WORK ZONE DESIGN AND OPERATION ENHANCEMENTS

Final Report

SPR 669

RESEARCH

Oregon Department of Transportation

WORK ZONE DESIGN AND OPERATION ENHANCEMENTS

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by

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16. Abstract

Oregon Department of Transportation contractors are required to implement Traffic Control Plans (TCPs) to protect and direct traffic through work zones. The design and implementation of TCPs have shown variation from project-to-project across the State. The impact of this lack of consistency is magnified as a result of an increase in the number of work zones, higher traffic volumes, more work being conducted at night to minimize traffic interruptions, a greater number of parties (consultants) involved, and the pressure to complete projects faster. The primary purpose of this research study was to enable improved safety performance through work zones on state roadways. To fulfill this goal, the research aimed to identify ways to modify TCPs to improve their quality and consistency and develop suggested guidelines to follow to design, review, implement, and inspect TCPs. Implementation of the research results is expected to improve consistency of TCPs and decrease the number of work zone fatalities and injuries. Auxiliary benefits resulting from improvements in traffic flow through work zones and the elimination of work zone crashes will include greater mobility, smoother operations, and increased efficiency across the State's roadway network.

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APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
	NOTE: Volumes greater than 1000 L shall be shown in m^3.			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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DISCLAIMER

WORK ZONE DESIGN AND OPERATION ENHANCEMENTS

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EXECUTIVE SUMMARY

The Oregon Department of Transportation (ODOT) develops traffic control plans (TCPs) for the highway construction projects it undertakes. The intent of the TCP is to communicate required traffic control measures to the construction team, and to control traffic through the work zone in an effort to ensure safe motorist travel through the work zone and a safe worksite for the construction workers. The quality of the design, review, implementation, and inspection of TCPs impacts the safety hazards experienced by motorists and workers in the work zone.

A research study was initiated to identify how to effectively design, review, implement, and inspect TCPs in order to minimize work zone safety hazards, prevent worker and motorist injuries and fatalities, and optimize mobility throughout the state's highway transportation system. As part of the study, the development and implementation of TCPs on ODOT projects were reviewed

The research study was designed to draw from the knowledge and experiences of those involved in transportation construction projects at both the state and national levels. The primary research tasks included a review of literature relevant to the topic, a survey of ODOT personnel and others involved in ODOT projects regarding the TCP process, and analyses of case study projects. The case study process included numerous data collection efforts: a survey of the project personnel, review of inspector and Traffic Control Supervisor reports, review and evaluation of the TCPs for the projects, collection and analysis of crash data on the projects, and analysis of work zone tour scores from the annual ODOT tour of work zones.

The study found that there is general consensus throughout project personnel (both ODOT personnel and others) that the quality of TCP design, review, implementation, and inspection is high. There is also general agreement that motorist safety and worker safety are of higher priority to project success as compared to other project objectives such as cost, schedule, and productivity. The support from the main ODOT office in Salem is beneficial to the TCP process, and close proximity of the design teams to the regional construction offices also benefit the TCP design. Other strengths are the use of designers with extensive years of experience, and regular and early involvement of TCP designers. The entire process is enabled when there is early cooperation and buy-in from all members of the project team. Each project and work zone, however, is different. TCPs need to be tailored to each project, and the TCP process should accommodate the need to create project-specific TCPs.

Barriers and weaknesses of the TCP process exist as well. There is a different standard of care between those involved in TCP design and those involved in TCP implementation. Although designers and constructors consistently identify safety as a high priority, the means by which work zone safety is achieved differs between these groups. This can affect the importance placed on specific aspects of a TCP design and the ultimate level of safety in a work zone. There is a need for earlier and more thorough TCP constructability reviews, and a need to communicate more clearly with and educate the traveling public about work zones on a project by project

basis. The identified barriers and weaknesses highlight the importance of ODOT communicating its expectation with respect to the quality of TCP design and TCP implementation and call for clarification of the Department's TCP oversight and quality control process.

The study revealed that the following distinctions between regions in regards to TCP quality, and some features of the TCP process that impact the quality, consistency, and safety of TCPs:

- In regards to the TCP design, the number of years of experience of the TCP designer was found to be a differentiator when judging the quality of TCP designs. On those projects in which the TCP designers had more years of experience, the projects had a higher level of quality.

- The use of solely standard TCP design drawings can be a detriment to the quality of the TCP and safety in the work zone. Standard drawings may not provide sufficient detail, and may not convey the importance of the TCP to the contractor. Accommodation of site detail was viewed as a challenging part of implementing the TCP. If no site specific detail is provided, TCP design modifications made during construction may not be appropriate. A lack of a full review of site modified TCPs, which is sometimes the case, may result in inappropriate traffic control measures and less safe work zones.

- Some confusion and frustration with the TCP process exists. Specifically, with respect to the design, those who implement the design stated that the greatest frustrations were that the TCP design does not match the site conditions and that the TCP design documents are unclear and/or contain errors. As a result, TCP implementers indicated that they need to frequently modify the TCP design because they felt it does not provide a safe work environment. In addition, implementers indicated that the most common reasons for modifying the TCP in the field is that: the TCP cannot be constructed as designed, traffic flow is excessively impeded through the project, motorists ignore specified turn movements, and the construction methods chosen are not compatible with the TCP design.

- The review function in the TCP process is critical to its success. Reviews, both peer design reviews and reviews of field modified TCPs, provide a means to assure quality in the TCP design. The lowest review ratings were given for Regions 3 and 4. The points in the process in which it was identified that needed the most improvement were in the Advance Plans TCP Package and the Plans-in-Hand Review phases. It is also important to ensure that the right people participate in the reviews. Incorporating both personnel who have TCP design experience and personnel who are knowledgeable about construction means and methods is critical to conducting a quality review. No documents containing best practices related to peer and constructability reviews for TCP's were discovered in the literature review. Further research on this topic may provide guidance toward developing a formal and effective TCP review process.

- Implementers (construction contractors) should have TCP training and experience in TCP implementation. Requiring a TC Supervisor on projects, or during critical construction activities on projects, is one means to ensure that this experience and oversight is present on projects. For example, night time construction or stage changes are critical activities that impact safety in work zones and the presence of a TC Supervisor on-site would provide additional experience and expertise to mitigate potential hazards. A TC Supervisor is used more frequently in other states, while being rated as having a high impact on work zone safety.

- From the TCP designer's perspective, greater adherence to the TCP design is needed by the contractors. This requires an increased level of enforcement of the TCP design. The most commonly cited problems with implementation of the TCP are: improper transition lengths, incorrect degree of curve, over-signing the work zone, leaving gaps in traffic control measures, unknown utility schedules and locations, inadequate separation of traffic and work areas, and improper allowances for drainage. In regards to the phasing of the work, not integrating the TCP with the construction schedule was recognized as a problem as well.

- The amount of training was also found to be important in addition to the amount of experience. Training helps to communicate the expected standard of care to the implementers, an issue that is especially important on complex projects and on projects in which the TCP needs to be modified to accommodate changed site conditions or construction methods.

- The research study revealed that the frequency and quality of inspection during construction is perceived as sufficient. However, inspection quality from one project to another, and between regions, is not consistent and should be improved. This is reflected in the lack of detailed information provided in the inspection reports and the TCS reports on some projects, especially on the days when a crash occurs on the project. Inspection methods and levels of expectation (for the design staff as well as for the field staff) should be standard across all projects and effectively communicated. Improved crash related data collection methods through modifications to the TCS and Daily Report templates and more thorough review of the reports would help to standardize inspection expectations and provide greater opportunity for 'lessons learned'.

- Supporting quality TCP designs encompasses the sharing of lessons learned from past projects. It was found that lessons learned are shared, although the means of sharing varies. Commonly cited means in which lessons are shared were: ODOT post-project narrative, word of mouth between project team members, and crew and design team meetings during the project. However, there was recognition of a lack of, and need for, a project-to-project lessons learned/knowledge management system. This lessons-learned system should be accessible across all regions and to consultants.

1.0 INTRODUCTION

1.1 BACKGROUND

Crashes continue to occur in roadway construction work zones throughout Oregon and the rest of the United States. In Oregon, the number of work zone involved crashes has increased in the past several years (493 in 2004; 511 in 2005; 532 in 2006; 591 in 2007) according to ODOT's Crash and Analysis and Reporting Section (CARS) database. Many, if not all of these crashes, result in motorist and construction worker injuries and fatalities. Table 1.1 shows both the total number of fatal crashes and number of fatal crashes in construction zones for the United States and Oregon over the last 10 years.

Table 1.1: Motor Vehicle Crash Fatalities 1998 - 2008

	National			Oregon		
Year	Construction Zone motor vehicle traffic crash fatalities	Total motor vehicle traffic crash fatalities	Fatalities (nationwide) in construction zone as % of total	Construction Zone motor vehicle traffic crash fatalities	Total motor vehicle traffic crash fatalities	Fatalities (Oregon) in construction zone as % of total
2008	720	37261	1.9%	6	416	1.4%
2007	835	41059	2.0%	11	455	2.4%
2006	1004	42708	2.4%	5	478	1.0%
2005	1058	43510	2.4%	20	487	4.1%
2004	1063	42836	2.5%	12	456	2.6%
2003	1095	42844	2.6%	2	512	0.4%
2002	1186	43005	2.8%	5	436	1.1%
2001	989	42196	2.3%	5	488	1.0%
2000	1026	41945	2.4%	6	451	1.3%
1999	872	41717	2.1%	9	414	2.2%
1998	772	41501	1.9%	14	538	2.6%

*Fatality Analysis and Reporting System (FARS).FARS. "Fatalities and Fatality Rates", Last Access 9/2/09, http://www.fars.nhtsa.dot.gov/States/StatesFatalitiesFatalityRates.aspx

The impact of the crashes goes beyond the social and emotional impact of the loss of life and injured citizens. The cost associated with each fatal crash can amount to millions of dollars including the additional losses to the public due to road closures, decreased mobility, and increased travel times as a result of crashes in work zones have a significant impact to the State's economy.

ODOT's contractors are required to implement traffic control plans (TCPs) to protect and direct traffic through work zones. TCPs are developed and implemented to provide a safe and efficient path for traffic though the work zone and a safe environment for construction workers. A quality TCP design and effective implementation are goals for every project. However, TCP quality can vary from project-to-project. In fact, in Oregon, it is theorized that the design and implementation of TCPs is beginning to vary greatly from project-to-project across the State. The variance between projects may be the result of many factors; the process by which TCPs are designed, reviewed, implemented, and inspected; the features and layout of TCPs; and communication of TCPs to the constructor (a term used to represent the construction contractor as opposed to the design contractor). The impact of inconsistent and poorly designed TCPs is magnified as a result of an increase in the number of work zones across the state, higher traffic volumes, more work being conducted at night to minimize traffic interruptions, a greater number of parties (consultants) involved, and the pressure to complete projects faster.

On October 12, 2007, the new Federal Highway Administration (FHWA) rule titled "Work Zone Safety and Mobility" went into effect (FHWA 2007). Within the rule, FHWA asks DOTs to develop and maintain a Transportation Management Plan (TMP) for each of their "significant" highway construction projects. The TMP is meant to serve as a record of all work zone analysis and TCP decision-making that transpired during the project development phase of the project. The hope is to record and preserve important decisions made regarding the TCP designs and construction staging strategies that, in the past, were forgotten, lost, or too easily overridden due to a lack of supporting documentation. The TMP is to be used to help construction offices quickly and efficiently respond to proposed changes to the TCP, yet avoid inadvertently superseding previous efforts and key decisions made by the Project Development Team.

1.2 STUDY GOALS AND OBJECTIVES

The primary goal of this research study was to enable improved safety performance for the motorists, as well as the construction personnel, in work zones on state roadways. The research focused on improving safety performance through reductions in safety hazards, improving project development processes, and identifying quality control issues. That is, by efficiently designing and implementing high quality TCPs that eliminate or reduce safety hazards in work zones, it is assumed that safety performance will improve. To fulfill this goal the following objectives were established:

- Identify ways to modify TCPs to improve their quality and consistency.
- Identify how the process of designing and reviewing TCPs can be modified to improve their quality and consistency.
- Identify effective processes and practices for implementing and inspecting work zones for compliance with the TCPs.
- Develop suggested guidelines for ODOT to follow to design, review, implement, and inspect TCPs.

Implementation of improvements based on the research results would serve to improve statewide quality and consistency of ODOT TCPs, reduce safety hazards in work zones, and help decrease the number of work zone fatalities and injuries. Auxiliary benefits resulting from improvements in traffic flow through work zones and the elimination of work zone crashes will include greater mobility, smoother operations, and increased efficiency across the State's roadway network. The research provides ODOT with a means to improve and maintain safety performance levels in construction work zones.

1.3 RESEARCH SCOPE AND METHODS

To achieve the research goal and meet the stated objectives, seven primary research tasks were planned for the study:

Task 1: Project Initiation

This task involved collecting background information on the design and implementation of TCPs. TCPs were collected and reviewed for a variety of projects in each ODOT region and projects delivered by Oregon Bridge Delivery Partners (OBDP). The intent of this task was to develop an understanding of what type of information is available, how it can be accessed and how easy it is to access, and how it can be used in the study.

