review the schedule, and check progress on a specific item at any point during the project. A well designed set of Web documents would allow users to view the project in its entirety and to zoom in on various functions (traffic, structures, geotechnical information) as desired. Associated with each aspect of the design would be comment forms that users could fill out and e-mail to either a specific person or function responsible for a design decision or to a wider audience.

We envision that accompanying this on-line set of documents would be a set of "smart forms," essentially active checklists that designers or reviewers could fill out, annotate, and distribute on the Web. These forms would consist of answers to a set of questions about possible omissions and conflicts. Appendix E shows the kind of information that these forms would contain. Naturally, these items would be listed hierarchically: in brief form at the early phases of PS&E and in more detail as additional design details were finalized. Again, the result of these item-by-item checks would be Web documents that other functional disciplines could browse and comment on as needed.

The fast turn-around time for these communications and the ability to trace a design decision or a review comment to a specific person would facilitate design modifications and would identify various functions that might be affected by a design change.

Phase II of this project will develop a prototype set of Web documents for one of the SR 18 projects and an initial set of forms that could be used at various stages to check consistency and completeness of evolving designs.

4.4.1.3. Lessons-Learned Documents

The last set of documents that seems beneficial is a record of all the lessons learned. These lessons could be recorded in a central database that would be updated regularly as projects developed. The 90 percent PS&E CRP would also provide an opportunity for reviewing and completing the lessons learned during design. A post-construction evaluation would provide similar opportunity for lessons learned during construction. This database could contain text, plans, maps, and any other relevant documentation of the case and would be indexed by function, location, level of detail, or other element. Having these lessons shared on the network would allow users from various disciplines to refer to them at any time. Users would query the database by using key words or specific cases. Information concerning design, permits regulation, right of way, environmental, construction, and other experiences would form a "historic" database that would contain significant WSDOT lessons learned. Environmental mitigation experiences are particularly good candidates because they change quickly. These lessons might be particularly beneficial for new engineers and could then help them avoid previous mistakes or repeat good examples. This database would help participants know which functions were having the most problems so that actions could be taken to improve their status.

4.4.2. Three-Dimensional Visualization Tools

Three-dimensional computer graphics CAD tools are another category of tools with the potential to improve constructability reviews and evaluations. These CAD tools are a natural extension of the drafting-oriented tools (e.g., CEAL) currently used to automate production of drawings. Although drafting tools are useful in the generation of contract plans, they only enter into the development process late in the game. Three-dimensional graphical computer tools, combined with systems that can represent and display construction activities, might be able to enhance the effectiveness of constructability reviews at a very low cost and earlier in the development process. The ability to "walk through" a model of a planned facility interactively, and to animate the staging sequence, would provide opportunities for detecting potential constructability problems. This would give a review team an opportunity to ensure that every step in the construction sequence was executable with the available equipment and crew. Spatial conflicts, potential instabilities, excavation requirements, and sequencing constraints are examples of potential constructability problems that might be uncovered by three-dimensional design and planning tools.

Highly interactive, three-dimensional tools would allow for visualization of design alternatives during the preliminary engineering stages. They might be especially useful on projects in which facility geometry was involved, such as those involving bridges or complex interchanges. Given the limited amount of time available for constructability reviews, it would be advantageous to provide the review team with three-dimensional computer models that offered convenient mechanisms for interpreting design plans and reducing the time spent visualizing and interpreting two-dimensional drawings. Moreover, because three-dimensional models are unambiguous representations of the facilities they portray, they have the ability to reveal potential inconsistency or ambiguity problems in two-dimensional drawings.

In addition, three-dimensional computer models offer the exciting possibility of incorporating a project's "time dimension" in explicit detail for constructability reviews. The animation of staging and construction sequence would allow planners, designers, construction personnel, and other reviewers to step through construction phases, evaluating potential difficulties early on. Finally, if three-dimensional computer models were linked to project management programs, construction activities and schedules might be generated and tracked more accurately. Such information might prove useful for contractors as well as designers. Phase II will demonstrate the effectiveness of these three-dimensional computer models in the review of selected SR 18 projects.

5. CONCLUSIONS AND RECOMMENDATIONS

Phase I of this research sought to (1) identify critical issues that appear to affect constructability of WSDOT facilities, and (2) propose elements of a continuous review process to improve constructability. It is hoped that this effort will help keep projects within their planned schedules, scopes, and budgets. This chapter summarizes critical issues revealed in the course of the literature search and in interviews with WSDOT staff and the consultants. Recommendations are proposed to solve the current problems; these recommendations are based on the approach of re-engineering the existing project development process.

5.1. SUMMARY OF FINDINGS

Although WSDOT has made some significant improvements toward meeting schedules and project budgets, critical issues identified in the course of the research can be summarized as the following needs:

1) to consider constructability in a statewide Project Management Process
2) to form a multi-disciplinary CRP team at the project scoping stage
3) for closer communication, coordination, and team building between the Headquarters Structures Service Center and the Regional Design Offices
4) for plans review coordination with the final constructability review
5) for structured project checklists for use throughout the project development process
6) for an accessible record of design decisions made as well as design and post-contract lessons learned.

5.2. RECOMMENDATIONS

The following recommendations represent a re-engineering of the project development process. A new review feature in the project development process is proposed. The main aspects of this new process are summarized as follows:

- At the draft PIR stage, a project-level Value Engineering study should be considered to evaluate every possible alternative for the project and to confirm the preferred scope, schedule, and budget for programming purposes.
- A set of up to four constructability reviews should be implemented, and the number should depend on the project's size and complexity. In the case of relatively straightforward projects, a comprehensive study may be possible at one meeting. Each constructability review has a specific goal. The first is a Programmatic Review (at the PIR stage), the second is a Geometric Review (at the 30 percent PS&E stage), the third is a General Plans Review (at the 60 percent PS&E stage), and the fourth is a Contract Plans Review (at the 90 percent PS&E stage). The general purpose of these constructability reviews is to continuously assure that the scope, schedule, and budget are being maintained and that programmatic and technical constructability issues are identified and resolved before they become problems.
- A system of checklists and a compendium of lessons learned should be developed for use throughout the project. These checklists must be hierarchical so that all of the items within them can be checked at the appropriate level of review. They could be computer-based for potentially better effectiveness, ease of access, and sharing among multiple functions. Electronic media also offer the opportunity for the easy updating and data expansion that are well suited to modern management practices.

Effective implementation of these recommendations could be further enhanced with implementation of a comprehensive Project Management Process (PMP) for the continuous monitoring of project progress and status. This process should also allow the various involved functions to track their responsibilities on each project. WSDOT could consider assigning a person in each Region and at the State level to ensure that the PMP was tracking, scheduling and monitoring each of the constructability (CRP) reviews.

Phase II of this research will test, further develop, and provide an Implementation and Training Plan for the proposed process. Computer tools necessary for a more effective implementation should also be considered as a future CRP and project development enhancement.

REFERENCES

Associated General Contractors (1991); "Partnering".

Conrex Inc. (December 1993), "Constructability Review of Design and Bid Document Review for the Department of Transportation, SR 5 eastbound SR 526 to Northbound SR 5—Ramp Addition".

Construction Industry Institute (July 1986), "Constructability: a Primer," Publication 3-1.

HDR Engineering Inc. (November 1994), "Constructability Review for SR 18 Issaquah/Hobart Road Interchange and Raging River Bridge," for the Washington State Department of Transportation.

Houston Business Roundtable (1995), "Model Plan For Constructability".

Lee H., Clover P.A., (December 1991), "Constructability Improvement of Highway Projects in Washington," Final Report for Washington State Department of Transportation.

Sproull L., Kiesler S. (September 1991), "Computers, Networks and Work," *Scientific American*..

Texas Transportation Institute and the University of Houston, "Constructability Review Process for Transportation Facilities," ongoing project under the National Cooperative Highway Research Program.

The Construction Management Committee of the ASCE Construction Division (March 1991), "Constructability and Constructability Programs: White Paper," *Journal of Construction Management and Engineering*, vol. 117, no. 1.

WSDOT, "The Training Manual for CPMS".

WSDOT (December 1994), "Design Development and Documentation Study," Final Report.

WSDOT (from 1986 to 1993), "Change Order Review," District 1 projects.

WSDOT (September 1988), "Extending Applications of Value Engineering within the WSDOT," Final Report.

WSDOT Eastern Region (December 1994), "Milestone Report".

WSDOT Northwest Region (November 1994), "Sunshine Report".

SUPPLEMENTAL REFERENCES

Hammer M., Champy J., (1993), "Reengineering The Corporation".

Hauser J., Clausing D., (May-June 1988), "The House of Quality," *Harvard Business Review*.

APPENDIX A

Other Ongoing Studies

A.1 NCHRP study 94-10-42 (TTI study on constructability)

This project is planned to take up to four years to complete and is under contract with the Texas Transportation Institute (TTI). Because of the NCHRP timeline, WSDOT decided to proceed with this joint study. The Department wants to accelerate implementation of improved procedures because of concerns and problems associated with current constructibility issues and because of WSDOT's on-going commitment to quality. The TTI study is still in a literature search and questionnaire phase where a great deal of information is being collected nationwide. The preliminary information which has been shared or requested of WSDOT indicates that the format and process outline is similar to this study. Since the results of the NCHRP Study will be useful verification of our findings, we conclude that any revisions and/or improvements we develop should be considered for implementation. Any unique or improved systematic procedural change forthcoming from the TTI study could be considered for later implementation.

A.2 TRAC project gc 8720 task 5 (WSU study on constructability)

This study was completed in December 1991. The WSU study basically computerized the Department's plans review and pre-advertisement process. While we found no record of any recommendations formally being implemented, we did find that many of the problems identified in the earlier study were still exacerbating the process when our study began. Several of the problem issues have been subsequently addressed and processes are being revised at this time.

A.3 The Washington Quality Initiative (WQI)

The Washington Quality Initiative (WQI) is directly tied to the National Quality Initiative and the quality directives and mandates contained in ISTEA. The WQI joined the national effort to initiate a continuous quality improvement program that is involving the entire transportation industry. A Washington State Policy on the Quality of Transportation Systems was adopted on November 10, 1993 in a session that included all of the transportation industry leaders. The Policy, signed by representatives of the entire industry, established the commitment to the general direction, objectives, principles expressed in the Policy and to the practice tenets that can help organizations implement quality programs. Probably the most important aspect of this effort is that it brings together Federal, State, and Local Agencies with Contractors, Consultants, Vendors, and Suppliers into one very large and comprehensive coalition with a singular objective; improve transportation products and services to the transportation customers in Washington state.

WASHINGTON TRANSPORTATION QUALITY INITIATIVE (WQI)

A. THE WASHINGTON TRANSPORTATION QUALITY POLICY OBJECTIVES

Provide quality transportation system for the customer and user that is durable, smooth, safe, aesthetically pleasing, environmentally sensitive, efficient and economical.

B. THE WASHINGTON TRANSPORTATION QUALITY POLICY PRINCIPLES

All federal, state, local, academic, and transportation industry organizations **and** agencies who plan, develop, construct, operate, maintain, and/or provide services on Washington's transportation systems are responsible to assure:

1. Comprehensive planning and public involvement to ensure flexibility is designed into the transportation systems **to meet changing needs** and values of the customer;

2. Partnering, **both** internally and externally, **to accomplish** the quality policy objectives;

3. Developing "seamless" transportation wherever possible and practical by encouraging and supporting transportation entities and sponsors to provide dependable intermodal transportation **that moves** people and goods expeditiously, safely, and comfortably;

4. Proper design, construction, and maintenance **through the use of value engineering**, performance specifications, adherence to specifications, quality materials, and qualified (and trained) personnel;

5. Constant improvement of transportation technology through increased emphasis on cooperative research, technology sharing, and implementing new **and innovative** technology.

6. Maximum flexibility is provided, within limits of responsibility, for designers, contractors, workers, suppliers, and system operators **to exercise innovative approaches and practices;**

7. Owner agencies provide **benchmarks and** measurements of assured quality achievement during planning, design, construction, maintenance, and system operations;

8. Providing incentives that reward achievements and innovations where a demonstrated level of value-added quality has been accomplished;

9. Cooperatively develop quality management systems, spec., and value engineering practices; and

10. Commit to improving the quality of staff resources through cooperative training and education.

The research study team considered that as the constructibility proposal was being developed it became essential to measure it's relativity to the WQI. Several of the changes proposed are in direct relationship with the principles in the Policy and methods being recommended in this study are directly compatible with the WQI Practice Tenets. While the proposal agrees in principle with all aspects of the Policy, Principles 2, 4, 6, 9, and 10 are specifically tied to the proposal recommendations.