Task 2: Literature and Current Practice Review

For this task, an in-depth review of literature, reports, and procedure manuals used as guidance for creating and implementing TCPs was conducted. Special consideration was given to the current practices of State Agencies that have processes and resources similar to that of ODOT. The research builds upon previous research efforts and does not duplicate work published by the Transportation Research Board (TRB), FHWA, and other organizations.

Task 3: Survey ODOT Personnel and Consultants

This task involves conducting interviews of ODOT personnel, contractors, and consultants who participate in designing, reviewing, and implementing TCPs. The purpose of the interviews is to gain their perspectives on current policy and practices and the enablers and barriers to successful design and implementation of TCPs. A list of interview candidates was selected with input from the TAC. An interview questionnaire was developed and utilized to ensure consistency and clarity in the interviews.

Task 4: Develop Sample of Study Projects

Task 4 entails developing a representative sample of roadway construction projects to study that includes a combination of both current and past projects. Project characteristics considered when developing the study sample include: type of project, type of highway, regional representation, project size, percent completion of the project, and the availability of data. Projects on which there were work zone crashes and those that were crash-free were included in the sample. In addition, projects in which the TCPs were designed by ODOT staff and those designed by hired consultants are included.

Task 5: Collect Project Data

After the sample of study projects was identified, data from the projects was collected. This task begins with identifying the personnel involved in the projects and locating where and how to collect the data. The following activities were undertaken for each sample project:

- Collect data related to the nature and characteristics of the TCP design and implementation along with roadway crash data.

- Collect the actual TCPs and any accompanying documentation that describes the development and implementation of the TCPs.
- Contact and interview personnel involved in the projects to gain an understanding of implementation in practice.
- Collect for review the annual work zone review and evaluation reports conducted by the ODOT Traffic/Roadway Section which show the quality of implementation of the TCPs on the work site.
- Collect any additional information pertinent to assess the TCP development and implementation process.

Task 6: Analyze Project Data

Following the collection of project data, the TCP documentation and work zone data was analyzed to determine:

- The TCP features (both design and implementation) that were contributing factors to work zone crashes;
- Potential revisions to the TCP design and review process to improve safety; and
- The impacts of ODOT's TCP design practices, including related to in-house and outsourced designs, on the quality and consistency of TCPs with respect to design standard compliance, staging methods, device usage, and drafting similarities.

Task 7: Development of TCP Guidelines and Recommendations

Based on the results of the analysis in Task 6, guidelines were developed to assist ODOT with ensuring high quality and effective TCPs. The guidelines will provide guidance on designing and reviewing TCPs, communicating the TCP information, and implementing and inspecting the TCPs in practice. It is anticipated that the guidelines would be incorporated into current ODOT documents for dissemination and use.

1.4 IMPLEMENTATION

The results of this research may potentially modify the way ODOT plans, designs, and implements work zone TCPs, and result in safer worksites for construction workers and the general traveling public. The project Technical Advisory Committee held a meeting to discuss the recommendations of the report and implementation. Among other items, interest was expressed for potential changes in the following areas:

- Increase knowledge, sharing, and consistency among TCP designers similar to that previously available under a centralized organizational structure.
- Increase training opportunities for TCP designers statewide so that they can gain a better understanding of TCP designs and process.
- Identify potentially high risk and/or more complex TCPs during the planning stage.

It is also possible that additional resources and equipment investments may be identified to support implantation, such as the need for added personnel, adding supplemental message signs, providing additional traffic control devices, and improving information delivery to the traveling public and freight carriers. The guidelines are expected to be implemented in practice by design and construction personnel when developing and implementing TCPs on construction projects.

2.0 LITERATURE REVIEW

An extensive search was conducted to uncover literature on the development and implementation of TCPs for construction work zones. Keyword searches of article databases (TRIS Online and Compendex) and of the World Wide Web (using Google as a search engine) were used to locate research articles, reports, industry standards, and other documents that address issues related to TCPs. Applicable State and Federal standards were also examined as part of the literature review and are presented here. Regulatory requirements in place for traffic control measures are provided in Section 2.2 of the report.

2.1 PREVIOUS RESEARCH

2.1.1 Work Zone Crashes

In order to determine how to optimize the design of TCPs for construction work zones it was necessary to understand the types of crashes that commonly occur in work zones. Using crash reports and other resources, rear-end collisions and sideswipes were identified as the most common types of crashes (*Muttart et al. 2007; Tsyganov et al. 2003; FHWA 2003a; Sun et al. 2006; Upchurch 1996; Khattak et al. 2002*). Other common types of accidents include the following:

- joint collision of vehicles;
- vehicles running into materials and equipment;
- getting into pits and potholes;
- running into road workers;
- running into pedestrians; and
- vehicles colliding with road-building machines or mechanisms (*Tsyganov et al. 2003*).

Especially concerning for roadway workers is the fact that most fatal work zone accidents occur with road widening or resurfacing projects (*Tsyganov et al. 2003*).

It is important to note that crash data can be unclear and difficult to access. Making this data accessible and usable is one of the key objectives identified by AASHTO in the NCHRP report, "Guide for Reducing Work Collisions" (*Antonucci et al. 2005*).

2.1.2 Safety in Construction Work Zones

Providing and enhancing construction work zone safety has been the topic of several research articles and government reports. For example, Stidger (*1990*) suggests the use of visible manned or unmanned police cars and/or the use of radar as the most effective deterrent to motorists speeding in work zones. This sentiment was echoed by Pratt et al. (*2001*), Antonucci et al. (*2005*), and South (*1998*). Additional suggestions for means to enhance safety in construction work zones that are common throughout the literature include the use of:

- High visibility apparel and signage, especially using fluorescent orange on clothing, equipment, and signs (*Stidger 1990; Pratt et al. 2001; FHWA 2003a; Upchurch 1996; Antonucci et al. 2005*).
- Clear, effective, and credible real-time signage indicating when the work zone will start and what is expected of drivers (*Stidger 1990; Pratt et al. 2001; South 1998; Upchurch 1996*). Problems such as ineffective traffic control are consistently identified as a safety issue in work zones (*Tsyganov et al. 2003*). The use of traffic control devices for multiple traffic control requirements can be confusing for drivers as well.
- Communication between workers in/on equipment and pedestrian workers through the use of portable radios (*Stidger 1990*). This is especially important during truck backup operations. A clear chain of command that requires the spotter to control the process increases safety in this work zone (*Connolly 2006*).
- Public information campaigns to educate the public about upcoming and current traffic construction (*Stidger 1990; Pratt et al. 2001; South 1998; Upchurch 1996; Antonucci et al. 2005*).
- A competent person for accountability and oversight on the work site (Pratt et al., 2001).
- Full lane closure significantly reduces the risk to workers and reduces project duration, yet can be more expensive. However, it has been received favorably by the public in projects in Delaware, Oregon, and Detroit (*FHWA 2003-4*).

Examples of the success of these practices can be seen in the FHWA "Best Practices Fact Sheets". The states of Illinois, Connecticut, Arkansas, and Delaware found their projects to be successful based on a strong public relations campaign. Connecticut was also successful in using a strong police presence during the campaign. Illinois was successful on another project with the use of real-time information through portable message boards. The State of Oregon follows the "Best Practices" listed below as identified by FHWA in its guidebook, "Work Zone Operations Best Practices Guidebook" (*2000*):

28. The specification for 20 Minute Maximum Delay Period
29. Performance Goal for Work Zones to be designed at the Posted Speed
30. Use of Commuter Incentives to Minimize Congestion in Work Zones
31. Minimum Geometric Standards for Work Zones
60. Develop Media Partnerships
61. Public Outreach Efforts to Increase Participation in Traffic Management Plan (TMP) strategies
134. Lane Rental Specification

135. Contract Award of the I-5 Interstate Bridge Lift Span Repair Project Based on Performance and Cost

Some notable research has been conducted regarding identification and use of specific traffic control devices. The State of New Jersey looked at devices that are most effective in short-term work zone operations (*Paaswell et al. 2006*). Nine devices worthy of short-term work zones were identified and tested for traffic control effectiveness. It was found that flashing Stop/Slow paddles are the only device effective for these types of work zones and worker safety. Some new devices are also being tested including the Balsi Beam which New Jersey found had "the greatest potential for protecting exposed workers in short duration work operations. The beam provides a positive protection from errant vehicles and is crash worthy as tested by NCHRP criteria. It can be set up in less than 10 minutes and requires no clear zone between the beam and workers." (*Paaswell et al. 2006*).

Lachhwani and Horowitz (*2005*) investigated applications of advanced traveler information systems (ATIS) for application in work zones. Some ATIS devices include variable message signs, radio highway advisories, CB radios, and speed advisory displays. Specifically, the researchers wanted to know when these devices could be used to increase work zone safety. Though the researchers felt the study periods were too short for a consensus, several devices showed promising results:

1. Real-time systems: These systems offer strong beneficial incentives, but they can be costly. The systems can alert drivers to problems, thereby reducing driver frustration and can improve the merging or diversion of traffic. However, there is not any "stock" system configuration, significant planning is required, and the advantages over static signs may not be significant enough with lighter traffic.
2. Stand-alone systems: Simple tasks required for this device are limiting, less flexible, and less effective, but are also less costly and can be used with static signing to mitigate speeding issues.

2.1.3 Traffic Control Design and Evaluation

The literature search uncovered several documents addressing the process to develop and evaluate traffic control plans. In their report titled, "Design of Construction Work Zones on High-Speed Highways" (*Mahoney et al. 2007*), the researchers identified design controls and design principles for traffic control plans. Design controls are elements outside of the designer's control, yet relevant to planning. Design principles are developed through research to determine the driving lessons for traffic control planning with safety being one of the principles of work zone traffic control design. Conceptual design must encompass "project-level" strategies such as lane closure, traffic functionality, capacity, and cost. More detailed design elements include traffic barrier design and placement, the use of arrow panels, screens, and lighting requirements. TCP input should include (*Federal 1988*):

- a description of the type, size, budget, and timeline for the project;
- data that describes the current traffic conditions, such as 24 hour volume counts, daily/seasonal volume variation, and daily volume counts; and

- a physical and locational description of the project and special features to be considered including right-of-way limits, cross-sectional feature, and possible detours.

Traffic control planning itself considers the type of work zone (maintenance, utility, construction), the length of the work zone, time of work including the amount of day versus nighttime work, the number of lanes affected by the work, the width of lanes during the work, speed control measures, and right-of-way methods (*Zwahlen and Oner 2006*). Traffic control planning breaks the work zone into multiple components such as pre-work or "advance warning" areas, transition areas, work zone activity areas, and work zone completion areas (*Transportation Builder 1993*).

Design should include additional evaluation of the alternatives that considers constraints, cost/budget, and traffic impacts (*Zwahlen and Oner 2006*). The use of computer models or other algorithms have been used to quantify and calculate capacity, constructability, and other mobility impacts during construction (*Zwahlen and Oner 2006; Schrock and Maze 2000; Heaslip et al. 2006*). "Construction experience input and consultations of lessons learned regarding traffic management can be very beneficial to an effective traffic control plan." (*Fisher and Rajan, 1996*). Most agencies, however, do not evaluate their traffic control plans post-construction to assist with future planning. Oregon does review some projects during construction during a 2-week review period (*Maze et al. 2005*).

Maze et al. (*2005*) identified problems in the traffic control planning processes used by state agencies. These problems included:

- the lack of "policy level direction" for safety in work zones,
- the lack of evaluation processes for work zone safety and mobility impact "throughout the project development",
- the lack of development of "processes to understand how various offices should interact throughout the life-cycle of project development" for planning and monitoring work zones; and
- the lack of "performance data collection processes" for comparison and improvement in traffic control planning for work zones.

Suggestions for improving work zone traffic control are provided in the literature as well. Zwahlen and Oner (*2006*) suggested the following to improve traffic control:

- keeping all design materials and references together;
- making sure signing material is visible and oriented correctly;
- worker clothing should be fluorescent yellow/green to distinguish from the fluorescent orange used on signing; and
- the use of intrusion devices to notify workers when someone has crossed a barrier.

2.1.4 Inspection and Enforcement

The researchers made an effort as part of the literature search to locate documents addressing safety impacts related to the inspection of work zones during construction and the enforcement of the requirements set forth in the traffic control plans. It was assumed that work zone safety improves with higher quality inspections and with added measures to make constructors accountable for implementation. However, no documents were located that addressed the inspection and enforcement aspects of traffic control plan implementation. These factors were investigated as part of the subsequent tasks in the research study.

2.1.5 Consultant Based Design

The literature search also aimed at uncovering documents discussing the process of using outside consultants to design traffic control plans. Consultant-based design of traffic control plans, as opposed to using DOT staff, is used in some states, including Oregon. The administrative and management requirements associated with consultant-based design may impact the quality of TCPs and, as a result, safety in construction work zones. Similar to the lack of literature related to inspection and enforcement of TCPs, no documents addressing the relationship between consultant-based design and TCPs were located. The use of consultants to design TCPs was considered when evaluating TCPs as part of the research study.

2.1.6 Traffic Control Plan Complexity

Research was conducted to identify standard methods used to rate the complexity of traffic control plan design and implementation. A traffic control plan that is relatively complex may be susceptible to design oversights and implementation deficiencies. "The complexity of a TCP will vary based upon the complexity of the circumstances and conditions accompanying the roadway operation. Each TCP should be uniquely appropriate to the actual set of conditions and circumstances surrounding the individual work zone operation" (*Transportation Builder 1993*).

The Manual for Uniform Traffic Control Devices (MUTCD) Chapter 6a-f discusses traffic control devices but makes no mention of impact on complexity. However, guidance is provided for implementation of devices in cases where traffic control is deemed more complex. MUTCD indicates that temporary traffic control "should be modified by incorporating appropriate devices and practices" from a list that specifies the use of certain additional devices, upgraded devices, increased warning distances, and lighting as a means of meeting the demands of more complex traffic control environments. The use of these devices and practices on roadway construction projects may indicate traffic control plan complexity.

Traffic control devices have been rated for effectiveness on a scale of 1 to 10, with 10 representing the highest effectiveness. Arrow signs (8.7) and flaggers (8.6) ranked first and second in terms of effectiveness on highway repair projects while barrels (8.2) and barriers (7.4) were rated the most effective for new highway construction. Other devices that were rated to be effective included portable changeable message signs, concrete barriers, and cones (*Stidger 1992*). No similar ratings were discovered that measured the complexity associated with each device used in traffic control plans. A similar survey of traffic control plan designers and constructors to rate the complexity associated with each device was implemented for projects considered for this study (see Section 4.0 of this report).

2.2 REGULATORY REQUIREMENTS, SPECIFICATIONS, AND STANDARDS

State and federal agencies provide standards that must be followed during highway construction operations to ensure the safety of motorists and workers. As part of the literature review, standards published by State of Oregon and national agencies were examined for content applicable to the design and implementation of TCPs. This section describes the regulatory requirements contained in those standards.

2.2.1 Oregon Standard Specifications for Construction

The "Oregon Standard Specifications for Construction" (*ODOT 2008a*) document describes the terms and conditions under which projects are to be constructed and the contractual obligations of the construction contracting parties. *Part 00200 – Temporary Features and Appurtenances of the Standard Specifications* provides the specifications for temporary work zone features including those related to traffic control.

Within the ODOT standard specs, *Section 00220 – Accommodations for Public Traffic* identifies the scope of work which the constructor must provide to ensure safe travel by the public through and around the work zone. In addition to general requirements addressing public safety and mobility, Subsection 00220.40 provides the following specific requirements related to construction sites:

> **00220.40 General Requirements** - Provide the following for public traffic in all construction areas:
>
> a) **Traffic Nuisance Abatement** - If loose rock or dust exists on roadway surfaces and shoulders, the Engineer may direct one or more of the following:
>
> - Use flaggers or pilot cars and flaggers.
> - Apply a fine spray of water to the surface as directed.
> - Sweep paved surfaces with power brooms.
>
> b) **Detours and Stage Construction** - Construct and remove, if required, detours, stage construction roadways, shoulders, and temporary bridges, including accessory features shown or ordered.
>
> c) **Driveways** - Provide reasonable access as follows:
>
> - Replace and maintain business accesses, driveways, approaches, crossings, and intersections as directed.
> - Use reasonably well-graded aggregate material.

- Before placing the permanent base, do one of the following:
    - Uniformly spread the temporary aggregate material over the subgrade.
    - Remove and place the temporary aggregate material in the shoulder slope area if it meets quality requirements.
    - Dispose of the temporary aggregate material in a manner satisfactory to the Engineer.

d) **Adjacent to Excavations** - Where paved shoulders adjacent to excavations are less than 4 feet wide, protect the traffic as follows:

- At the end of each working day, backfill pavement edge excavations to the elevation of the existing pavement with permanent base material or with a temporary wedge of aggregate as shown on the standard drawings.
- Do not excavate along both edges of the pavement adjacent to traffic at the same time. Before excavating at the edge of the pavement on the opposite side of the roadway, complete the construction to existing pavement elevation on the side which was excavated first.
- Remove the temporary wedge of aggregate material, if used, before placing permanent base material, and place it in the shoulder slope area or spread it uniformly over the subgrade.

e) **Lane Restrictions** - Do not close any traffic lanes during the periods listed below:

- **Weekdays:**
    - Between 7:00 a.m. and 9:00 a.m. and between 4:00 p.m. and 6:00 p.m. Monday through Thursday
    - Between 7:00 a.m. and 9:00 a.m. Friday morning
- **Weekends** - Between 3:00 p.m. on Friday and midnight on Sunday.
- **Holidays** - Between noon on the day preceding a legal holiday or holiday weekend and midnight on a legal holiday or the last day of holiday weekend, except for Thanksgiving, when no lanes may be closed between noon on Wednesday and midnight on the following Sunday. For the purposes of this Section, legal holidays are as follows:
    - New Year’s Day on January 1
    - Memorial Day on the last Monday in May

- Independence Day on July 4
- Labor Day on the first Monday in September
- Thanksgiving Day on the fourth Thursday in November
- Christmas Day on December 25

When a holiday falls on Sunday, the following Monday shall be recognized as a legal holiday. When a holiday falls on Saturday, the preceding Friday shall be recognized as a legal holiday.

- **Special Events** - Between noon on the day preceding and midnight on the final day of the special event.

Section 00225 – Work Zone Traffic Control focuses specifically on controlling traffic through the work zone. The concentration of this section is on the work of the contractor in implementing the TCP. It describes the work of providing temporary traffic control measures (TCM) and furnishing, installing, moving, operating, maintaining, inspecting, and removing traffic control devices (TCD) throughout the project area according to the standard drawings, the traffic control plan for the project, the Standard Specifications, or as directed by the engineer.

Section 00225 of the Standard Specifications is directly applicable to the research study. The level of coordination between the TCP and the Standard Specifications may be an impact on the implementation of traffic control measures and therefore safety through work zones. In addition, the quality of implementation and inspection of the requirements of the Standard Specifications is a consideration of the study. Section 00225 discusses the need for the constructor to submit a TCP as part of the project. Specifically, *Section 00225.05 – Contractor Traffic Control Plan* states the following:

00225.05 Contractor Traffic Control Plan - Submit for approval, the Contractor TCP in writing five days before the pre-construction conference. If modifying or if not using the Agency TCP, submit the following:

- Proposed TCP showing all TCM and quantities of all TCD.
- Proposed order and duration of the TCM.
- Two copies of a sketch map of the Project showing all existing tourist-oriented directional (TOD) and business logo signs and a written narrative describing how these signs will be kept in service and protected throughout all the construction stages.
- A detailed temporary striping plan.

Further TCP revisions will be subject to a Contract change order before implementation.

The Standard Specifications are accompanied by "Special Provisions" and "Unique Specifications" that contain requirements for traffic control during construction. These documents augment the information provided in the Standard Specifications and need to be followed by constructors. The Unique Specifications includes specialized project specs for issues such as Truck Mounted Attenuator, Slope End Terminal, Reflective Barrier Panels, and Tow Trucks, etc.

2.2.2 Manual of Uniform Traffic Control Devices for Streets and Highways (MUTCD)

The *Manual of Uniform Traffic Control Devices for Streets and Highways* (*FHWA 2003*) is recognized as the national standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel. Part 6 of the MUTCD discusses the design of temporary traffic control zones and the features included in the control zones. These guidelines address all types of traffic control design requirements including the individual control features and their location and use in work zones.

The MUTCD relates to this research study, in that TCPs should be designed to meet the requirements of the MUTCD and discrepancies between the TCP and the MUTCD may negatively impact safety through the work zone. The research investigated the quality of TCPs on ODOT projects compared to that required within the MUTCD.

2.2.3 2006 Oregon Temporary Traffic Control Handbook

The *2006 Oregon Temporary Traffic Control Handbook* (*ODOT 2006*) provides a reference for the principles and standards for temporary traffic control zones in place continuously for three days or less on public roads in Oregon. It is based on the principles set forth in Part 6 of the *Manual on Uniform Traffic Control Device for Streets and Highways* published by the Federal Highway Administration (FHWA), and is an Oregon Supplement to the 2003 MUTCD. For work requiring devices in place longer than three days, a site specific traffic control plan based on the principles in Part 6 of the MUTCD is required.

The manual provides extensive guidelines for how to provide temporary traffic control measures, including guidance on flagging and portable signals, signs, pavement markings, and other traffic control devices. Diagrams are provided to indicate how to apply the traffic control measures under specific work zone conditions.

The guidelines contained in this handbook provide guidance applicable to construction work zones. However, the need for traffic control on construction projects extends beyond three days. Therefore, use of this handbook for construction projects is limited, in favor of the MUTCD.

2.2.4 2008 Traffic Control Plans Design Manual

The *2008 Traffic Control Plans Design Manual* (*ODOT 2008b*) introduces Traffic Control Plan Designers to their responsibilities within this discipline and provides an organized collection of traffic control plan design standards, guidelines, policies, and procedures to apply in their designs. The TCP Design Manual is intended to be utilized by TCP Designers within ODOT, members of City or County Public Works offices and private consulting engineering firms responsible for the development of temporary traffic control and highway construction staging plans. The manual discusses traffic control plans design in general (job description, design processes) and the specific TCP design elements (traffic control devices, standard drawings, bid estimates, specifications, etc.).

The TCP Design Manual is critical to ensuring consistent and high quality traffic control through work zones around the state. The research includes an investigation regarding the nature in which the manual is used, its level of use, and the familiarity with which Traffic Control Plans Designers are with the manual. Connections between knowledge of and familiarity with the manual and safety in construction work zones are investigated.

Accompanying the design manual are standard drawings for temporary traffic control. These drawings provide Traffic Control Plans Designers examples of traffic control drawings. The drawings are designed to help maintain consistency and quality of TCPs between projects.

2.2.5 Project-Level Transportation Management Plan Guidance Document

The *Project-Level Transportation Management Plan (TMP) Guidance Document* (*ODOT and OBDP, 2006*) outlines the intended content and purpose of the Project-Level TMP and assists in the development of these documents. The purpose of the transportation management program is to minimize disruptions to motorists, the freight industry, and communities without compromising public or worker safety, or the quality of work being performed. A Project-Level TMP, used for either single projects or coordination of multiple projects within a given area, provides the details behind the development of the TCP and other measures that are put in place for each project or group of projects to achieve this goal. The following documents are developed while the TMP is being prepared and need to be referenced in the TMP: (1) Temporary Traffic Control and Construction staging plans; (2) Detour plans, included in the Traffic Control Plan; and (3) Temporary Traffic Signal plans. These documents are of interest to the research study as they are used in conjunction with the TCP.

2.2.6 ODOT Sign Policy and Guidelines

The ODOT *Sign Policy and Guidelines* (*ODOT 2002*) is a combination of State of Oregon Revised Statutes, Administrative Rules, Federal Highway Administration rules and guidelines, and engineering judgment. Since the MUTCD has been adopted by ODOT as policy, the *Sign Policy and Guidelines* deal exclusively with items not included in the MUTCD or items that need further clarification as they are used on the state highway system. Chapter 6 of the guidelines addresses construction and maintenance signs. This chapter provides guidance on the size, layout, color, location, and other features of signs to be used in construction work zones. Verification that the signs actually used in construction work zones meet these requirements is a consideration of the research study.

2.2.7 FHWA Standard Highway Signs Manual

The *Standard Highway Signs* manual (FHWA, 2004) provides specifications for signs described in the *Manual of Uniform Traffic Control Devices* (MUTCD). It is designed for use by all traffic authorities, agencies, jurisdictions and persons involved in the fabrication, installation, and maintenance of traffic signs on streets and highways. The specifications for signs used to control traffic in construction work zones are provided in this FHWA manual.

2.2.8 Work Zone Traffic Analysis Manual

The *Work Zone Traffic Analysis Manual* (*ODOT and OBDP 2007*) was written to familiarize analysts and their leaders with ODOT's work zone analysis methodologies, guidelines, policies, and procedures to use in their determination of lane closure restriction recommendations. The manual is intended to be utilized by analysts within ODOT, as well as analysts for local authorities, consultant analysts, and other professionals outside of ODOT. The purpose of the manual is to: (1) introduce the concepts of work zone traffic analysis; (2) explain how ODOT's lane closure restrictions are incorporated into section 00220.40(f) of the Special Provisions; (3) describe project delay concepts; and (4) introduce the MS Excel spreadsheet tool that is used to do the analysis. The manual is used to identify the windows of time during which lane or shoulder restrictions can take place without significant adverse effects to traffic operations, and determine estimated delays resulting from project staging strategies. In addition to the theory and practice of work zone traffic analysis, the manual contains examples of analysis and exercises that will help readers gain experience with work zone analysis. At the end of the manual are examples of forms, report letters, and other useful reference materials.