In addition, elements 2, 4, and 5 in the Practice Tenets (also adopted by WQI and shown below) are included as part of the process improvements being recommended in this study.

WASHINGTON TRANSPORTATION QUALITY INITIATIVE (WQI)

C. <u>FIVE BASIC PRACTICE TENETS OF AN ORGANIZATION TO MEET AND ASSURE QUALITY PRODUCTS AND SERVICES</u>

1. Customer focus and customer involvement;

2. Partnering in planning, design, construction, maintenance, operation, technology development, research, training and education;

3. Establishing incentive, recognition, and reward programs;

4. Establishing quality benchmarking and measurement methods, systems, and/or processes to assure quality improvement; and

5. Providing and/or encouraging training and education programs for staff dedicated to continuous technical and quality improvement.

As one of the major steps taken by the WQI to broaden the knowledge throughout the Washington transportation industry about the quality effort and to also reach deeper into the industry, two day workshops were conducted in Yakima and Lynnwood in February 1994. The success of this effort is attested to by the several hundred attendees who represented all levels of the Washington transportation industry including Federal, state, local, private entities as well as contractors, vendors, and suppliers.

WQI has been committed to professing that if quality improvements are to be met and continued, several paradigm shifts/changes are necessary to assure that quality programs, products, services are developed and delivered. To make this concept a part of the WQI effort, the WQI Steering Team decided that a great opportunity to get the industry involved with this concept was to have the attendees at the Yakima and Lynnwood Workshops begin to cast the direction that the quality movement should take into the future. Each of the breakout sessions were each focused on the concept of paradigm shifts. Paradigms have often been identified with resistance to change and are frequently cast in a role of pseudo-restrictions that prevent change.

The Workshop attendees took the seven paradigms that were identified with the quality movement and developed recommendations for future focus of industry wide study of what changes should be made to improve the quality of transportation products and services in Washington. This actually seems to be a rather unique approach. While each of the other states had breakout sessions, they primarily focused on discussions about functional quality improvements. Washington was the only state, according to from NQI, that made active participation of the attendees in terms of developing recommendations for paradigm shifts/changes a product of the Workshops. Listed below are the seven paradigms and the statement related to a necessary shift or change. It is clear that paradigm shifts and process improvements for quality and constructibility are related.

WQI'S SEVEN PARADIGM SHIFTS/CHANGES NECESSARY TO DEVELOP QUALITY PROGRAMS/PRODUCTS

1. Unbending controls/requirements to meet costs and schedules should change and become "Quality First" as the primary organizational objective;

2. Dogged adherence to internal standards should change and become listening to and meeting the (internal and external) customer needs;

3. A narrow focus on just fixing problems needs to be changed to a broader focus of preventing problems;

4. Managing quality improvement by experience and intuition needs changing to become managing quality improvement through facts;

5. Incremental step improvement approaches to providing quality should be changed to become continuous quality improvement programs;

6. Internally focused approaches to providing quality needs to be an outreach of mutual respect, listening, and partnering approaches between the organ. and customers, suppliers, regulators, etc.; and

7. Competition first and foremost should be changed and become partnering and teamwork to get the job done to mutual satisfaction.

A.4 The WSDOT Design Development and Documentation Study

In January 1995, WSDOT Management approved and adopted an Action Plan to implement the recommendations contained in the Design Development and Documentation Study (DDDS). The DDDS Study had been underway for nearly a year and contains recommendations that are similar and very compatible with the recommendations from this study. The discussion of identified problems and recommended actions is included in the following tabular format. Those items that are marked (*) are directly compatible with the research team discussions and recommendations.

A. DDS PROBLEMS

1- Scoping

- Need input from other offices: environmental, utilities, real estate services, materials, FHWA, architecture, bridge and structures, maintenance, public and local organizations or other agencies which can impact project costs and schedule.

- lack of documentation for scoping decisions.

- the scoping period is too short to define cost/schedule/scope.

- project definition and funding are set prior to design approval and becomes the Department legislative commitment.

2- Design

- duplication of the review of the design report (both OSC and regions).

- design report reviewers have no approval authority.

- bridge design is not started until geometrics are approved by OSC design office.

- environmental clearance needed for approval of the final design.

- delays due to interdependence between design report and right of way plans as well as approval of environmental documents.

- the processing time for securing design report approval affects project delivery.

- the design report is considered as unnecessary by many users.

- effect of new standards, policies and procedures on ongoing projects is not always considered.

- design manual need some changes; too much cookbook design (need innovation).

- the design process is schedule-driven and projects are designed to fit the money available rather than the need.

3- Environmental

- the final design and the right of way acquisition approval depend on the environmental documents approval.

- environmental concerns and timelines are not being adequately considered during scoping.

- information to obtain environmental permits comes too late.

- difficulty in obtaining commitments from agencies early.

- design reports repeat portions of environmental reports.

- permits processes often overlap and conflict.

4- Maintenance

- maintenance is not always involved at the Systems Plan stage which prevents them from receiving enough funding.

- the maintenance budget and workforce is not always enough due to added construction features or some design solutions.

- poor communication between maintenance and project development and program management results in designs without addressing maintenance issues.

5- Real Estate Services

- the R/W acquisition process is always on the critical path for project delivery.

- the R/W plans are developed by people who lack expertise.

- when R/W is too conservative, minor design changes require changes to the R/W plans.

- the R/W acquisition of mitigation sites can impact delivery.

6- Utilities

- the regional utilities office is not included during scoping.

- R/W purchases may hold up utility relocation.

- utility agreements and relocation impact the construction schedule.

7- PS&E

- duplication of reviews of the project development process in the regions and at OSC.

- participating agreements are initiated late in the process.

B. DDDS RECOMMENDATIONS

1- Scoping

- improve and expand the scoping process and adequately fund this process.

- include input from various organizations.

- document design decisions and assumptions made during scoping/identify OSC or region.

- for major improvement projects, require public involvement prior to the project definition process.

- redesign the project prospectus process for preservation and minor projects for OSC budget approval and provide the basic design documents for design approval once the environmental process is complete.

- for funded projects, communicate the results of the scoping process to all impacted offices.

- the project definition, design activity duration and estimate must reflect design, stewardship and environmental realities; include experimented personnel in the scoping process.

2- Design

- replace the current design report process with a permanent, retrievable design documentation file maintained at a central location with:
    - design decisions and assumptions should be documented.
    - changes should be documented and approved and added to the file.
    - the file should contain all approvals and required documents.

- frequent contact among OSC, designers and regional reviewers are necessary to avoid delays.

- final design approval should be written and follow the environmental clearance (NEPA/SEPA); delegation of approval authority to the regions should be consistent with the stewardship plan.

- rewrite the Design Manual.

- develop a design database to record approved design exceptions by milepost.

- establish a process that creates an implementation plan for policy or procedural changes that minimizes the impact to projects already underway.

3- Environmental

- improve WSDOT staff knowledge of environmental regulations.

- continue effort to simplify and streamline the environmental permit process

- consider partnering with resource agencies on major projects for continuous input, understanding of all issues and competing interests.

- review the entire agreement process.

- continue efforts to improve the federal permit process via early involvement of federal environmental agencies in WSDOT planning and project development.

4- Maintenance

- minimize future maintenance cost increases as part of design decisions

- develop a systems plan service objective to address maintenance deficiencies and funding sources.

- hold meetings between maintenance personnel, project scoping and design personnel for better communication.

- develop the systems plan to incorporate future maintenance and operations costs.

5- Real Estate Services

- explore the feasibility of a Certification Acceptance process for R/W plan review and approval.

- develop a new R/W plan approval process to do the following:

- R/W plan approval will certify the technical adequacy of the plan and will allow appraisals and appraisal reviews to proceed.

- negotiation and acquisition will proceed only after environmental document approval.

6- Utilities

- include regional utilities office during scoping.

- revise the agreement process to maximize delegation approval to the regions.

- develop additional standard form agreements to reduce the need for Attorney General review and approval.

7- PS&E

- OSC and the regions should clarify their duties to avoid duplication of the reviews.

- examine contract documents and plans to identify requirements for use by WSDOT and contractors.

- initiate participating agreements earlier with more emphasis on scope than on estimate of costs.

- a new standard agreement format should be jointly developed to allow an earlier participation commitment (Washington State Association of counties, Association of Washington Cities and WSDOT).

APPENDIX B

Sample Questionnaire

TO: MR. B.RENNIE
MR. P.JONHSON
MR. T.LENTZ
MR. D.RUSH

INTERVIEW QUESTIONNAIRE

The purpose of these interviews is to cover existing processes, identify problem areas, and to discuss various impacts of suggestions/modifications that would lead to a standardized constructibility review process. The target goal is to improve where needed to save time, costs, and working procedures and avoid future problems during construction/maintenance phases. The University research team has developed an initial series of questions to use as a starting point for our interview scheduled at **1:30 PM** on **WEDNESDAY, SEPTEMBER 28th** in **ROOM 6A**. Please review these questions and be prepared to either discuss these questions in depth and/or furnish the reference material requested. While this material and/or information is deemed important, if what has been requested is extremely difficult to obtain please let's discuss during the interview.

Please look on these questions as a starting point. The maximum benefits are expected to be found during the free-form discussions that should also take place. Your thoughts and ideas are critical to the success of this project. There is no suggestion that will be taken lightly or be thought of as frivolous. We look forward to meeting with you.

1. Where and when is metrication going to interface in your function? Are any problems anticipated?

2. Does our "Project Activity Network" fit the current way WSDOT proceeds through your part of the project development process? (see attached)

3. Are there any structured guidelines published available that detail activity/document flow for your function and show all of the procedural steps to be followed from beginning to end of work in your function?

4. Are there any checklists that are readily available for any/each function that are used to check completeness of all work?

5. Is Partnering being applied in your function? How? When?

6. Is Value Engineering being employed within your function? How? When? Does the V.E. team include external members, i.e. outside function, dept.? Ever include public? Regulatory agencies? When? How?

7. What is the age profile in your project development area? Has there been a large attrition due to retirements? Is there any problem due to an increase or replacement of staff?

8. What was the value of new construction claims for FY91? FY92?

9. What was the value of construction claims paid during FY91? FY92?

10. During the past four years are you experiencing a downward/upward trend in contract claims?

11. Are typical claims alleged to result from design errors/omissions? Construction delays? Both?

12. Have there been recorded increases/decreases in construction contract delays due to changes, revisions, corrections occurring at the final plan review stage?

13. Are there either formal or informal CRP's available/used by WSDOT engineers/engineering/planning/R W personnel today? How about 1992 WSU study? Has any of that process been implemented? If not, why?

14. What do you think is the best approach to improving the constructibility of your functions proposals? Should CRP's be required and vary by project complexity? Dollar value or size?

15. Have there been any studies about construction claims/constructibility issues/performance that have been made by your function or others within the past four years?

16. Have there been any consideration given to development of a simple "Procedures Guide" for each of the WSDOT's Project Development functions? Available for consultants? Local agencies?

17. How are Headquarters review and approval procedures conducted? By whom? When? What is the basic purpose of the review? Approval? Required by policy?

18. What and how much approval authority is delegated within your function? Has empowerment/approval authority been delegated to staff members in your function in HQ? In the Districts? By policy?

19. Have there been any studies made during the past four years that document the quality of consultant work done for the Department?

20. Are there any other questions/items/procedures, etc. that should be discussed?

APPENDIX C

Contract Change Order Statistics

Year	87	88	89	90	91	92*	93
# CCOs	322	341	273	282	383	1843	967
$ (million) CCOs	2.699	1.233	1.793	1.213	1.909	17.05	25.92
# CCOs per project	no data	7.3 (47 jobs)	6.5 (42 jobs)	5 (56 jobs)	7.8 (49 jobs)	36.9 (50 jobs)	13.6 (71 jobs)
$ per CCO	8,382	3,616	6,568	4,301	4,984	9,251	26,805

LEGEND: # CCOs: number of contract change orders
$ (million) CCOs: added cost in million dollars due to contract change orders
# CCOs per project: average number of contract change orders per project
$ per CCO: average cost of one contract change order
*: year 1992 contrarily to the other years, includes the CCO due to the I-90 project; if only non I-90 projects are considered, these numbers become: 395/3.21/11.3 (35 jobs)/8,140.