The manual is related to the research study in that it s used to assess the nature of traffic expected through work zones. This information is used when designing TCPs. Familiarity with and use of this manual Traffic Control Plans Designers was a consideration in the research study.

2.2.9 OR-OSHA Construction Safety and Health Manual

The Oregon Occupational Safety and Health Division (OR-OSHA) publishes safety and health standards for employees. Division 3 of the standards applies specifically to the safety of workers on construction sites (*OR-OSHA 2002*). The purpose of the Division 3 rules is to prescribe minimum safety and health requirements for employees engaged in construction work, including demolition, blasting and use of explosives, and power transmission distribution and maintenance work. Within Division 3, standards are provided that cover safety and health measures applicable to all types of construction. No requirements are included that specifically address safety and health in highway construction work zones. However, constructors involved in highway construction projects must abide by the requirements set forth in the OR-OSHA standards.

2.3 CURRENT PRACTICES OF STATE AGENCIES

The TCP development and implementation process utilized in Oregon may be unique compared to other states. One of the research activities undertaken was to contact other states to obtain information on the processes used in the state to design and implement TCPs. This activity began with an on-line search of the websites of the different DOTs. Documents related to traffic control and TCPs were downloaded and reviewed. In addition, where documents were not available on-line, e-mails were sent to the DOTs to request the documents.

This effort yielded documents from all of the states plus the District of Columbia. Copies of the work zone traffic control sections within the states' standard specifications were collected. While all of the standard specifications related to work zone traffic control are different in some way, they all address approximately the same information. Similar to that within the Oregon *Standard Specifications*, the other standard specifications of other states address various requirements such as materials, illumination, signs, signals, flaggers, barricades, and temporary striping. Maintenance of the traffic control measures is also addressed.

Documents that provide guidelines for designing traffic control measures in work zones were also available in many states. Each of these documents is designed to be used in coordination with the MUTCD. The topics covered in the documents typically include a description of temporary traffic control elements, types of traffic control activities, and the application of traffic control devices to different work zones (layout, spacing, locations, etc.).

No documents were found that provide guidance on the review of TCP designs, the use of consultants to design TCPs, appropriate means for inspecting TCP compliance, and suggestions for ensuring compliance with the TCP during construction.

Recently, the practices of Texas and Ohio were discussed in the July 2009 issue of 'Safety + Health' (*Bello 2009*). Bello writes that, "Texas has been successful in reducing crash incidents by using special provisions in projects that allow the inclusion of law enforcement presence on worksites, while lawmakers have enacted stronger penalties that double fines for drivers who speed through work zones." The State of Ohio reported successes during the current decade as well. "The number of work zone related vehicular crashes decreased to 5,772 in 2006 from 8,339 in 2001'', said David Holstein, state traffic control engineer for Ohio DOT (*Bello 2009*). Ohio focuses on analyzing crash data rather than fatality reports to prevent future incidents. Holstein credits the improvements to better planning and design process for projects. This includes reviewing work zone design details at the beginning of the planning process. 'Maintenance of Traffic Alternative Analysis' takes place before right-of-way acquisition, design, and environmental assessments." Similar to Texas, the Ohio DOT also noted an increase in law enforcement presence as a means of reducing work zone crashes, as well as incorporating those law enforcement officials early in the TCP design process (*Bello 2009*).

2.3.1 National DOT Survey

In addition to the review of literature, a short survey of state DOTs was conducted. The aim of the survey was to investigate the TCP processes and features used on highway construction projects in other states for comparison to those used in Oregon, and to identify their impact on work zone safety. This information was intended to provide guidance to ODOT regarding how best to modify ODOT practices to benefit work zone safety.

To conduct the survey, two questions were developed regarding TCP characteristics and practices. Based on the literature review and preliminary discussions with ODOT and other personnel, a list of eighteen different project characteristics and practices that are relevant and important to the TCP design and implementation process was developed. The list is shown in Figures 2.1 and 2.2. The list was developed into two survey questions. Respondents were first asked to rate the *frequency* with which each of the listed characteristic or practice is used on highway projects in their respective states using a scale of 1 (never used) to 5 (always used). Respondents were then asked to rate the *impact* that each has on work zone safety using a scale of 1 (negative impact) to 5 (positive impact) with a rating of 3 taken as no impact on work zone safety.

An electronic survey was prepared and sent to the other 49 states and Canadian provinces using a listserv. State and province DOT research departments then forwarded the survey on to qualified individuals familiar with state or province traffic control practices to complete the survey. The questions were also sent to an ODOT employee familiar with ODOT's TCP design process to complete them on behalf of Oregon.

In addition to a response from ODOT, responses were received from twelve other states or provinces (AK, AR, IL, IA, KS, MS, SD, TX, WA, WV, WY, and Saskatchewan). Figure 2.1 shows the average responses to the question regarding the frequency with which the characteristic is present on projects. As shown in the figure, those characteristics that are more frequently used in other states are: traffic control supervisor (TCS) assigned to the project, TCP standard drawings are specified, peer reviews conducted, daily inspections, constructability reviews, TC designer with formal TC design training, and TC design. Oregon differs from the other states in some areas. Oregon uses standard TCP drawings more often than other states, and maintains continuity of the project manager through design and construction more frequently than other states. On the other hand, Oregon does not implement the following as frequently as other states: assigning a TCS to the project, conducting constructability reviews, and using a central office to design TCPs.

Figure 2.2 presents the survey responses regarding the average impact of each of the characteristics on work zone safety. Those characteristics which were identified as having the greatest positive impact were: TC designer visits the site, TC implementation subcontracted, constructability reviews, TC designer with 10+ years of experience, and TCS supervisor assigned to the project. Four of the characteristics were identified as having no impact or negative impact. These were: GC modifies the TC design prior to construction, use of a consultant TC designer, use of a consultant project management firm, and use of design build project delivery.

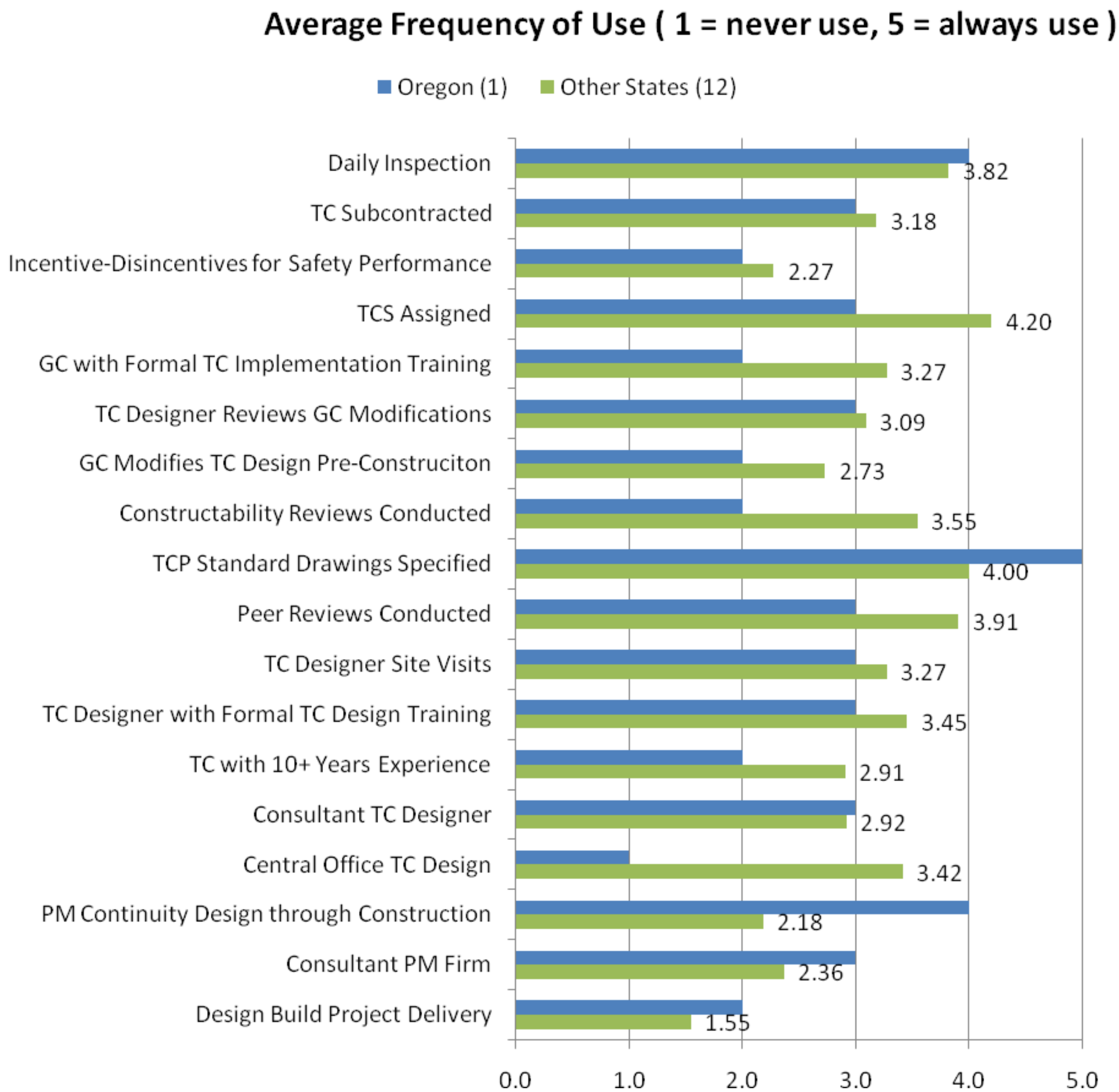

Figure 2.1: Average Frequency of Characteristics Used on Projects

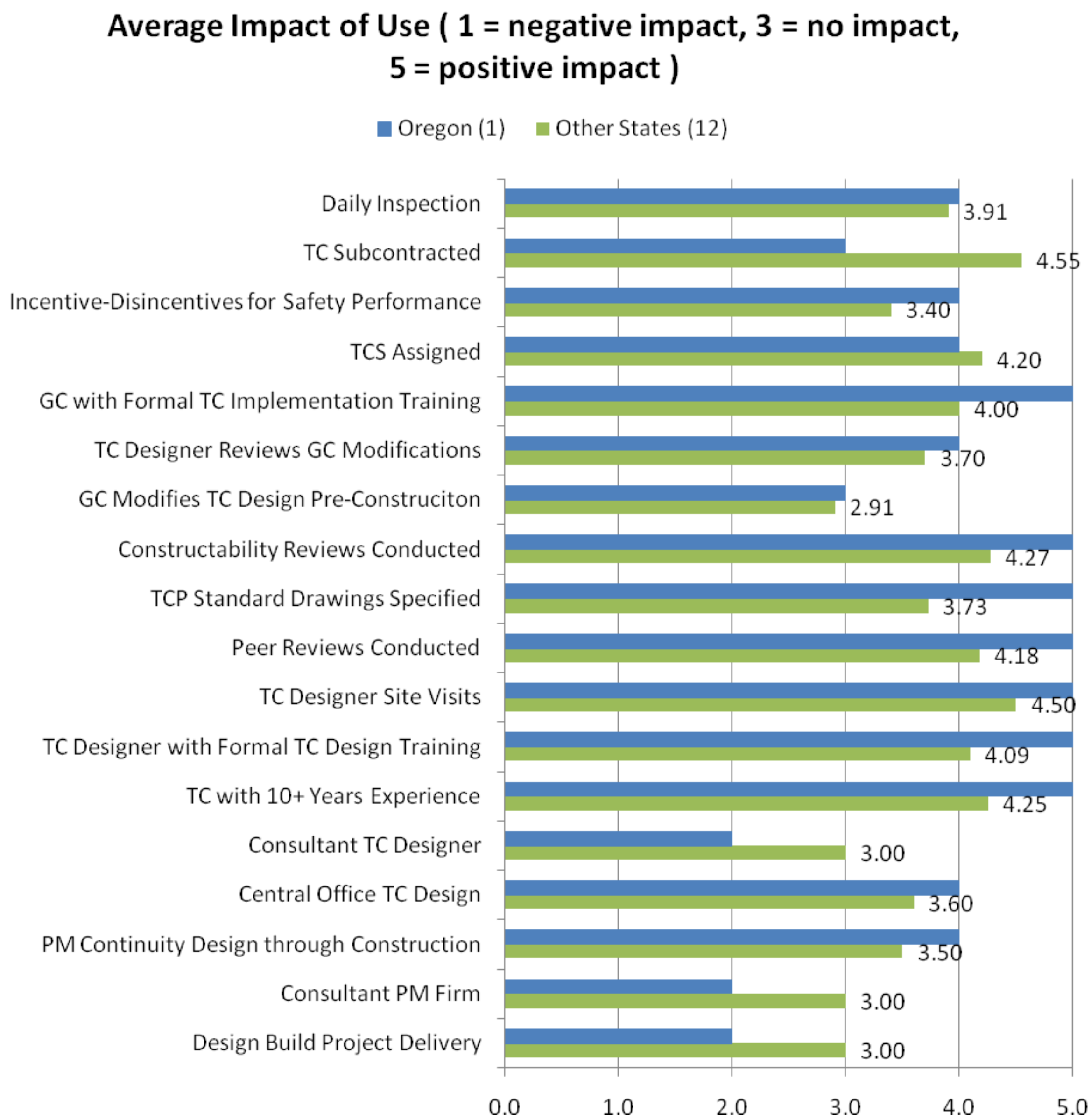

Figure 2.2: Average Impact of Characteristics Used on Projects

2.4 SUMMARY

Providing safe work zones during construction operations is a significant concern of state DOTs. Numerous documents are available that provide standards and guidelines for the design and implementation of traffic control plans to help ensure the safety of motorists and workers in construction work zones. These documents provide guidance on the elements to include in work zones to control traffic and on the layout and sequencing of work zones. Traffic Control Plan Designers utilize these documents when developing TCPs. Previous research has been conducted to augment these documents and provide further guidance to TCP designers.

While research has been conducted on specific features contained within TCPs and how those features are implemented and located, further understanding of the impact of TCP development and implementation is needed. To help fill this knowledge gap, the research project investigated how the TCP design process impacted work zone safety. Because the process used by ODOT involves consultant-based design of TCPs, the research considered the impact of this factor on the quality of TCPs. On the implementation side of TCPs, the research evaluated whether inspection and enforcement efforts were sufficient to ensure effective implementation of TCP features. From these efforts, the research project developed guidelines to assist ODOT and TCP designers with creating quality TCPs in a timely manner and maintaining effective implementation of TCPs during construction projects. The results of the research effort are described in the following sections of this report.

3.0 SURVEY OF ODOT PERSONNEL AND CONSULTANTS

This section describes the survey that was conducted of ODOT personnel, contractors, and consultants who participate in designing, reviewing, and implementing TCPs. A survey was included in the study in order to obtain input on the research questions from a broad perspective of the highway engineering and construction community. The project case studies described in Section 4.0 of this report provide for in-depth, focused investigation of TCPs to complement the broad perspective gained from the survey.

The survey was used to collect data on aspects of processes, projects, and behavior for work practices and work culture issues surrounding TCP design and implementation. The focus of the survey was on the "typical" or "average" process, project or behavior, rather than the specific. This focus allows for multiple responses to be aggregated and compared in the analysis. While surveying is the best method to attain this data, it should be noted that a major limitation of the survey method is that it relies on a self-report method of data collection. The extent to which the researchers are able to obtain data is based on the interest and availability of the sample subjects. In addition, intentional deception, poor memory, or misunderstanding of the question can all contribute to inaccuracies in the data. Furthermore, this method is descriptive, not explanatory. It therefore does not verify any cause-and-effect relationships but simply provides evidence from which the relationship can be inferred.

3.1 SURVEY OBJECTIVES

The overall purpose of the survey was to gain perspectives on current ODOT policy and practices and the enablers and barriers to successful design and implementation of TCPs.

Analysis of the data collected from the survey entailed correlating specific features of TCP design and implementation with key project and TCP outcomes. Based on the intent of the study and the research questions presented in the research proposal, the following nine outcomes (metrics) were identified as measures of effectiveness of TCP design and implementation:

1. Quality of the TCP design and review
2. Quality of TCP implementation and inspection on the construction site
3. Consistency of TCP quality from project-to-project
4. Efficiency and effectiveness of the TCP design and review process
5. Understanding of the TCP design and review process by those involved
6. Availability of sufficient resources to design, review, implement, and inspect TCPs
7. Level of worker and motorist safety provided by TCPs
8. Priority of work zone safety with respect to other project parameters
9. Quality with which the TCP process is managed

Each of the metrics listed above were identified as a critical aspect of TCP design and implementation and, therefore, of interest to the research study. The survey was intended to investigate these metrics in several ways. Of interest was measuring the level or degree of each metric on current ODOT projects. That is, for example, determining what the level of consistency of TCP quality is from project-to-project under the current TCP design and implementation process. The following were identified as factors to focus on in the survey:

- TCP design:
  - Who designs the TCP
  - When during the project development phase is the TCP designed
  - The amount of time given to design TCPs compared to what is desired/needed
  - The roadway and traffic information available and provided to the designers (traffic volume, speed, type of vehicles, road type, # of lanes, geometry, obstructions, etc.)
  - The construction information available and provided to the designers (scope of work, size of work zone, duration, phasing of the work, complexity, delay times, illumination, entry/exit points, etc.)
  - How TCPs are designed (process, procedures, standards)
  - How oversight of the design is provided (who, when, how communicated)
  - Whether the TCP design is conducted in-house or outsourced, and how this is determined on a project
  - What traffic control measures are typically included in TCPs (devices, layout, location, etc.)
  - How lessons learned from past projects are communicated for future use
- TCP design review:
  - Who reviews the TCP designs
  - How the review is completed
  - When in the TCP design process is the review conducted
  - The information/resources used in the review process
  - How the review comments are communicated to the designer
  - What oversight is provided to ensure that the comments are incorporated
- TCP implementation:
  - Who is responsible for implementation
  - How implementation is communicated

  - Whether what is implemented in the work zone match the TCP (timing, location and layout of control devices, appropriate control devices, devices in good working order, etc.)
  - What quality control process is used
  - How modifications are approved and communicated
  - What is priority of implementation compared to other project objectives
  - How lessons learned are communicated to the designer and other constructors

- TCP implementation inspection:
  - Who conducts the inspections
  - How the inspections are conducted
  - When are the inspections conducted
  - What resources do the inspectors have for making the inspections
  - What is inspected
  - What level of authority do the inspectors have on the project
  - What training is provided to inspectors
  - How non-conformance issues are communicated to the constructor
  - What enforcement mechanisms do inspectors have to ensure compliance with the TCP

As mentioned above, the survey aimed to assess the performance on an average or typical project as opposed to a specific project.

3.2 SURVEY METHODS

The methods selected for the survey of ODOT personnel and consultants were a combination of interviews (in-person and telephone) and e-mailed questionnaires. Interviews provided a means to gather detailed information about a project or process along with general information that was applicable to a broad spectrum of ODOT projects. During an interview the researchers were able to explore topics in further detail if warranted and/or ask additional questions if time permitted. The open nature of interviews made them useful in gathering subjective information that could be analyzed on its own and used in support of other objective data.

Time and resource limitations on studies typically do not allow for conducting detailed interviews on large sample populations, especially if the information requested is extensive and the subjects are widely dispersed. On-line and e-mailed questionnaire surveys are typically used to survey large populations that are spread over a large geographic area. As a result, and to optimize the survey response rate, questionnaires used for on-line and e-mailed surveys typically contain primarily closed-ended questions that gather more objective information.

The process for surveying ODOT personnel and consultants included four activities: (1) developing the survey sample; (2) development of the survey instrument (questionnaire); (3) distributing the survey; and (4) collecting the responses. Each of these activities is described further below.

3.2.1 Sample Population

The target population for the survey consisted of those individuals who design, review, implement, and inspect TCPs on ODOT projects. This included: TCP engineers/designers, TCP standards engineer, TCP quality assurance engineer, traffic management personnel, transportation safety/transportation operations engineer, ODOT construction engineers, and ODOT construction inspectors. Those working for contractors and design consultants, including jobsite superintendents, construction project managers, and design staff, were included in the target population as well.

The sample of participants for the survey was selected based on convenience. Members of the TAC were contacted via e-mail to solicit names and contact information of ODOT and Oregon Bridge Delivery Partners (OBDP) personnel to include in the survey. The TAC members were asked to provide names of people who they interact with in their positions and who they think should be included in the survey. No restrictions were placed on the selection of participants except that they should be involved in the design, review, implementation, inspection, and/or project management of TCPs. Any people suggested by the TAC were included in the survey list of contacts. The members of the TAC were also included as survey participants. Based on the input from the TAC, a total of 116 people were identified for the survey. Of these 116 people, 89 (77%) worked for ODOT, 15 (13%) worked for Oregon Bridge Delivery Partners (OBDP), and 12 (10%) worked for outside contractors/consultants. The contacts were organized into the following categories according to their involvement in the TCP process: design, review, implementation, inspection, and project management. An effort was made to make sure there was a balance in the number of people in each category. For the categories in which the number of people was low compared to the other categories, additional e-mails were sent to the TAC soliciting additional names. The number of people on the contact list in each category is as follows: 14 (12%) in TCP design, 4 (3%) in TCP review, 22 (19%) in TCP implementation (construction), 59 (51%) in TCP inspection, 16 (14%) in project management and one (1%) with no specific role identified.

3.2.2 Survey Instrument

The data collection instrument used in the survey was an on-line questionnaire. A total of five questionnaires were developed, one for each discipline involved in the TCP design and implementation process: design, review, implementation (construction), inspection, and project management. Different questionnaires were developed for each discipline, instead of one questionnaire for all disciplines, in order to ask questions focused on each discipline and minimize the length of the questionnaire. It was assumed that some participants who design TCPs, for example, would not have sufficient knowledge of the inspector's role and experience with TCPs. Limiting the questionnaires to specific disciplines also led to shorter questionnaires and therefore a higher expected response rate. A copy of the questionnaire sent to those identified as designers is provided in Appendix A.

The format of the questionnaires was kept relatively the same from one to the other. The questionnaires asked the respondent to answer questions about: background demographic information on the respondent, TCP policy and process, resources, training, and their overall perspectives of TCPs. A special effort was made to ensure that the nine metrics discussed in Section 3.1 were addressed in the questionnaire. Where possible more than one question was asked related to each metric in order to provide multiple data points for the analysis.

3.2.3 Conducting the Survey

To pilot test the questionnaires, initial versions of the questionnaires were sent to five members of the TAC, one for each discipline, for review and comment. The TAC members completed the questionnaires and provided feedback on their content and length. Comments and suggested revisions received from the pilot test were incorporated into the final versions of the questionnaires.

After finalizing the questionnaires, e-mails were sent to each person on the list of contacts to ask for their participation in the survey. A copy of the e-mail used to contact the participants is included in the Appendix A. If no response was received, follow-up e-mails were distributed in order to increase the response rate.

The e-mail sent to the participants included, as an attachment, a questionnaire. The specific questionnaire (Design, Review, Implementation, Inspection, or Project Management) that the participants received was based on the initial indication of their discipline. In the e-mail the participants were asked whether the questionnaire which they received was appropriate, or whether they identified with another discipline. If a different questionnaire was appropriate, the participants were asked to contact the researchers to receive a different questionnaire.

Several contacts in each discipline were selected for interviews instead of the e-mailed survey. It was desirable to conduct some interviews in order to gain additional background and experiential information in each discipline area. Those contacts selected for interviews were sent e-mails asking whether they would agree to be interviewed and their availability. The interviews were conducted by telephone or in-person. A total of 12 people on the contact list were identified for interviews.

In addition to those contacted by e-mail, others were interviewed as a part of the ODOT State Traffic Control annual work zone tours. A total of six interviews (three construction superintendents, two inspectors, and one assistant project manager) were conducted on five projects. The researcher was unable to conduct interviews on all of the projects visited during the annual tour due to a lack of available time spent at each project and the lack of availability of the superintendents and inspectors. The information gathered from the interviews is included with the documentation for the case studies (see Section 4.0).

The completed questionnaires from the e-mail survey and interviews were collected and saved for review. The responses to each question were recorded in an MS Excel spreadsheet for analysis. Simple statistical measures (average, range, standard deviation) were calculated for closed-ended, objective responses (e.g., select from a list and Likert scale responses). Responses to open-ended questions were separated out for independent review by the researchers to determine common responses and themes.

3.3 SURVEY RESULTS

The survey was successful in collecting responses to the e-mailed questionnaire and in conducting interviews of ODOT and OBDP personnel. A total of 116 ODOT, OBDP, and heavy civil industry employees were contacted to participate in the e-mail survey and interviews. Fifty questionnaires were filled out and returned for a response rate of 43%. Of the 50 completed questionnaires, 45 (90%) were completed and returned via e-mail, and five (10%) were completed through interviews.

The participants who provided responses to the surveys worked for ODOT, OBDP, or a firm primarily involved in civil design or construction work. Thirty-three of the participants (66%) worked for ODOT, while five (10%) worked for OBDP, and 12 (24%) worked for a private firm. The number of years of experience working for ODOT/OBDP ranged from less than a year to 34 years, with an average of 15.8 years. With respect to their involvement in the TCP design and implementation process, the 50 respondents can be categorized as follows: 14 Design, 4 Review, 14 Implementation, 8 Inspection, and 10 Project Management. The respondents worked on many different types of projects with the majority being bridge replacement projects (27.9% of respondents), multi-lane highway projects (20.7%), and freeway preservation projects (20.7%). In terms of location throughout the State, the respondents worked in all ODOT regions and some perform work in multiple regions. Eighteen of the respondents (36%) performed work in Region 1, 23 (46%) in Region 2, 24 (48%) in Region 3, twelve (24%) in Region 4, fourteen (28%) in Region 5, and sixteen (32%) performed work for OBDP projects statewide.