Year 93	1st quarter	2nd quarter	3rd quarter	4th quarter	Total
# CCO's	238	264	246	219	967
$ (million) CCO's	4.9	12.1	5.75	3.17	25.92
# CCO's per project	3.4 (69 jobs)	4.1 (64 jobs)	3.5 (71 jobs)	3.7 (59 jobs)	13.6 (71 jobs)
$ per CCO	20,588	45,833	23,374	14,475	26,805

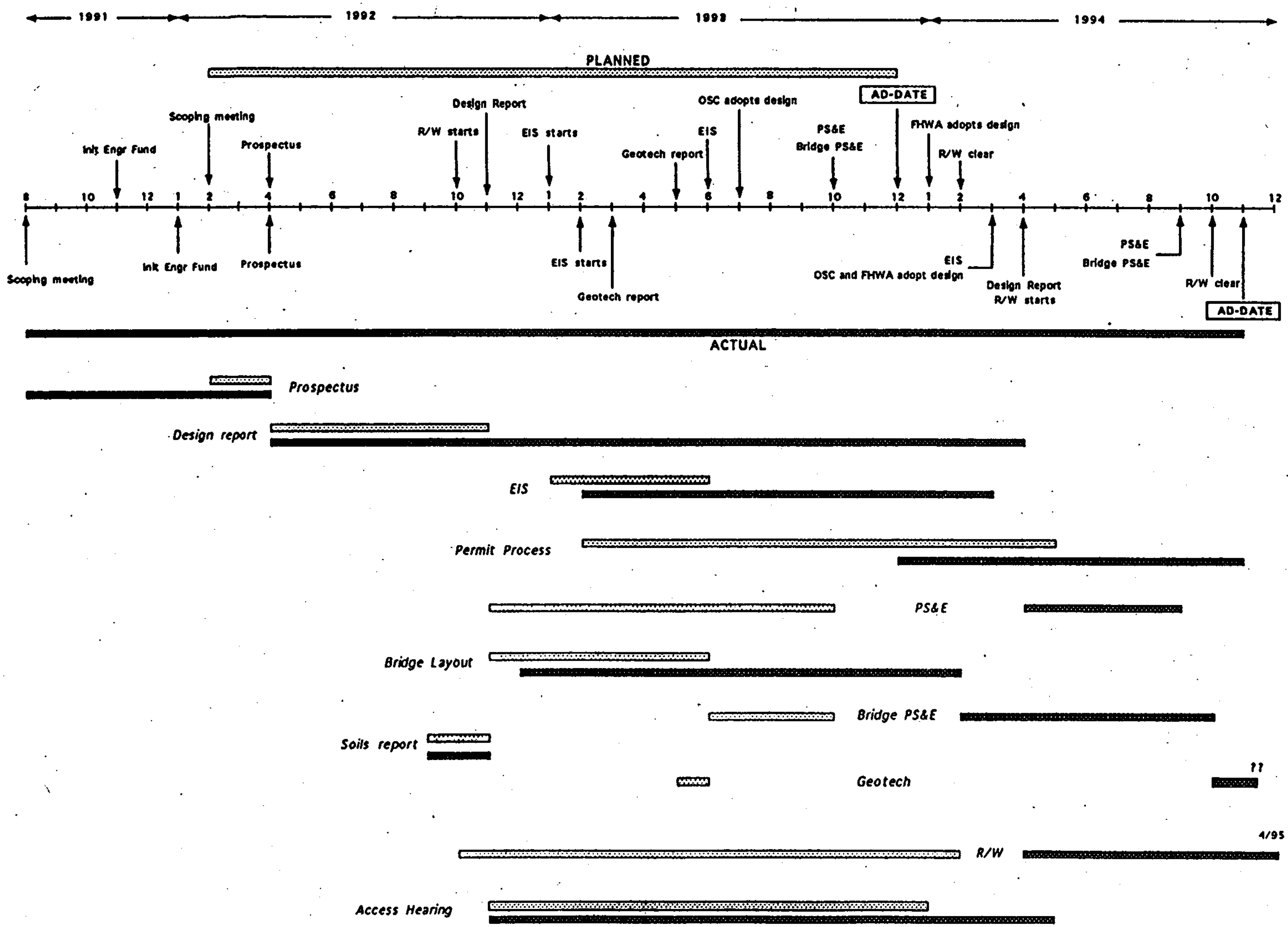
APPENDIX D

Schedule Review

D.1 Timeline Graphs of WSDOT Projects

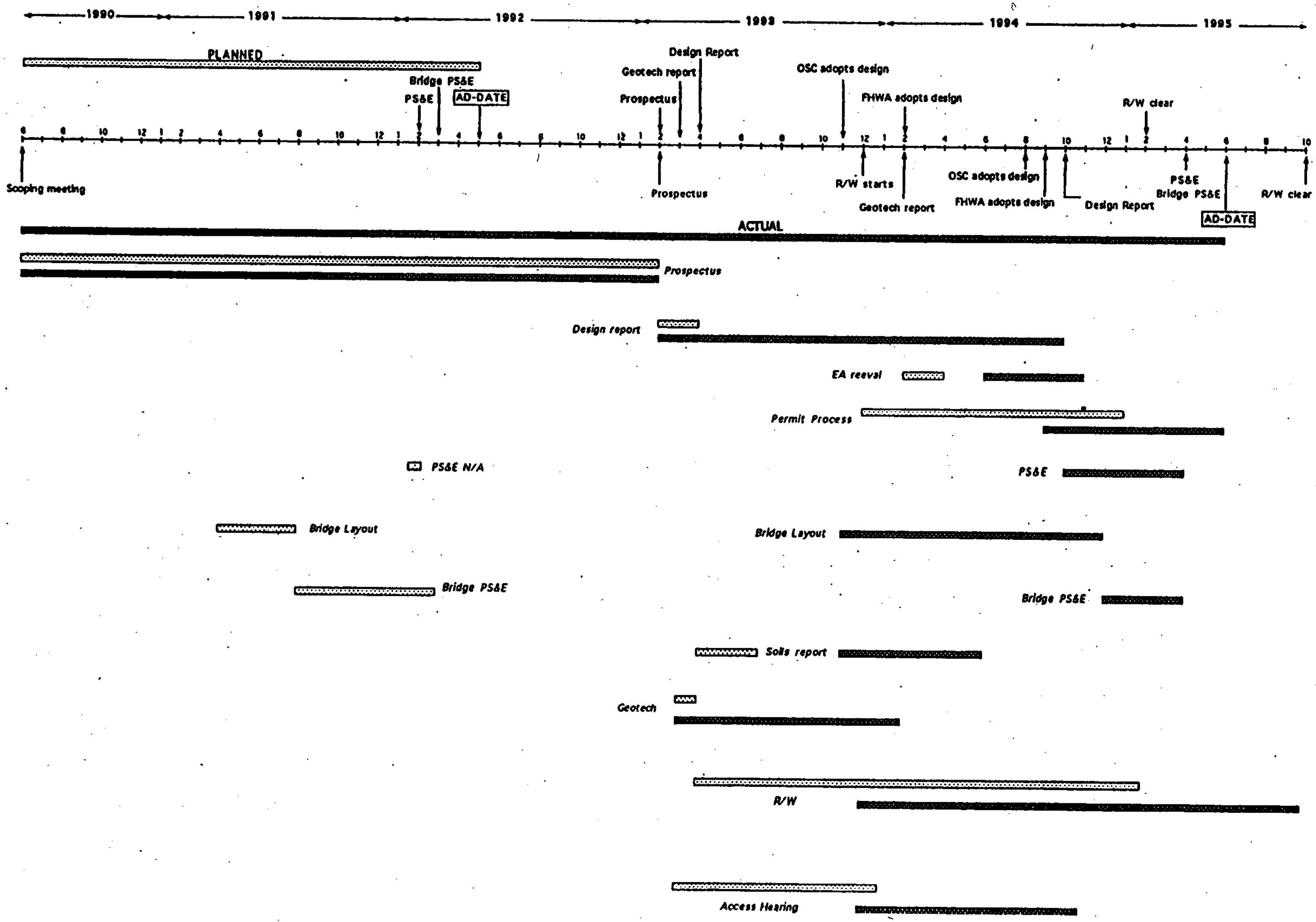
NORTHWEST REGION : ISSAQUAH-HOBART RD I/C AND RAGING RIVER BRIDGE PROJECT
NEW I/C, NEW BRIDGES AND WIDEN EXISTING BRIDGE - CN COST = $25.274 MILLION

SUNSHINE REPORT, NOV 17, 1994



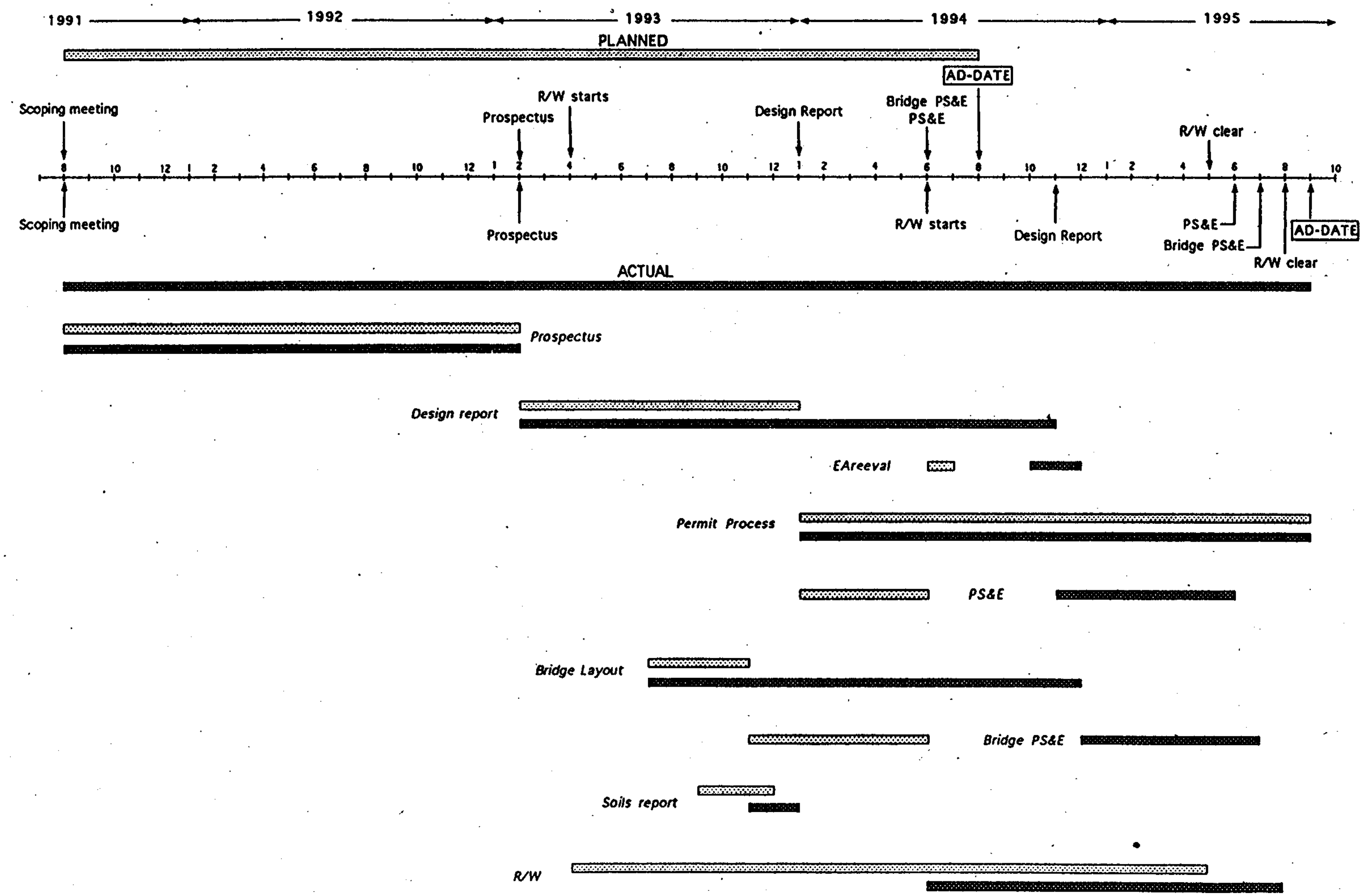
NORTHWEST REGION : SE 312TH WAY TO 304TH STREET PROJECT
WIDEN EXISTING ROADWAY TO 4 LANES - CN COST = $37.306 MILLION