3.3.1 Quality of the TCP Design and Review

The Design, Review, and Implementation questionnaires asked the participants for input on the quality of the TCP designs and reviews. The Design and the Review questionnaires asked two questions: "What is the quality of the typical TCP design? Use: 1 = Poor quality, 5 = Excellent quality"; and "What is the quality of the typical TCP design review? " The mean responses to these questions are shown in Figure 3.1. Both the designers and reviewers rated the TCP design and the TCP review as above average. While the reviewers rated both the design and the review at the same level (mean = 3.5, range = 3 to 4), the designers indicated a lower rating of quality for the TCP review (mean = 2.7, range = 2 to 4) than for the TCP design (mean = 3.96, range = 3 to 5).

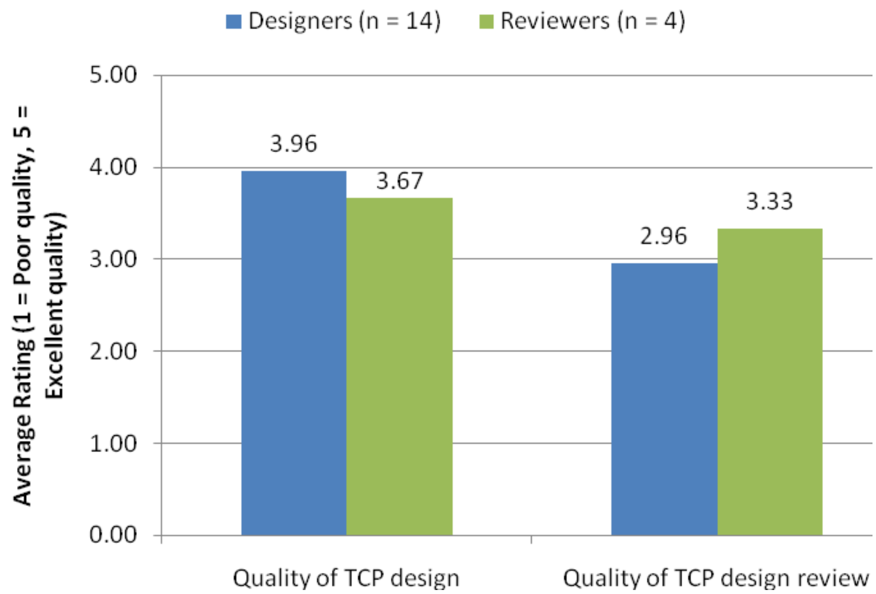

Figure 3.1: Designer and Reviewer Rating of Quality of TCP Design and Review

The number and type of mistakes commonly found in TCPs can be another indication of quality. TCPs that contain a high number of mistakes would be judged to have lower quality, and vice versa. When asked, "What are the common TCP design mistakes?", the designers indicated a variety of TCP problem areas including: improper transition lengths, incorrect degree of curve, over-signing the work zone, leaving gaps in traffic control measures, unknown utility schedules and locations, inadequate separation of traffic and work areas, and improper allowances for drainage. In regards to the phasing of the work, not integrating the TCP with the construction schedule was recognized as a problem as well. Other problems with TCP designs that were identified by the respondents included not taking off-system affects of the work zone into account, and not placing detours in the most effective locations.

Construction personnel in regional ODOT construction offices, project inspectors, and contractor superintendents are the end users of TCP designs. The ease with which TCPs are implemented and the degree to which the initial design matches the field implementation are both functions of TCP design and review quality. When asked, "Based on your experience, how easy are TCPs to implement?" construction personnel responded with a mean rating of 2.8 (range = 2 to 4) on a 1 to 5 scale (from 1, very easy to 5, very difficult). The same group was asked, "If there are difficulties implementing a TCP, what are the sources of frustration or confusion when implementing a TCP?" Figure 3.2 tallies the responses to this question. Thirteen out of fourteen (93%) respondents noted the TCP design not matching site conditions as a source of confusion or frustration when implementing the TCP. Errors and lack of clarity contained within the designs were identified by four out of six (79%) construction personnel surveyed.

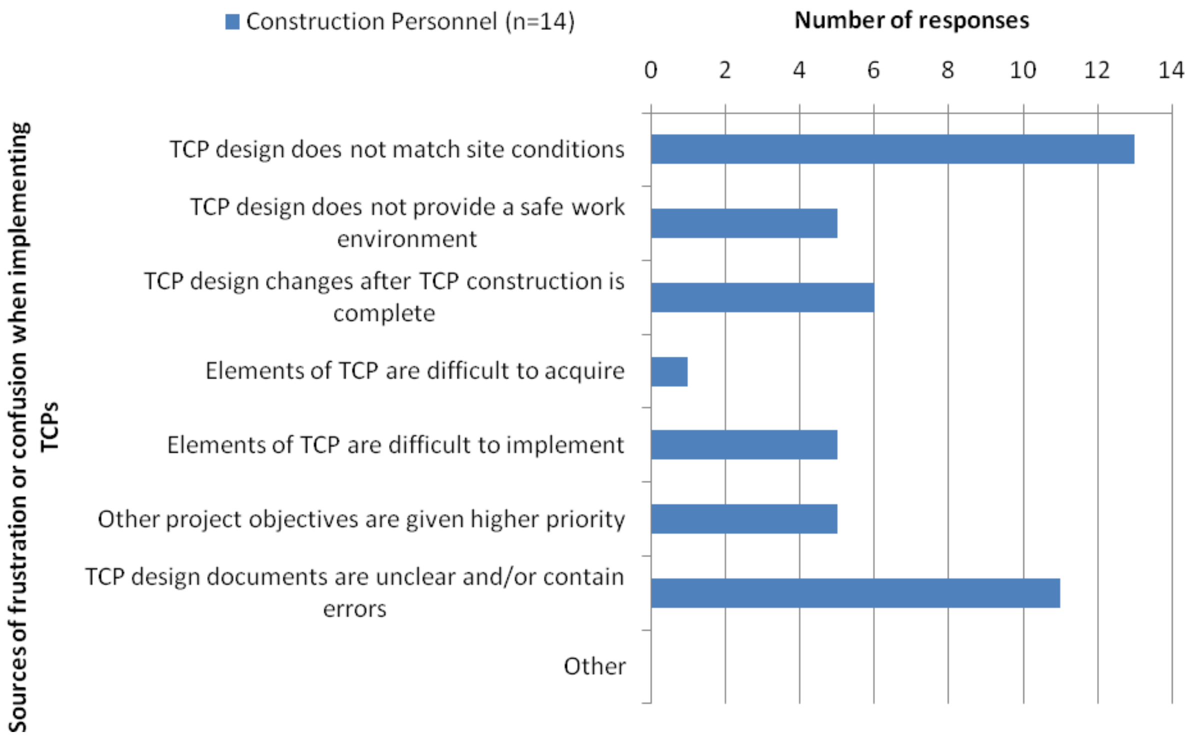

Figure 3.2: Sources of Frustration/Confusion when Implementing TCPs

The need to change a TCP in the field from its original design is also an indication of the quality of a TCP design. While some field conditions cannot be anticipated in the design, TCPs should accurately reflect the expected field conditions. TCPs that effectively take into account work zone features and conditions are of higher quality. Both construction personnel and project inspectors were asked, "How often does the implementation of a TCP in the work zone match the written plan/drawings for the TCP?" Construction personnel responses to this question ranged from 1 to 4 with a mean response of 3.6. The participants were also asked to specifically identify why the implemented features of the TCP might differ from the written TCP plan/drawings. The distribution of responses to this question was as follows, with the number of responses shown in parentheses:

- Incomplete inventory of specified TCP elements (1)
- Traffic entering the work zone is initially uncontrolled (2)
- Motorists ignore specified turn movements (5)
- Traffic flow excessively impeded (5)
- Worker safety threatened (4)
- TCP cannot be constructed as designed (8)

Several respondents also added that the contractor's chosen construction methods can lead to changes of the TCP in the field. The frequent need to modify TCPs to accommodate field conditions was identified by many survey participants, and is an indication of the quality of TCP designs.

3.3.2 Quality of TCP Implementation and Inspection on the Construction Site

A significant part of the success of a TCP depends on the quality of its implementation. A TCP design may be of high quality, but without effective and timely implementation, work zone safety can be compromised. Part of maintaining high quality implementation is the level of quality of the field inspections. The Implementation and the Inspection questionnaires investigated quality in the field by asking two questions: "What is the quality of the typical TCP *implementation*? " and "What is the quality of the typical TCP *inspection*?" The mean responses to these questions are shown in Figure 3.3. Both the construction personnel and inspectors rated the TCP implementation and the TCP inspection as above average. Both inspectors and construction personnel rated the implementation quality lower than the inspection quality. Inspectors rate implementation and inspection with means of 4.0 (range = 3 to 5) and 4.25 (range = 3 to 5) respectively, while the construction personnel indicated a rating for the implementation (mean = 3.75, range = 3 to 5) and the inspection (mean = 4.0, range = 3 to 5).

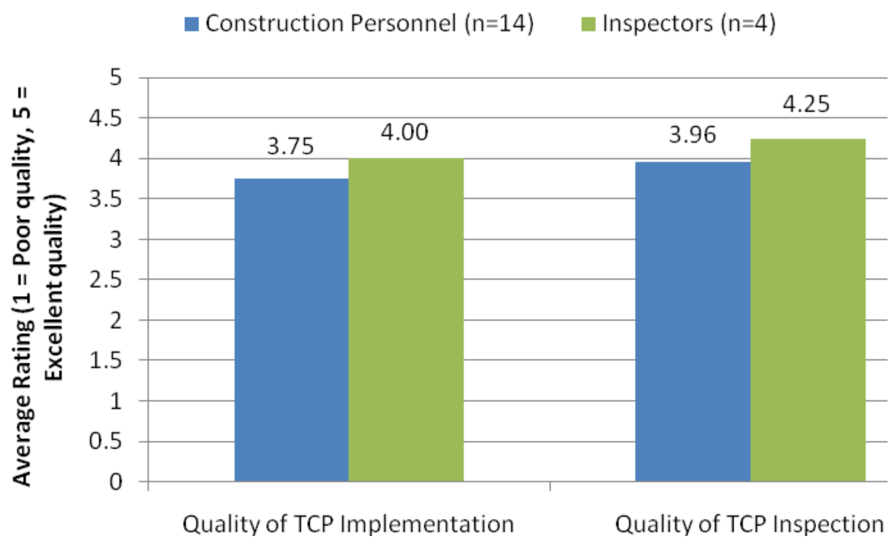

Figure 3.3: Construction Personnel and Inspector Ratings of Implementation and Inspection Quality

Quality of TCP implementation and inspection will also be a function of the frequency with which TCPs are reviewed in the field once construction has begun. It is assumed that a greater frequency of reviews leads to improved quality. Construction personnel were asked the question, "How often are quality control reviews conducted during implementation of the TCP?" Twelve out 14 (86%) participants responded that TCPs are inspected for effectiveness and quality a minimum of once a day. Six out of 14 (43%) replied that for more complex projects, such as those requiring flaggers, lane shifts, and/or significant detours, quality control of TCPs can take place multiple times per day.

In addition to the information obtained from construction personnel and inspectors, designers were questioned about how safety could be improved in the work zone. The designers provided the following commentary regarding the overall quality of TCP implementation and inspection:

- Construction personnel should follow the intent and guidelines of TCP design more closely. (n = 5)
- Increased level of enforcement of the TCP by inspectors is needed. (n = 3)
- Improved spacing of signs and warning devices by construction personnel are needed. (n = 1)

3.3.3 Consistency of TCP Quality from Project-to-Project

Designers, reviewers, construction personnel, and inspectors typically performed their work either in one of the five ODOT regions or statewide for OBDP. Quality of TCP design, review, implementation, and inspection varied from project-to-project. Figures 3.4a and 3.4b show the standard deviation (SD), a measure of variability, of responses to the previously posed questions regarding quality of TCP design and review, and quality of TCP implementation and inspection, respectively.

Figure 3.4a shows that reviewers responded with a slightly higher degree of deviation from the mean when rating TCP design quality (SD = 0.71) compared with TCP design quality (SD = 0.69). Designers rated TCP design review with the least degree of consistency (SD = 0.92). Figure 3.4b shows both construction personnel (SD = 0.80) and inspectors (SD = 0.71) responded with a higher degree of deviation from the mean when rating the quality of TCP inspection compared to the quality of TCP implementation (SD = 0.64 and 0.53, respectively). Construction personnel rated inspection with the least degree of consistency (greatest standard deviation).