SUNSHINE REPORT, NOV 17, 1994



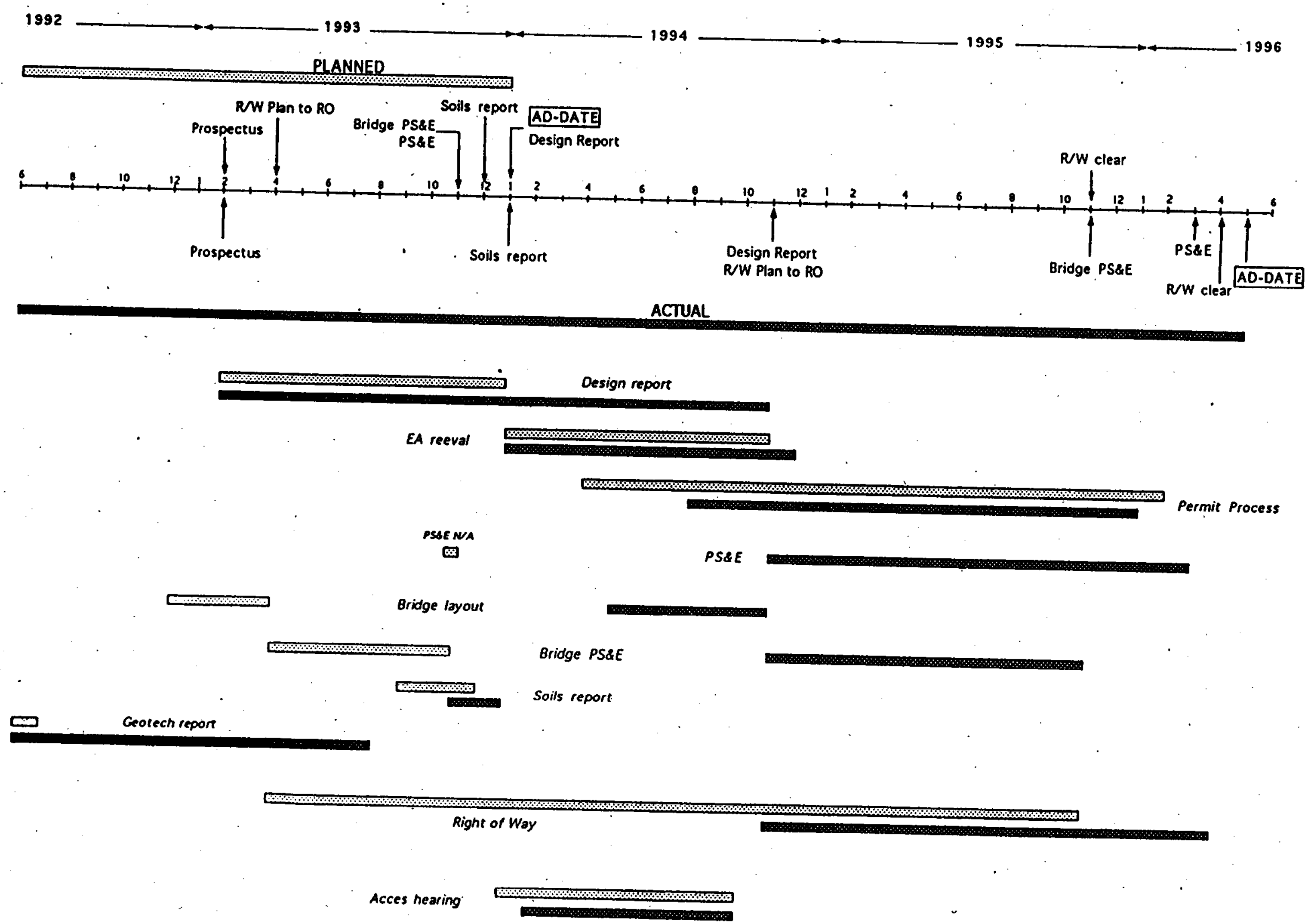
NORTHWEST REGION : **SE 304TH TO COVINGTON WAY PROJECT**
WIDEN EXISTING ROADWAY TO 4 LANES FREEWAY - CN COST = $17.458 MILLION

SUNSHINE REPORT, NOV 17, 1994



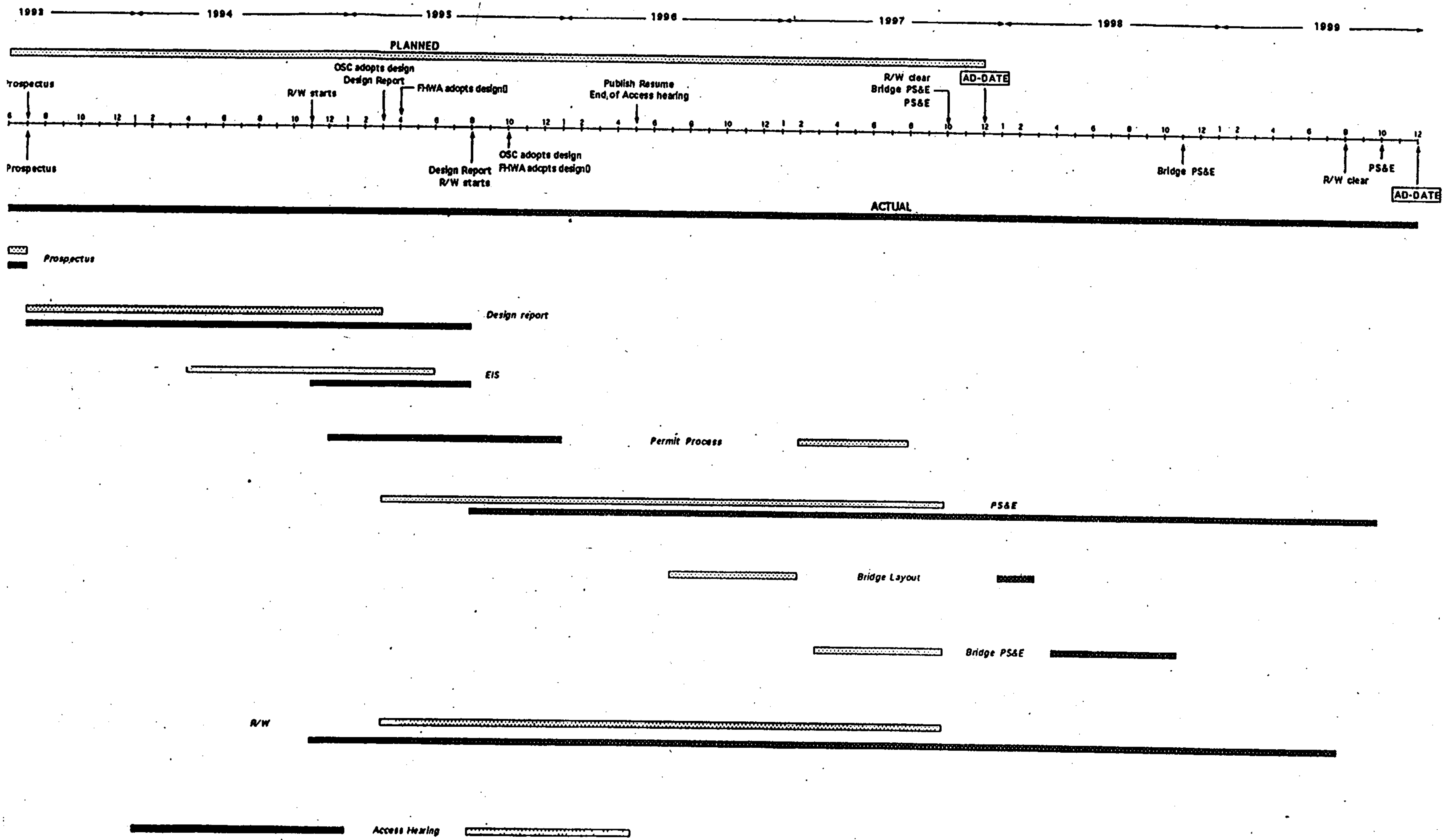
NORTHWEST REGION : **COVINGTON WAY TO MAPLE VALLEY - STAGE 1 PROJECT**
WIDEN EXISTING ROADWAY TO 4 LANE FREEWAY - CN COST = $37.852 MILLION

SUNSHINE REPORT, NOV 17, 1994



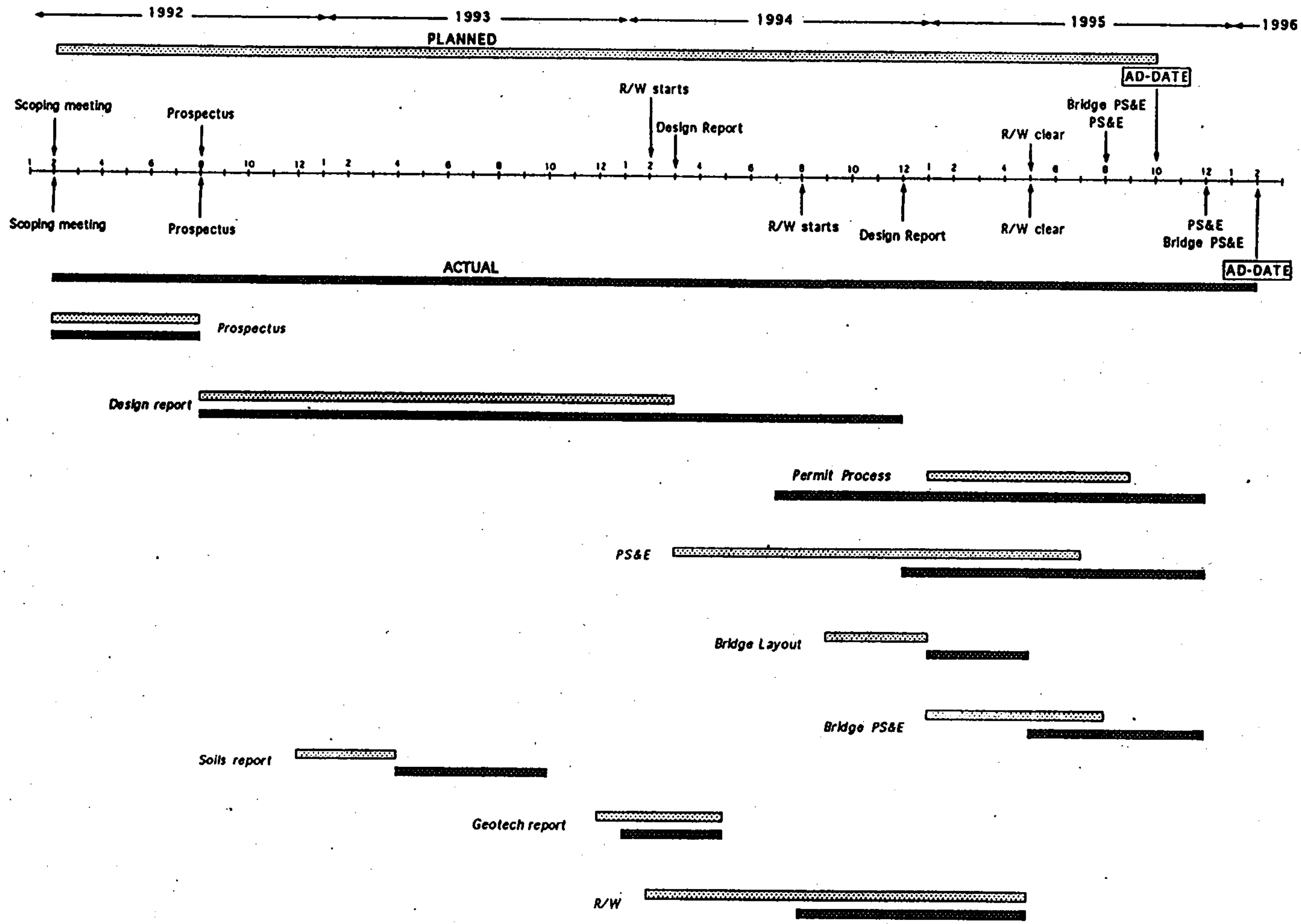
SUNSHINE REPORT, NOV 17, 1994

NORTHWEST REGION : SR20 FREDONIA TO SR5 I/C PROJECT
WIDEN EXISTING ROADWAY - CN COST = $28.086 MILLION



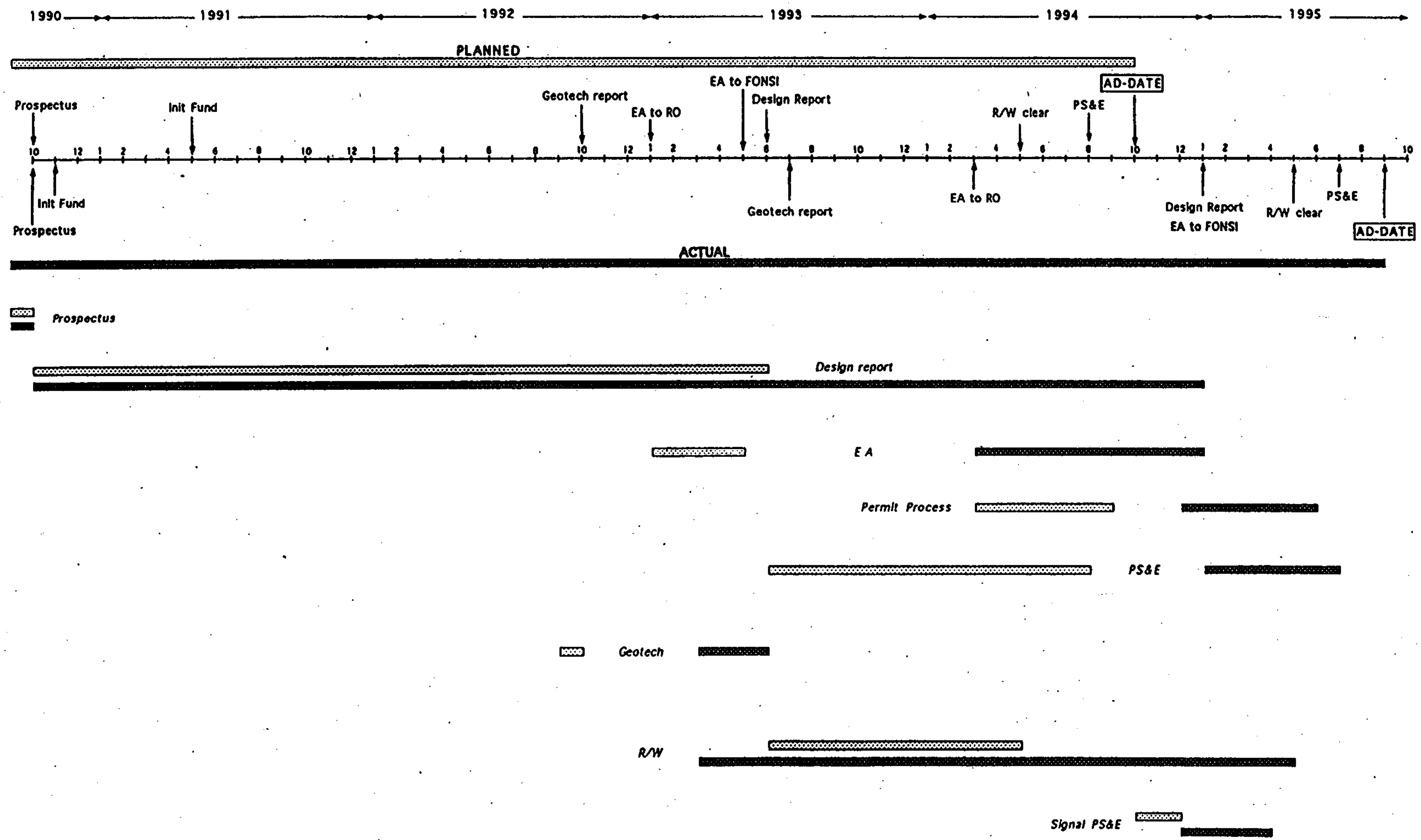
NORTHWEST REGION : SR 405: BOTHELL TO SWAMP CREEK - STAGE 1
CONSTRUCT HOV LANES - CN COST = $28.945 MILLION

SUNSHINE REPORT, NOV 17, 1994



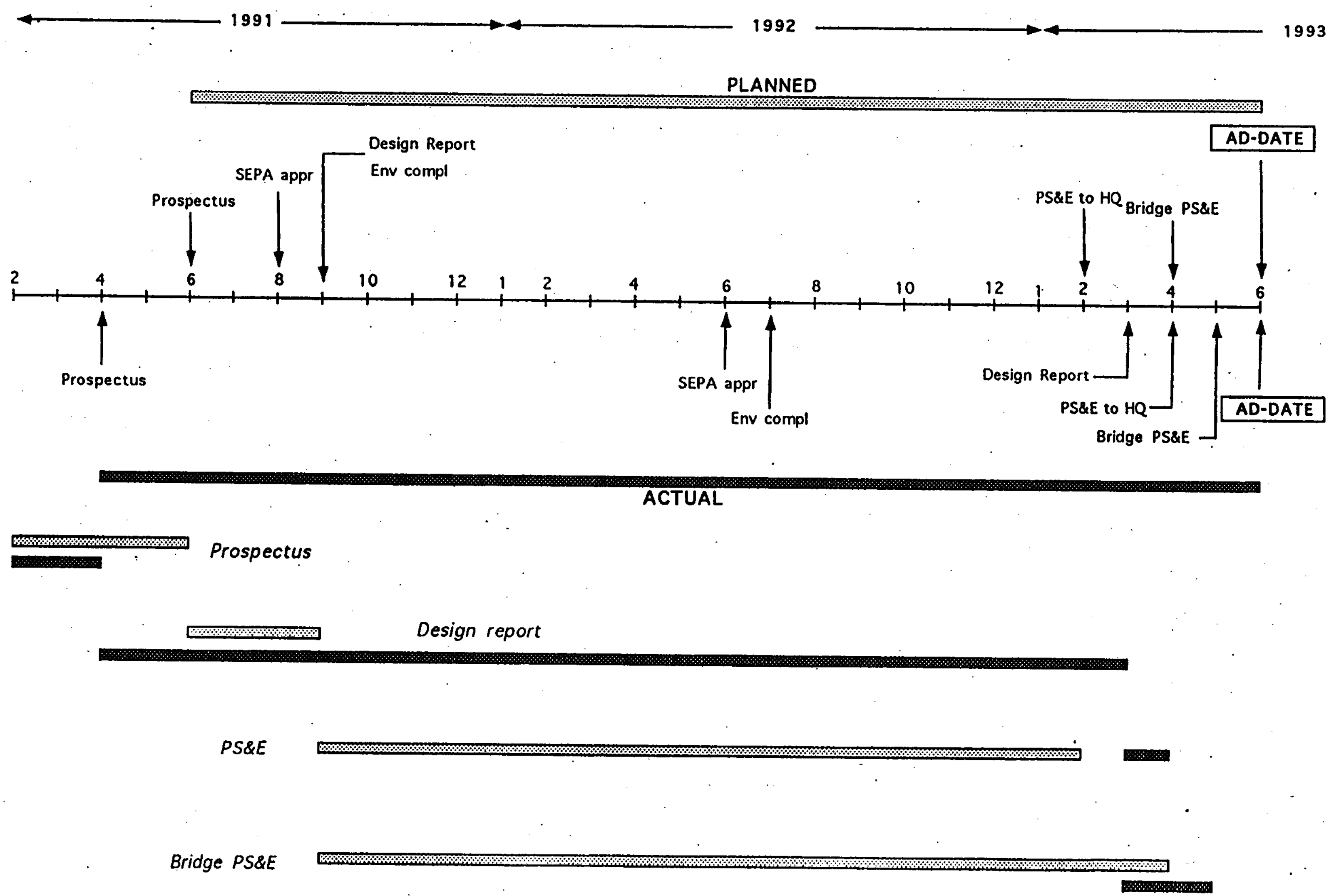
NORTHWEST REGION : I-5 FEDERAL WAY PARK&RIDE LOT#2 PROJECT
SELECT SITE FOR PARK&RIDE LOT - CN COST = $7.469 MILLION

SUNSHINE REPORT, NOV 17, 1994



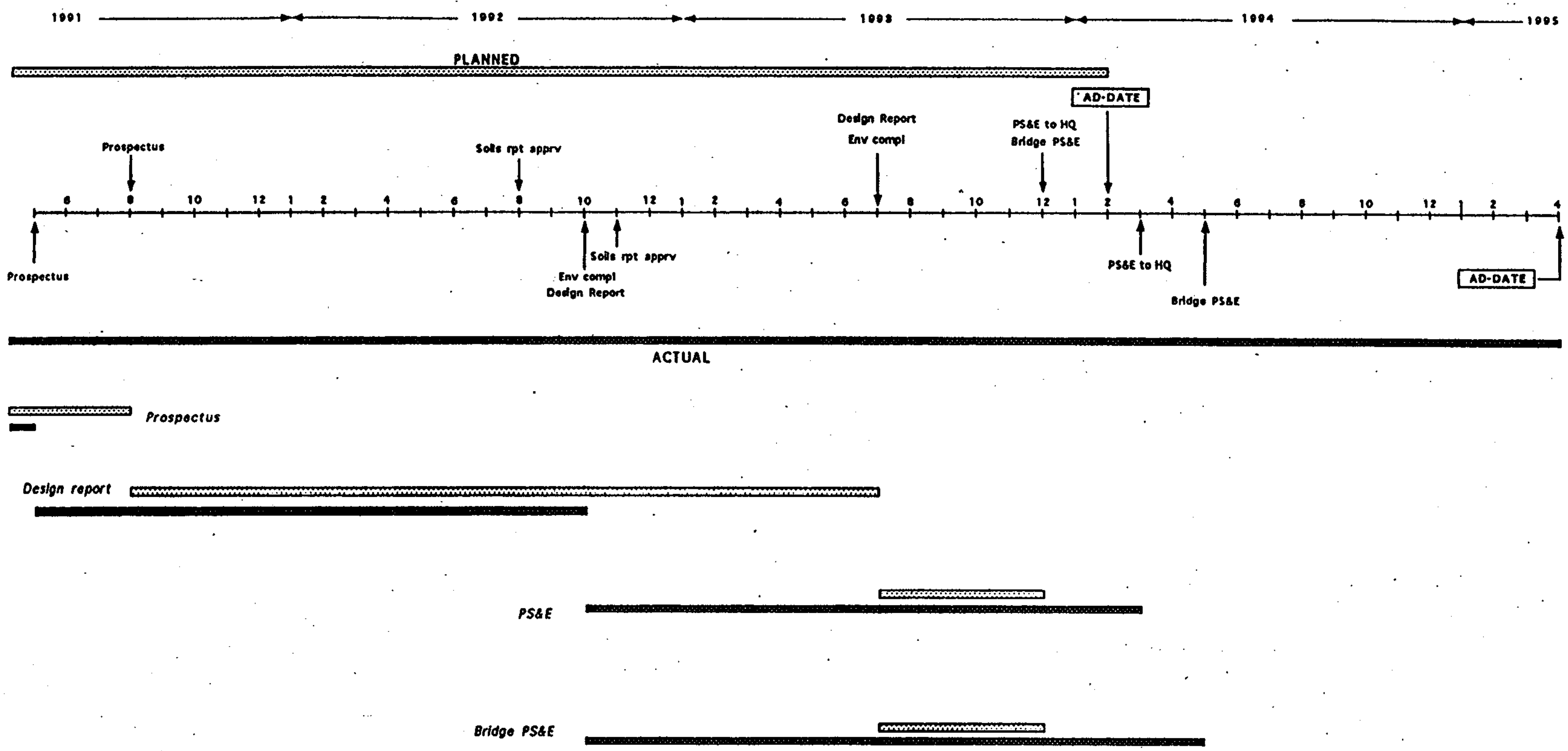
EASTERN REGION : NORTH SPOKANE: SR2 STAGE 1 PROJECT
COUPLET - CN COST = $4.950 MILLION .