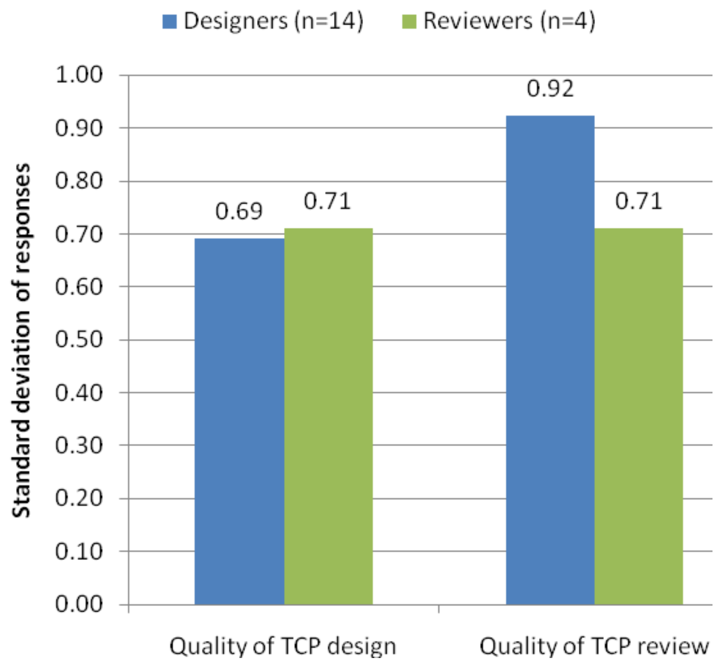

Figure 3.4a: Standard Deviation of Designer/Reviewer Ratings of TCP Quality

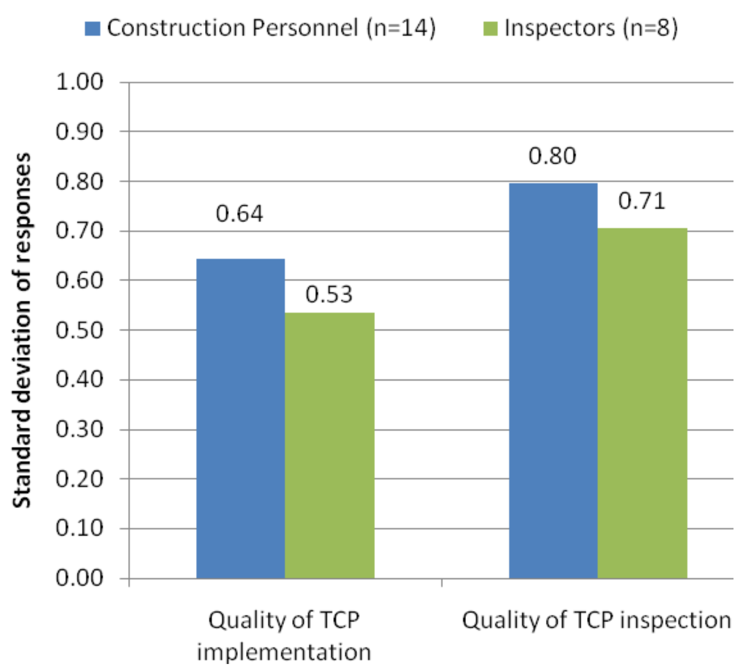

Figure 3.4b: Standard Deviation of Construction Personnel/Inspector Ratings of TCP Quality

Consistency from region-to-region was also measured from the data collected in the survey. Designers and reviewers were asked to rate the quality of typical TCP *designs* within their respective regions. The ratings of designers and reviewers from each region were grouped together and are presented in Figure 3.5. The TCP designs in Region 2 received the highest rating for quality (mean = 4.17). The other regions received above average ratings as well, but lower ratings than Region 2. The ratings for the other regions were as follows: 4.00 for Region 1; 3.75 for Region 5; 3.67 for Region 4; and 3.64 for Region 3. Projects managed by OBDP received a TCP design quality rating of 4.12.

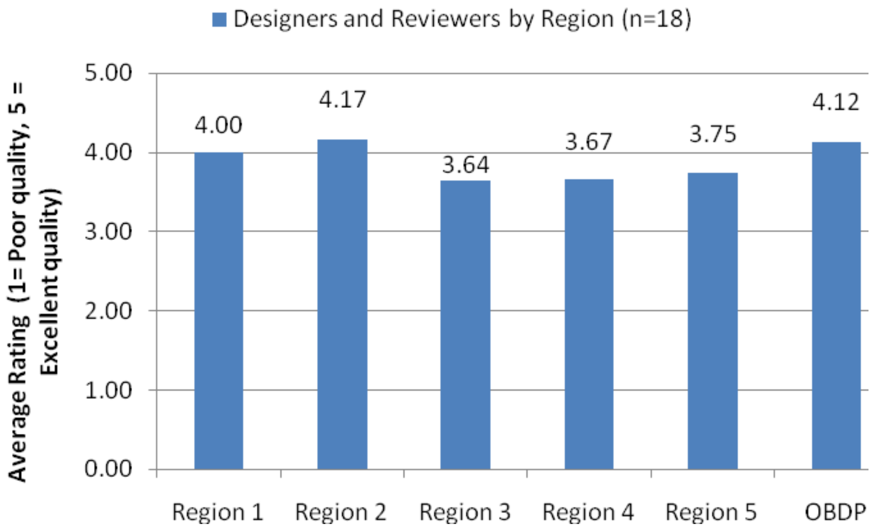

Figure 3.5: Designer/Reviewer Ratings of TCP Design Quality by Region

Similar questions were posed in the survey regarding the typical TCP *design reviews*. The designers and reviewers were asked to rate the quality of TCP design reviews in their region. Figure 3.6 presents the average ratings for each region. The average ratings were all fairly consistent across the regions and OBDP. The highest rating was given to Region 4 (mean = 3.67), followed by OBDP (3.38), Region 1 (3.29), Region 5 (3.25), Region 2 (3.19), and Region 3 (3.07).

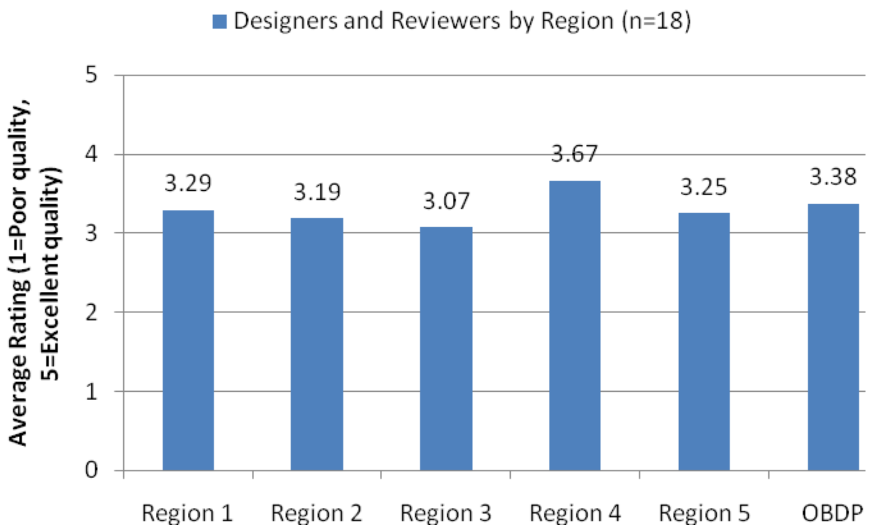

Figure 3.6: Designer/Reviewer Ratings of TCP Design Review Quality by Region

Similar to the Design and Review questionnaires, construction personnel, inspectors and project managers were asked to rate the quality of the typical TCP *implementation* within their respective regions. The ratings of construction personnel, inspectors, and project managers were grouped together and are presented in Figure 3.7. Implementation quality ratings in each of the regions from highest to lowest were as follows: 3.88 for OBDP; 3.83 for Region 1; 3.81 for Regions 2 and 5; 3.78 for Region 3; and 3.64 for Region 4.

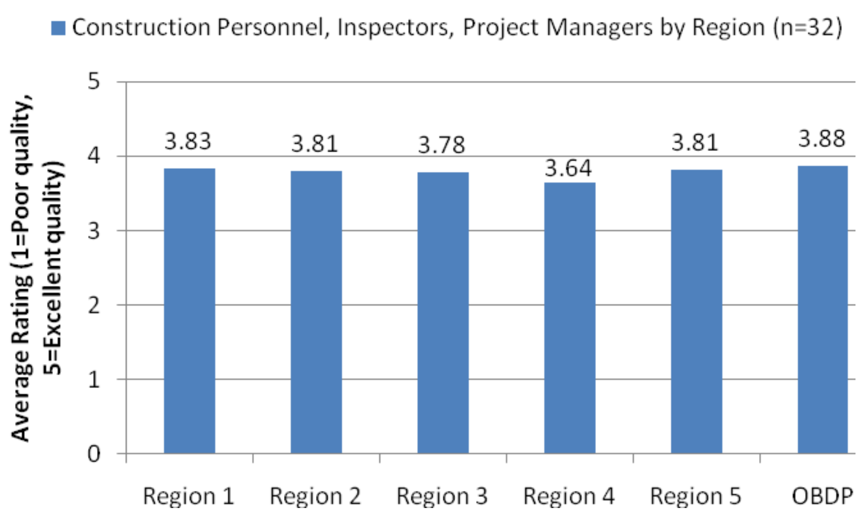

Figure 3.7: Construction Personnel, Inspectors, PMs TCP Implementation Quality by Region

Figure 3.8 shows the survey results when asked about typical TCP *inspection*. Inspection quality ratings in each of the regions from highest to lowest were as follows: 4.12 for Region 2; 4.05 for OBDP; 3.94 for Region 1; 3.92 for Region 4; 3.88 for Region 3; 3.75 for Region 5.

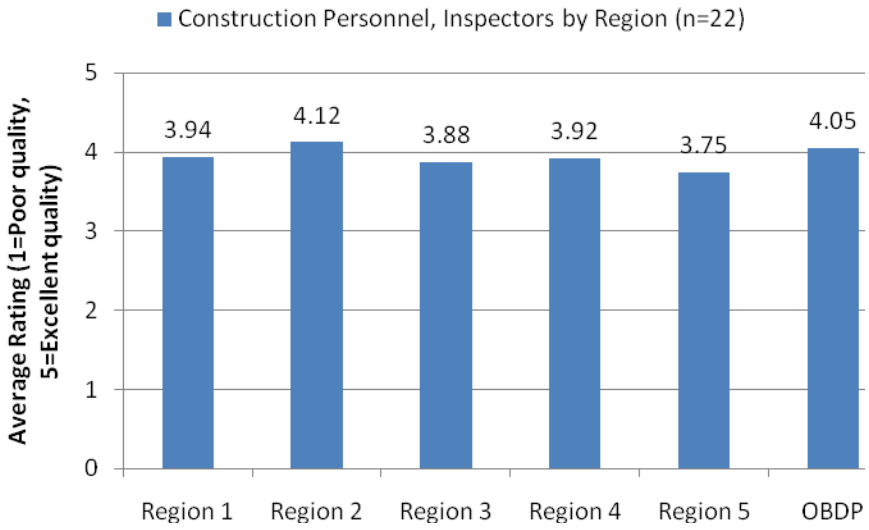

Figure 3.8: Construction Personnel, Inspectors TCP Inspection Quality Rating by Region

Lastly, project managers were asked directly about consistency of TCP implementation from project-to-project. In their role as managers of multiple projects, project managers are in a good position to evaluate how implementation of TCPs varies. The project managers were asked the question, “How consistent is TCP implementation from project to project? ” The mean response from the project managers (n=7) was a rating of 3.7 with a range of 3 to 4.

3.3.4 Efficiency and Effectiveness of the TCP Design and Review Process

Multiple people contribute at various project stages to the development of a TCP design. The process begins when the scope of the project is investigated and then details are discussed at the initial project team meeting. TCP design and review continue through creation of the Design Acceptance Package, the Preliminary Plans Workshops, creation of Advance Plans TCP Package, the Plans-In-Hand review, writing of specifications, and ultimately to when the plans are handed over to the contractor for implementation. Designers, reviewers, and project managers were asked to rate each of the preceding steps in the TCP design process in terms of the improvement needed in order to improve overall TCP design. The respondents were asked to use the following scale: 1 = No improvements needed, 10 = Significant improvements needed. The mean responses are displayed in Figure 3.9.

As shown in Figure 3.9, designers rated, “Implementation of the final design” as needing the most improvement (mean rating = 6.0). Reviewers rated “Plans in hand review” and “Creating the Advance Plan TCP Package” as needing the most improvement (mean rating = 5.0). Project managers also rated “Creating the Advance Plan TCP Package” as needing the most improvement (mean rating = 4.8). Designers, reviewers, and project managers all rated “Initial project team meeting” as needing the least improvement (mean ratings = 3.5, 1.5, and 1.8, respectively). Additionally, all three types of respondents collectively rated “Implementation of the final design” as needing the most improvement (mean rating = 5.2) followed closely by

“Creating the Advance Plan TCP Package” (mean rating = 4.5) and “Plans in hand review” (mean rating = 4.6).