MILESTONE STATUS REPORT, DEC 1, 1994



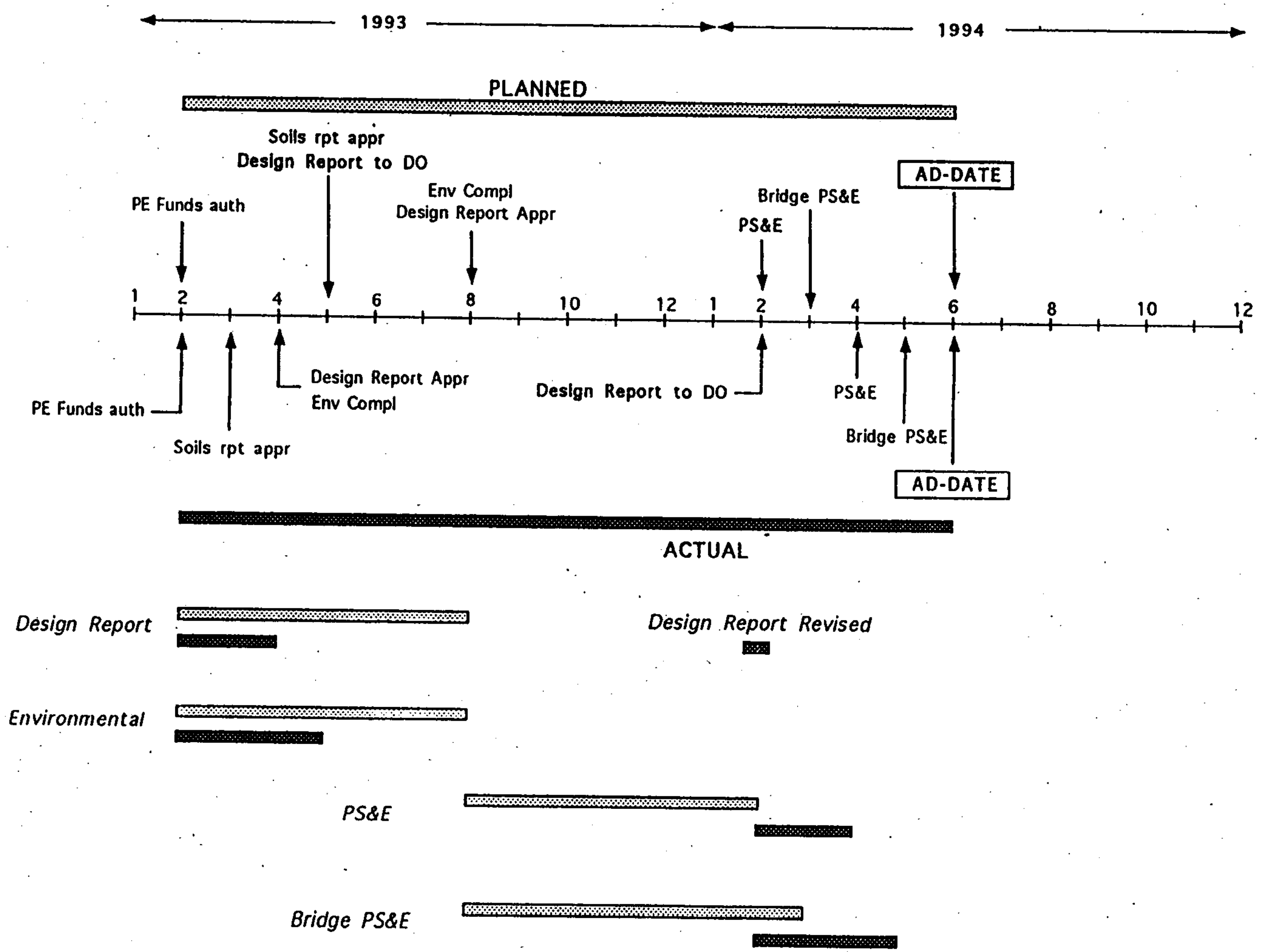
MILESTONE STATUS REPORT, DEC 1, 1994

EASTERN REGION : NORTH SPOKANE: SR2 STAGE 2 PROJECT
CONSTRUCT ADDITIONAL LANES - CN COST = $3.600 MILLION



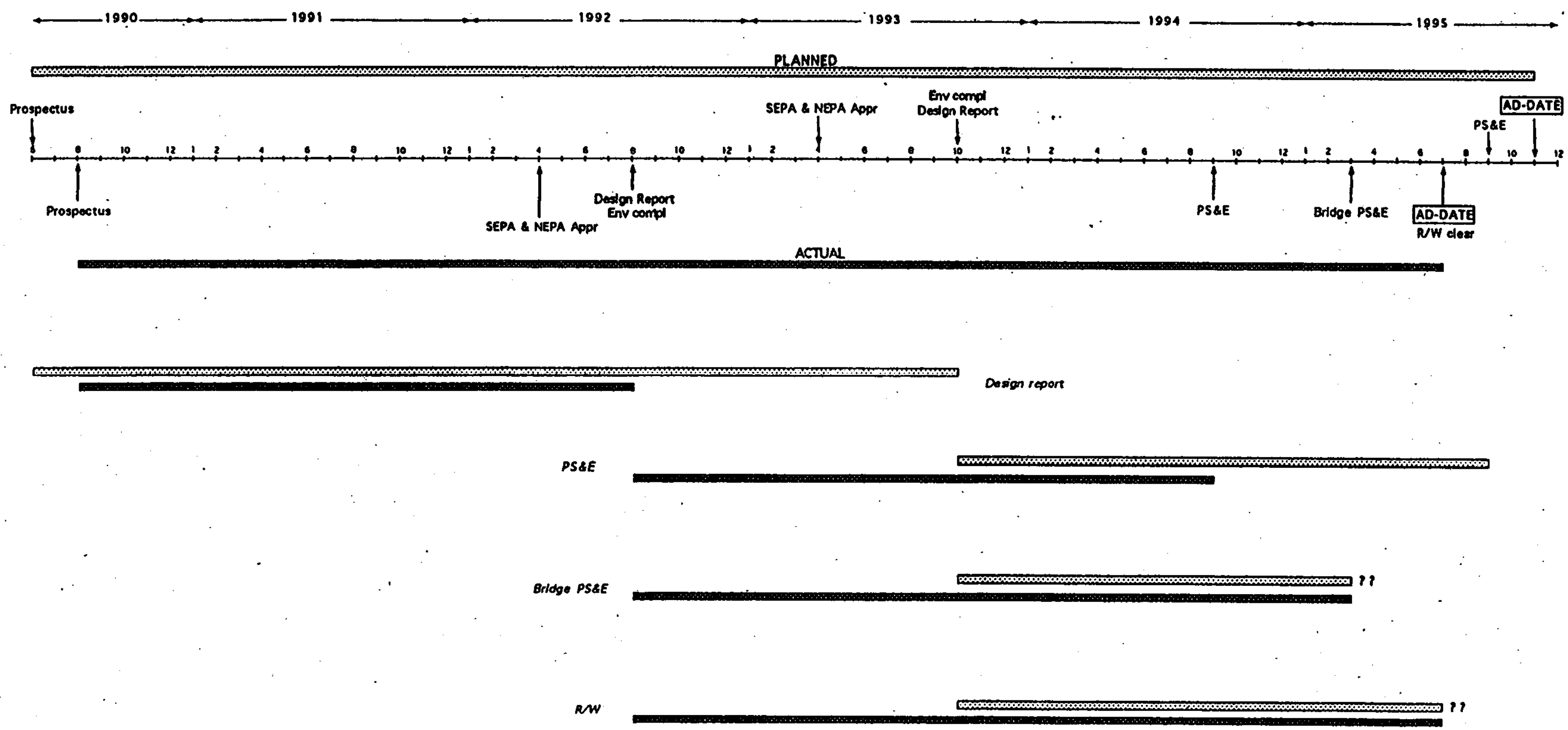
EASTERN REGION : SR 395 LIND TO RITZVILLE - STAGE 1 PROJECT
CONSTRUCT TWO ADDITIONAL LANES - CN COST = $24.063 MILLION

MILESTONE STATUS REPORT, DEC 1, 1994



EASTERN REGION : SR290 MISSION AVE TO ARGONNE RD PROJECT
CONSTRUCT ADDITIONAL LANE - CN COST = $2.920 MILLION

MILESTONE STATUS REPORT, NOV 30, 1994



D.2 Advertisement dates of major WSDOT projects

These dates have been taken from the Project Development Status Reports ("Sunshine Report" of the Northwest region and the "Milestone Report" from the Eastern region). Here are compared the planned ad-dates and the actual ad-dates, and the number of lag days is also computed to give a better idea of what is happening. The projects considered are only major projects like improvement or widening of highways and roads.

The average number of days late for the SR18 projects in the Northwest region is 790. For the whole Northwest region, the average number of days late is 870. No projects that are ahead of time in this region.

For the Eastern region, there is a lower tendency to be late: some projects are on time and others are even ahead of time; however, there still are some projects that are late. But in general, this region seems to have less problems than the Northwest region which tendency is to be late.

1- Northwest Region

1-1 SR 18 Projects

Projects	Planned date	Actual date	# of days late
SR99 to I5	7/93	11/94	492
SE 312 to 304	5/92	6/95	1150
SE 304 to Covington	8/94	9/95	400
Covington to Maple Valley - stage 1	1/94	5/96	854
Covington to maple Valley - stage 2	8/98	/	/
Maple Valley to Hobart	10/96	12/00	1515
Issaquah-Hobart I/C & Raging River Bridge	12/93	11/94	336
Issaquah-Hobart rd to Tigertate	6/2005	/	/
Tigertate to SR90	12/07	/	/

Average: 790

1-2 Other Projects

Projects	Planned date	Actual date	# of days late
SR2/Vic SR522 I/C	3/95	9/95	189
SR9/SR522-SR9 I/C	7/94	6/95	356
SR20/Fredonia to SR5 I/C	12/97	12/99	735
SR99/King-Snohomish Co line to 60th SW	2/94	7/97	1250
SR99/Vic 60th SW to SR525	8/95	8/97	735

SR161/Jovita to S 360th	7/95	7/99	1460
SR161/360th to SR18	8/94	7/95	350
SR169/SR516 to 196th	4/96	2/01	1760
SR405/NE 160th I/C	9/94	12/94	112
SR405/Woodinville I/C	3/95	9/95	183
SR522/Sr9 to Paradise Lk	4/94	7/95	455
SR525/SR99 to SR526	8/95	10/96	441
SR525/Cameron rd to SR20 - stage 3	4/93	2/96	1030
SR525/Cameron rd to SR20 - stage 4	4/95	01/98	1000
SR527/164 SE to 132 SE	7/94	3/99	1700
SR527/132 to 112	10/97	2/00	850
SR530/I5 to old SR99	1/96	1/99	1095
SR530/Montague creek to Hazel	11/92	05/95	910
SR539/Horton to Tenmile	6/95	02/99	1340
SR539/Tenmile to int'l	10/96	02/99	850
SR542/Orleans st to Britton rd	10/97	2/01	1215
SR900/Duvale ave to SR90	10/96	2/01	1580

Total average for the Northwest Region: 870

2- <u>Eastern Region</u>

SR2/North Spokane stage1	6/93	6/93	0
SR2/North Spokane stage2	2/94	4/95	425
SR270/Spring st to Johnson rd	4/94	4/94	0
SR90/Sprague ave to Argonne rd - stage 1	4/95	3/96	336
SR90/Sprague ave to Argonne rd - stage 2	7/98	6/97	-399
SR290/Mission ave to Argonne rd	11/95	7/95	-112
SR395/Lind to Ritzville stage 2	12/94	1/95	49

The Eastern Region seems to have less delayed projects than the Northwest Region.

APPENDIX E

(CRP CHECKLISTS)

E.1 PROJECT IDENTIFICATION REPORT CRP SCOPING REVIEW PHASE

CRP Checklist -

For each of these items should be checked:
- omissions
- errors
- clarity
- completeness

Consensus must be reached at this stage on:
1- scope
2- schedule
3- cost/budget
therefore for each item must be checked:
- quantities
- cost estimates (unit costs and total costs)

1 INFORMATION/DOCUMENTS DESIRABLE AT THE PROJECT IDENTIFICATION PHASE CRP

ITEMS	Check (Y/N)	Required action	When By Whom
1- INFORMATION/DOCUMENTS			
obtain any existing reports, studies, mapping (location of structures too) or other information			
hazardous material/waste information			
preliminary materials (geotechnical) information			
environmental resources inventory and issues			
landscape information			
traffic data (existing and forecast traffic, level of service, capacity adequacy, operational analysis, accidents, etc.)			
preliminary structure studies			
right of way utility considerations			
local planning (land use)			
2- Programmatic issues			
proposed programming/scheduling			
staffing availability			

2 REVIEW OF ENGINEERING STUDIES

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
1- Value engineering studies and alternatives				
have VE studies been done?				
identify alternatives				
2- Favored proposal				
any deviations from the planning study or concept?				
3- Environmental study done?				
permit requirements				
special mitigations				
list of environmental resources				
potential impacts				
determine type of environmental study				
stage of the environmental study				
4- Hazardous materials				
has there been site assessment				
5- Traffic management plan (handling traffic through construction)				
6- Structures				
preliminary study including alternatives and cost				
special environmental considerations impacting structures				
permits				
traffic				
7- Geotechnical investigation				
critical issues				
slides				
erosion				
poor foundation, etc.				
8- Landscaping				
significant landscaping requirements?				
irrigation/water conservation issues?				
9- Right of Way				
adequate mapping/plats				
improvements				
property ownership				
assessors parcel numbers				
size of each parcel				
proposed right of way lines				
access control				
easements (permanent & temporary)				
significant property ingress modifications				
utilities				
railroad facilities				

10- Design standards				
lane width				
design speed				
cross slope				
grade				
superelevation				
stopping sight distance				
horizontal and vertical alignment				
horizontal and vertical clearance				
bridge structural capacity				
standards exemptions :				
description of the project				
project cost				
description of existing highway				
proposed nonstandard features				
added cost to make standard				
traffic and safety data and discussion				
incremental and other alternatives to the proposed nonstandard design				
plan drawings, cross-sections, photos, etc., to show the problem and justify the nonstandard features.				

3 REVIEW OF ALTERNATIVES, COST ESTIMATES AND SCHEDULES

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
1- Roadway items				
1.1- Earthwork				
stabilization treatment				
roadway excavation				
imported borrow				
clearing and grubbing				
develop water supply				
special foundation treatment (roadway)				
1.2- Structural section				
PCC pavement				
asphalt concrete				
lean concrete				
cement-treated base				
aggregate base				
aggregate subbase				
permeable material blanket and edge drains				
contractor/state supplied aggregates? Sources?				

1.3- Roadway Drainage				
large drainage facility				
storm drains				
pumping plants				
retention/detention ponds				
1.4- Specialty items				
retaining walls				
soundwalls				
equipment/animal passes				
relocate private irrigation facilities				
landscaping				
irrigation				
erosion control				
slope protection				
barriers and guardrails				
hazardous waste work				
environmental mitigation				
1.5- Traffic items				
lighting				
traffic signals				
permanent signing				
traffic control systems				
traffic management plan				
Minor item				
2- Structure items	Structure 1	Structure 2	Structure 3	Structure 4
bridge name				
structure type				
width ft. (out to out)				
span lengths ft.				
total area sq. ft.				
footing type (pile/spread)				
cost per sq. ft.				
total cost for structure				
any special foundation treatment (structure)				
3- Right of way				
acquisition, including excess lands and damages to remainders				
utility relocation (State share)				
clearance/demolition				
Relocation Assistance Program				
title and escrow fees				
construction contract work				
4- Other				
Roadway mobilization				
Roadway additions				
5- Engineering, right of way staffing cost.				

6 SPECIAL CONSTRUCTION AND/OR MAINTAINABILITY ISSUES

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
1-				
2-				
3-				
4-				

7- Contingencies (25%)				

E.2. 30% PS&E COMPLETION CRP GEOMETRIC REVIEW PHASE

CRP Checklist -

For each of these items should be checked:

- omissions
- errors
- clarity
- completeness

Should be checked:

1- *Plans* (drawings): sections, profiles, dimensions, spacing, quantities, grading, elevations, names (designations) or numbering, connections between items (i.e., drainage).
2- *Specifications or requirements for Special Provisions*
3- *Quantities and estimates of cost for each item(quantity, unit, unit cost, total cost)*
4-*Total Project Cost Estimate*

- **DESIRED INFORMATION/DOCUMENTS AVAILABLE AT THE 30% PHASE CRP**

ITEMS	Check (Y/N)	Required action	When by Whom
Design level mapping			
Geotechnical report			
Hydraulics report			
Site map (sent to bridge?)			
Site data report (sent to bridge?)			
Bridge preliminary report			
Right of Way plans			
Environmental permits/mitigation			

- **DRAINAGE**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
Water quality				
Surface drainage				
Groundwater problems				
Structures drainage				
Retaining walls				
Bridges				
Roadway drainage				
dewatering systems				
irrigation systems				

Roadway drainage (cont.)				
sewers				
detention ponds				
retention ponds				
temporary sediment ponds				
jacked pipes				
culverts				
crossdrain				
underdrain				
downdrain				
stormdrain system/storm sewer pipes				
special drainage structures (energy dissipators, filter windows, flow restrictors, flow spreader, sediment trap, fences, etc.)				
ditches				
catch basins				
junction boxes				
manholes				
waterlines (removal)				
shafts				
swales				

- **TRAFFIC**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
staging				
number of closed lanes				
night operations				
influence on other surrounding streets				
construction traffic control				
detour roads				
sequential arrows				
closure (days and hours)				
labor (number of hours)				
design				
delineation (pavement markings, guideposts, barrier delineation, raised pavement markers, impact attenuator markings)				
intersections, interchanges, auxiliary lanes				
signalization				
signs				
detection systems				
safety items (crash cushions)				
barriers, guardrail				
work zones				

design (cont.)				
illumination and lighting				
ramp meters				
transitions				
climbing lanes (for slow vehicles)				
special shoulder designs				
bicycle path				
HOV lanes				

- **ROADWAY SURFACE**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
pavement (cement concrete, asphalt concrete, bitumen)				
bases and subbases				
sidewalk				
curb				
shoulders/shoulder repair				
sawcutting				
slopes				
lanes/narrow lanes widths have to match roadway sections				
stationing (road, paving, striping, etc.)				
pavement method				

- **LANDSCAPING**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
irrigation system				
planting (seeding, fertilizing)				
plant establishment period				
fencing				

- **ENVIRONMENTAL MITIGATION**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
planting/wetland planting and re-vegetation				
seeding/fertilization				
trees/shrubs removal				
sandbag diversion dams				
hazardous waste cleanup				
pollution control				
groundwater contamination				
dust control				

- **HEARINGS**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
project hearings				
access hearings				

- **PERMITS**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
utilities agreements				
environmental permits				
US Department of the Army-Corps of engineers permits (section 10 and section 404 permits)				
Hydraulic Project Approval (Washington State Department of fisheries and wildlife)				
US coast guard permits				
US forest services				
Federal aviation administration				
Washington State Department of natural resources				
Washington State Department of Ecology				
local agencies (building, air pollution, shorelines permits, etc.)				
flood permit				
Sensitive area ordinance/public agency utility exemption permit (SAO/PAUE)				
grading/clearing permit				
noise variance				
temporary erosion and sedimentation control plan				
temporary water quality modification permit				
national pollution discharge elimination system permit application (NPDES)				
storm water site plan				

- **GEOTECH/EARTHWORK**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested action
roadway excavation/embankment				
excavation for ponds or wetlands				
structure excavation				
fill				
stockpiling/storage/dumpsites				
materials usage/salvage				
stabilization				

site conditions (topography, profiles, etc.)				
boring/drilling				
soil compaction				
clearing, grubbing, roadside cleanup				
removal of structures and obstructions				
Earthwork haul				
slope treatment				
subgrade preparation				
watering				
ditch and channel excavation				
trimming and cleanup				

- **STRUCTURES**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
site data report				
timber structures				
bridges				
concrete mix/steel				
bearings				
girder				
foundation				
expansion joints				
piles/columns				
reinforcement				
bridge railing				
walls/retaining walls				
material (concrete mix)				
live poles between wall layers				
foundation				
panels				
reinforcement				
panels/stem panels				
appurtenant structures				
pedestrian/animals structures (habitat for fish, animal passage, etc.)				
tunnel				
mud slab/waterproofing				
roof slab				
pavement method				
painting				
waterproofing				
cribbing				

- **UTILITIES**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
electricity/power lines/power poles				
wire conduits				
power sources location				
gas				
cable				
telephone				
sewer lines				
utility conflicts				

- **RIGHT OF WAY & ACCESS CONTROL**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
existing/proposed right of way limits				
appraisal				
transaction				
acquisition				
condemnation				
relocation				
cattle passes				
pit, stockpile and waste sites (haul road, detour routes)				
utility				
railroad				
international boundaries				
easement/construction permits				
programming for funds				
access control				
access report/access hearing plans				
monuments (alignment, property corner, others)				
fencing				
At the design report stage				
right of way estimate				
purchase cost				
relocation assistance benefits payments				
other land management staff expenses (acquisition services, relocation services, interim property management services)				

- **CONSTRUCTION**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
access roads				
construction signs				
temporary signalization/striping/illumination/impact attenuators				
site preparation				
construction space				
field office building location				
equipment/material				
construction schedule/sequence				
survey control staking and monuments				
construction equipment				
cranes, derricks				
trucks				

- **MAINTENANCE AND MAINTAINABILITY ITEMS**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
roadside cleanup				
drainage cleanup				
fire protection systems				
Drainage accessibility				
- access to detention/retention ponds				
- access to downdrains/underdrains				
- special drainage features/structures				
Slope accessibility				
- top of cut/toe of fill				
Special Environmental/Permit Maint.				

- **CONTRACT DOCUMENTS/BID DOCUMENTS**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
consistency				
consistency of presentation				
organization				
Special Provisions				

- **CONTINGENCIES**

15%				

E.3 60% PS&E COMPLETION CRP
GENERAL PLANS REVIEW PHASE

CRP Checklist

For each of these items should be checked:

- omissions
- errors
- clarity
- completeness

Should be checked:

1- *Plans* (drawings): sections, profiles, dimensions, spacing, quantities, grading, elevations, names (designations) or numbering, connections between items (i.e., drainage).

2- *Specifications or requirements for Special Provisions*

3- *Quantities and estimates of cost for each item(quantity, unit, unit cost, total cost)*

4-*Total Project Cost Estimate*

- **INFORMATION NEEDED AT THE 60% STAGE**

ITEMS	Check (Y/N)	Required action	When by Whom
All information that was required at the 30% stage			
Line/grade/earthwork quantities			
Roadway geometry, design complete			
Hydraulic plans complete			
Bridge general plan complete			

- **DRAINAGE**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
Water quality				
Surface drainage				
Groundwater problems				
Structures drainage				
Retaining walls				
Bridges				
Roadway drainage				
dewatering systems				
irrigation systems				
sewers				
detention ponds				
retention ponds				
temporary sediment ponds				
jacked pipes				
culverts				
crossdrain				
underdrain				
downdrain				
stormdrain system/storm sewer pipes				
ditches				

Roadway drainage (cont.)				
special drainage structures (energy dissipators, filter windows, flow restrictors, flow spreader, sediment trap, fences, etc.)				
catch basins				
junction boxes				
manholes				
waterlines (removal)				
shafts				
swales				

- **TRAFFIC**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
staging				
number of closed lanes				
night operations				
influence on other surrounding streets				
construction traffic control				
detour roads				
sequential arrows				
closure (days and hours)				
labor (number of hours)				
design				
delineation (pavement markings, guideposts, barrier delineation, raised pavement markers, impact attenuator markings)				
intersections, interchanges, auxiliary lanes				
signalization				
signs				
detection systems				
safety items (crash cushions)				
barriers, guardrail				
work zones				
illumination and lighting				
ramp meters				
transitions				
climbing lanes (for slow vehicles)				
special shoulder designs				
bicycle path				
HOV lanes				

- **ROADWAY SURFACE**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
pavement (cement concrete, asphalt concrete, bitumen)				
bases and subbases				
sidewalk				
curb				
shoulders/shoulder repair				
sawcutting				
slopes				
lanes/narrow lanes widths have to match roadway sections				
stationing (road, paving, striping, etc.)				
pavement method				

- **LANDSCAPING**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
irrigation system				
planting (seeding, fertilizing)				
plant establishment period				
fencing				

- **ENVIRONMENTAL MITIGATION**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
planting/wetland planting and re-vegetation				
seeding/fertilization				
trees/shrubs removal				
sandbag diversion dams				
hazardous waste cleanup				
pollution control				
groundwater contamination				
dust control				

- **HEARINGS**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
project hearings				
access hearings				

- **PERMITS**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
utilities agreements				
environmental permits				
US Department of the Army-Corps of engineers permits (section 10 and section 404 permits)				
Hydraulic Project Approval (Washington State Department of fisheries and wildlife)				
US coast guard permits				
US forest services				
Federal aviation administration				
Washington State Department of natural resources				
Washington State Department of Ecology				
local agencies (building, air pollution, shorelines permits, etc.)				
flood permit				
Sensitive area ordinance/public agency utility exemption permit (SAO/PAUE)				
grading/clearing permit				
noise variance				
temporary erosion and sedimentation control plan				
temporary water quality modification permit				
national pollution discharge elimination system permit application (NPDES)				
storm water site plan				

- **GEOTECH/EARTHWORK**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested action
roadway excavation/embankment				
excavation for ponds or wetlands				
structure excavation				
fill				
stockpiling/storage/dumpsites				
materials usage/salvage				
stabilization				
site conditions (topography, profiles, etc.)				
boring/drilling				
soil compaction				
clearing, grubbing, roadside cleanup				
removal of structures and obstructions				
haul				

slope treatment				
subgrade preparation				
watering				
ditch and channel excavation				
trimming and cleanup				

- **STRUCTURES**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
site data report				
timber structures				
bridges				
concrete mix/steel				
bearings				
girder				
foundation				
expansion joints				
piles/columns				
reinforcement				
bridge railing				
walls/retaining walls				
material (concrete mix)				
live poles between wall layers				
foundation				
panels				
reinforcement				
panels/stem panels				
appurtenant structures				
pedestrian/animals structures (habitat for fish, animal passage, etc.)				
tunnel				
mud slab/waterproofing				
roof slab				
pavement method				
painting				
waterproofing				
cribbing				

- **UTILITIES**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
electricity/power lines/power poles				
wire conduits				
power sources location				
gas				
cable				
telephone				
sewer lines				
utility conflicts				

- **RIGHT OF WAY & ACCESS CONTROL**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
existing/proposed right of way limits				
appraisal				
transaction				
acquisition				
condemnation				
relocation				
cattle passes				
pit, stockpile and waste sites (haul road, detour routes)				
utility				
railroad				
international boundaries				
easement/construction permits				
programming for funds				
access control				
access report/access hearing plans				
monuments (alignment, property corner, others)				
fencing				
At the design report stage				
right of way estimate				
purchase cost				
relocation assistance benefits payments				
other land management staff expenses (acquisition services, relocation services, interim property management services)				

- **CONSTRUCTION**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
access roads				
construction signs				
temporary signalization/striping/illumination/impact attenuators				
site preparation				
construction space				
field office building location				
equipment/material				
construction schedule/sequence				
survey control staking and monuments				
construction equipment				
cranes, derricks				
trucks				

- **MAINTENANCE**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
roadside cleanup				
drainage cleanup				
fire protection systems				

- **CONTINGENCIES**

10%				

E.4 90% PS&E COMPLETION CRP
CONTRACT PLANS REVIEW PHASE

CRP Checklist

For each of these items should be checked:
- omissions
- errors
- clarity
- completeness

Should be checked:

1- *Plans* (drawings): sections, profiles, dimensions, spacing, quantities, grading, elevations, names (designations) or numbering, connections between items (i.e., drainage).

2- *Specifications or requirements for Special Provisions*

3- *Quantities and estimates of cost for each item(quantity, unit, unit cost, total cost)*

4-*Total Project Cost Estimate*

- **INFORMATION NEEDED AT THE 90% STAGE**

ITEMS	Check (Y/N)	Required action	When by Whom
All information that was required at the 60% stage			
Traffic plans complete			
Bridge plans complete			
Plans and estimate complete			

- **DRAINAGE**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
Water quality				
Surface drainage				
Groundwater problems				
Structures drainage				
Retaining walls				
Bridges				
Roadway drainage				
dewatering systems				
irrigation systems				
sewers				
detention ponds				
retention ponds				
temporary sediment ponds				
jacked pipes				
culverts				
crossdrain				
underdrain				
downdrain				
stormdrain system/storm sewer pipes				
ditches				
catch basins				

Roadway drainage (cont.)				
special drainage structures (energy dissipators, filter windows, flow restrictors, flow spreader, sediment trap, fences, etc.)				
junction boxes				
manholes				
waterlines (removal)				
shafts				
swales				

- **TRAFFIC**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
staging				
number of closed lanes				
night operations				
influence on other surrounding streets				
construction traffic control				
detour roads				
sequential arrows				
closure (days and hours)				
labor (number of hours)				
design				
delineation (pavement markings, guideposts, barrier delineation, raised pavement markers, impact attenuator markings)				
intersections, interchanges, auxiliary lanes				
signalization				
signs				
detection systems				
safety items (crash cushions)				
barriers, guardrail				
work zones				
illumination and lighting				
ramp meters				
transitions				
climbing lanes (for slow vehicles)				
special shoulder designs				
bicycle path				
HOV lanes				

- **ROADWAY SURFACE**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
pavement (cement concrete, asphalt concrete, bitumen)				
bases and subbases				
sidewalk				
curb				
shoulders/shoulder repair				
sawcutting				
slopes				
lanes/narrow lanes widths have to match roadway sections				
stationing (road, paving, striping, etc.)				
pavement method				

- **LANDSCAPING**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
irrigation system				
planting (seeding, fertilizing)				
plant establishment period				
fencing				

- **ENVIRONMENTAL MITIGATION**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
planting/wetland planting and re-vegetation				
seeding/fertilization				
trees/shrubs removal				
sandbag diversion dams				
hazardous waste cleanup				
pollution control				
groundwater contamination				
dust control				

- **HEARINGS**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
project hearings				
access hearings				

- **PERMITS**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
utilities agreements				
environmental permits				
US Department of the Army-Corps of engineers permits (section 10 and section 404 permits)				
Hydraulic Project Approval (Washington State Department of fisheries and wildlife)				
US coast guard permits				
US forest services				
Federal aviation administration				
Washington State Department of natural resources				
Washington State Department of Ecology				
local agencies (building, air pollution, shorelines permits, etc.)				
flood permit				
Sensitive area ordinance/public agency utility exemption permit (SAO/PAUE)				
grading/clearing permit				
noise variance				
temporary erosion and sedimentation control plan				
temporary water quality modification permit				
national pollution discharge elimination system permit application (NPDES)				
storm water site plan				

- **GEOTECH/EARTHWORK**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested action
roadway excavation/embankment				
excavation for ponds or wetlands				
structure excavation				
fill				
stockpiling/storage/dumpsites				
materials usage/salvage				
stabilization				
site conditions (topography, profiles, etc.)				
boring/drilling				
soil compaction				
clearing, grubbing, roadside cleanup				
removal of structures and obstructions				
haul				

slope treatment				
subgrade preparation				
watering				
ditch and channel excavation				
trimming and cleanup				

- **STRUCTURES**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
site data report				
timber structures				
bridges				
concrete mix/steel				
bearings				
girder				
foundation				
expansion joints				
piles/columns				
reinforcement				
bridge railing				
walls/retaining walls				
material (concrete mix)				
live poles between wall layers				
foundation				
panels				
reinforcement				
panels/stem panels				
appurtenant structures				
pedestrian/animals structures (habitat for fish, animal passage, etc.)				
tunnel				
mud slab/waterproofing				
roof slab				
pavement method				
painting				
waterproofing				
cribbing				

- **UTILITIES**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
electricity/power lines/power poles				
wire conduits				
power sources location				
gas				
cable				
telephone				
sewer lines				
utility conflicts				

- RIGHT OF WAY & ACCESS CONTROL

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
existing/proposed right of way limits				
appraisal				
transaction				
acquisition				
condemnation				
relocation				
cattle passes				
pit, stockpile and waste sites (haul road, detour routes)				
utility				
railroad				
international boundaries				
easement/construction permits				
programming for funds				
access control				
access report/access hearing plans				
monuments (alignment, property corner, others)				
fencing				
At the design report stage				
right of way estimate				
purchase cost				
relocation assistance benefits payments				
other land management staff expenses (acquisition services, relocation services, interim property management services)				

- CONSTRUCTION

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
access roads				
construction signs				
temporary signalization/striping/illumination/impact attenuators				
site preparation				
construction space				
field office building location				
equipment/material				
construction schedule/sequence				
survey control staking and monuments				
construction equipment				
cranes, derricks				
trucks				

- **MAINTENANCE**

ITEMS	Check (Y/N)	Required action	When by Whom	Suggested estimate
roadside cleanup				
drainage cleanup				
fire protection systems				

- **CONTINGENCIES**

5%				

E.5 Last 90% CRP checklist

ITEM #	ITEMS TO BE CHECKED	CHECK (Y/N)	ACTION
1	*PLANS*		
1.1	*Completeness*		
1.1.1	All originals provided with the PS&E submittal (at 90%)		
1.1.2	All original plan sheets signed (at 90%)		
1.1.3	Required information complete		
a	Typical layouts		
b	Typical sections		
c	Profiles, grade lines, superelevations		
d	Contour grades, topo, original ground elevations		
e	Summary of quantities, stationing		
f	Construction details		
g	Construction area signing		
h	Drainage profiles		
i	Earthwork		
j	Structural details		
k	Quantity and unit designations		
l	Utilities		
m	Illumination		
n	Traffic signal systems		
o	Final pay designations		
p	Other		
1.2	*Accuracy and clearness*		
1.2.1	Clarity of plans (readable) in general		
1.2.2	Limits of work		
1.2.3	Details		
1.2.4	Terminology, abbreviations, symbols (legends on drawings)		
1.2.5	Summary of quantities (exactitude and appropriateness)		
1.2.6	Cross references		
1.2.7	Final pay designations		
1.2.8	Other		
1.3	*Conformance to Policy*		
1.3.1	Drafting and plans manual followed		
1.3.2	High and low risk policy		
1.3.3	Use standard plans		
1.3.4	Final pay items		
1.3.5	Traffic control		
1.3.6	Trade names		
1.3.7	Required local agency plans		
1.3.8	Other		

ITEM #	ITEMS TO BE CHECKED	CHECK (Y/N)	ACTION
2	***SPECIFICATIONS***		
2.1	*Completeness*		
2.1.1	All items of work covered		
2.1.2	Order of work		
2.1.3	Method of payment included for each item of work		
2.1.4	Obstructions included		
2.1.5	Cooperation included		
2.1.6	Railroad requirements included		
2.1.7	Special conditions covered		
2.1.8	State furnished materials complete		
2.1.9	Method of measurements explained		
2.1.10	All documents provided (soils, borings report)		
2.1.11	Other		
2.2	*Accuracy and clearness*		
2.2.1	Accepted terms and abbreviations well used or correct		
2.2.2	Conflicting or ambiguous requirements solved		
2.2.3	Structures requirements properly integrated		
2.2.4	Materials needed known (concrete)		
2.2.5	Stationing correct		
2.2.6	Order of work		
2.2.7	Other		
2.3	*Conformance to Policy*		
2.3.1	Specific Special provisions edited correctly		
2.3.2	Standard specifications reworded or repeated		
2.3.3	Specific Special provisions instructions followed		
2.3.4	Standard format and style used		
2.3.5	Required local agencies specifications included (fills in, permits)		
2.3.6	Standard pay clauses used		
2.3.7	Special construction procedures		
2.3.8	Other		
2.4	*Specific Special Provisions need closer review by the Design team*		
2.4.1	Material		
2.4.2	Combining structures		
2.4.3	Order of work		
2.4.4	Maintenance of traffic		
2.4.5	Traffic control		
2.4.6	Pavement (PCC, AC)		
2.4.7	Existing highway facility		
2.4.8	Other		

ITEM #	ITEMS TO BE CHECKED	CHECK (Y/N)	ACTION
3	*ESTIMATES*		
3.1	*Completeness*		
3.1.1	All pay items of work included		
3.1.2	Specialty items included		
3.1.3	Supplemental work complete		
3.1.4	State furnished materials and expenses complete		
3.1.5	Structures items included		
3.1.6	Other		
3.2	*Accuracy and clearness*		
3.2.1	Correct item code numbers and descriptions		
3.2.2	Use of standard units of measure		
3.2.3	One-time items in correct order (specialty items)		
3.2.4	Correct quantities		
3.2.5	Reasonable prices		
3.2.6	Other		
3.3	*Conformance to Policy*		
3.3.1	Rounding of quantities correct		
3.3.2	Decimal quantities correct		
3.3.3	Other		