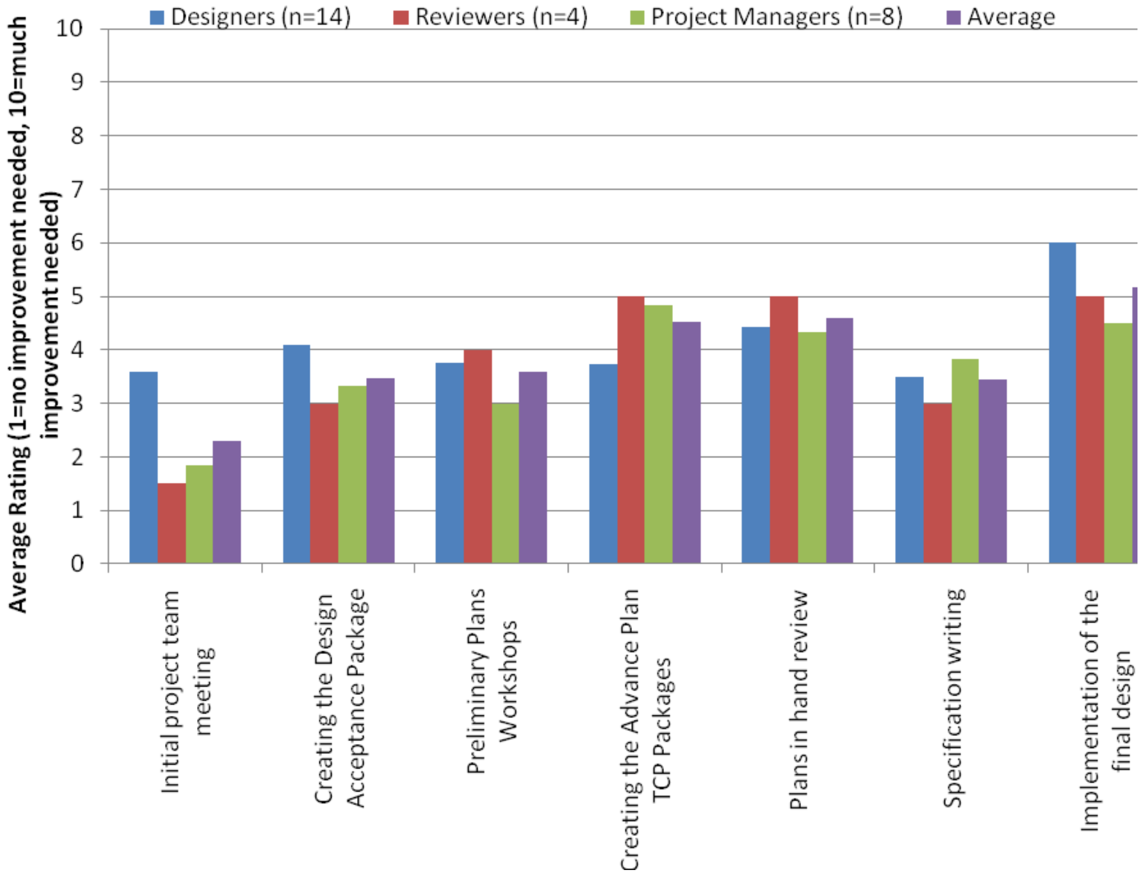

Figure 3.9: Ratings of Improvement Needed in Project Development Phases

3.3.5 Understanding of the TCP Design, Review, and Implementation Process

An important aspect of successful TCP design is the degree to which those involved in the process understand their role, the level of standards expected, and the overall project objectives. The level and breadth of training received by designers and reviewers, both formal and informal, is one measure of understanding the TCP design and review process. Formal training is provided through the State Traffic Control Design Class and Work Zone Analysis Class. Informal training consists of on-the-job training. Design and review surveys asked each respondent the following question: “What TCP design training have you received?” Of the 17 respondents, two (12%) had training in all three areas (Traffic Control Design Class, Work Zone Analysis Class, On-the-Job Training), eight (47%) had training in the Traffic Control Design Class and Work Zone Analysis Class, six (36%) had On-the-Job Training or Traffic Control Design Class only, and one (8%) had training in Work Zone Analysis and On-the-Job Training only.

Similarly, the level and breadth of training received by those implementing the TCP on the construction site is a gauge of the understanding of the TCP implementation process. Construction personnel were asked, “What TCP implementation training have you received?” The respondents to the Implementation questionnaire provided the following list of general responses to this question:

- Traffic control supervisor training
- Federal, state, and privately led traffic control courses
- ODOT work zone and flagging training
- On-the-job training through involvement in design and construction phases of projects

Some ODOT projects are designed ‘in-house’ using ODOT design staff. The remaining portion of projects is designed by private consulting firms. Several different criteria could potentially be used to determine whether or not a particular project is designed by an ODOT designer or by a consultant designer. The following question was asked of designers and project managers: “Please rate each of the following criteria from 1-10 (1 = low priority and 10 = high priority) on whether it is considered when determining if a TCP will be designed ‘in-house’ by ODOT or by a hired consultant?” Figure 3.10 shows the mean priority rating of each criterion when making that determination.

As can be seen in Figure 3.10, the current work load of ODOT designers was rated by designers and project managers as the highest priority when selecting a consultant to design a project (mean ratings = 8.2 and 5.7, respectively). Project budget was rated as the lowest priority by both designers and project managers (mean ratings = 2.0 and 1.1, respectively).

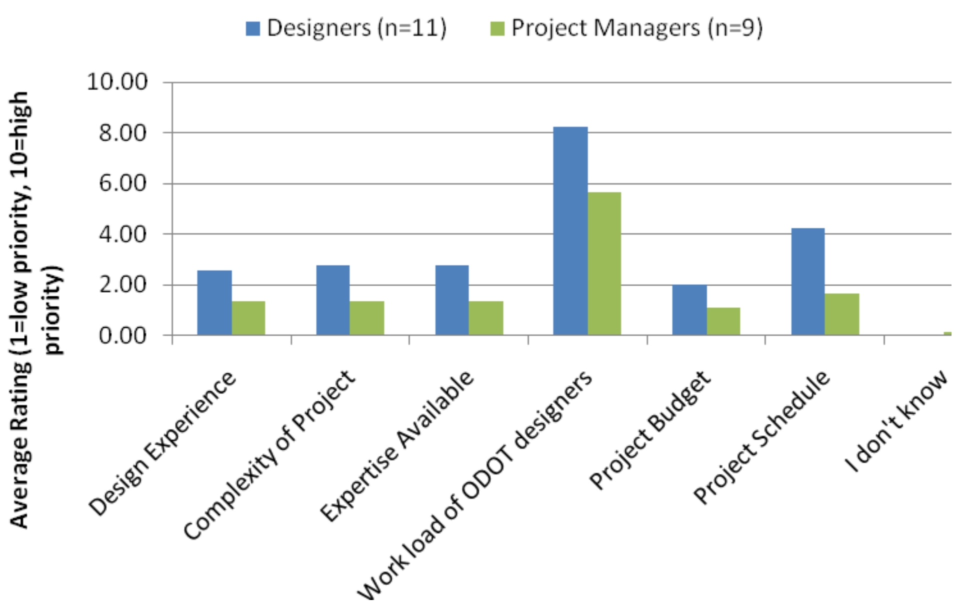

Figure 3.10: Factors for Selecting Use of Consultant TCP Designers

3.3.6 Availability of Resources to Design, Review, Implement, and Inspect TCPs

Sufficient resources must be made available to all members involved in the TCP development process to ensure delivery of a safe work zone. Many types of resources are used to develop TCPs including: design time, average daily traffic data, TCP design standards, TCP device performance data, standard TCP design drawings and specifications, and constructability requirements. Designers, reviewers, construction personnel, and inspectors were asked, "Do you have sufficient resources available to design/review/implement/inspect TCPs effectively? " The mean ratings from the responses were compiled and are presented in Figure 3.11. While no responses were provided by the Reviewers, the other disciplines gave high marks for the amount of resources available. Mean ratings of 4.0 or better were received for sufficiency of adequate resources.

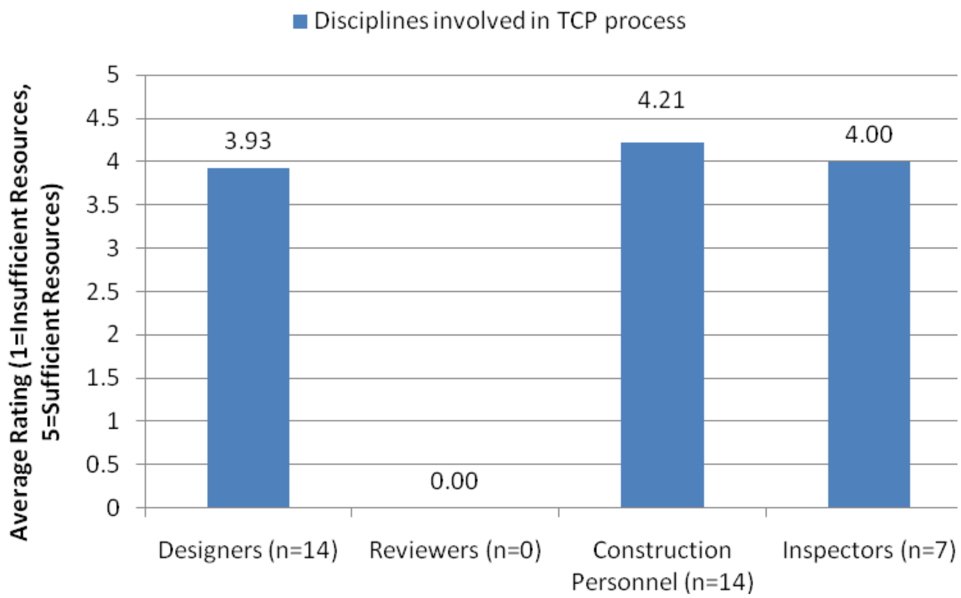

Figure 3.11: Resource Availability for Disciplines Involved in TCP Process

In another question, designers were asked to, "Indicate whether you agree or disagree with this statement: Designers are given enough time to complete a thorough TCP design.." The designers were approximately neutral with respect to this statement, providing a mean response of 3.3 (n=14).

Constructability is the ease with which a design can be implemented on the construction site. A high level of constructability indicates that contractors can conduct their work in an efficient and safe manner. Low levels of constructability lead to higher project costs, longer construction durations, more change orders, and poorer safety performance. TCP constructability depends in part on input given to designers from construction personnel during various phases of project development. Their input is a resource that impacts the quality and effectiveness of the final design, especially as it relates to the work site conditions and construction means and methods. The degree to which construction personnel are involved in the design process is a measure of design resource availability. Construction personnel were asked, "To what extent is your input requested in the design of a TCP? " Respondents were quite varied in their responses, giving a mean rating of 2.9 (n=13) which ranged from a low of 1 to a high of 5.

3.3.7 Level of Worker and Motorist Safety Provided by TCPs

Worker and motorist safety are functions of many different aspects of TCPs. Safety can be a function of traffic flow through the work zone, effectiveness of the original design, and also the accuracy with which the TCP design is implemented. Another aspect of TCPs that impacts worker and motorist safety is the extent to which enforcement is provided by inspectors for projects that use TCPs. One way to gauge the level of worker and motorist safety is to quantify the number of safety violations observed by these inspectors on the job site. Inspectors were asked, "Approximately what percent of all TCP implementations that you inspect have some kind of safety violation?" The mean response to this question from all of the respondents (n=7) was 19% of projects have a safety violation. The responses ranged to a great extent, from a high of 90% of projects to a low of 1%.

The level of worker and motorist safety can also be assessed by determining the sources of frustration or confusion encountered by construction personnel charged with implementing the TCP. Construction personnel were asked, "If there are difficulties implementing a TCP, what are the sources of frustration or confusion when implementing a TCP?" Five out of fourteen respondents (36%) noted that the "TCP design does not provide a safe work environment".

Changes to the TCP are sometimes made during implementation or once the TCP is in place. If the TCP is implemented as designed, and either the construction personnel or the inspector feels the work environment is not safe, changes to the TCP are made to adequately increase the level of worker and motorist safety on site. Construction personnel were asked, "Why might the implemented features of the TCP differ from the written TCP plan/drawings?" Of the fourteen respondents, two (12%) noted, "Traffic entering the work zone is initially uncontrolled." Four (29%) of the fourteen respondents felt that "Worker safety threatened" was a cause for necessary alterations to the written TCP.

3.3.8 Priority of Work Zone Safety with Respect to Other Project Parameters

It is often the case that construction projects have multiple objectives. Besides simply meeting the needs of the traveling public, it is common for projects to have objectives associated with cost, schedule, quality, safety, and mobility. The priority assigned to each objective and the degree to which each objective is achieved often characterizes the successes and shortcomings of a project. Work zone safety is one of these parameters that must be considered by all those involved in the project from beginning to end. The survey questionnaires and interviews of designers, reviewers, construction personnel, inspectors, and project managers asked the participants to, "Please rate each of the following project objectives in terms of their importance to project success." The question listed numerous common objectives and allowed the respondents to add other objectives. Figure 3.12 shows the mean ratings given to each objective by the five disciplines. Of the project objectives rated, motorist safety and worker safety were rated highest in terms of importance to project success by designers, reviewers, construction personnel, and project managers. The project objective with the highest overall rating from the five disciplines combined was worker safety (mean = 9.7). The lowest overall rating was given to cost (mean = 6.2).

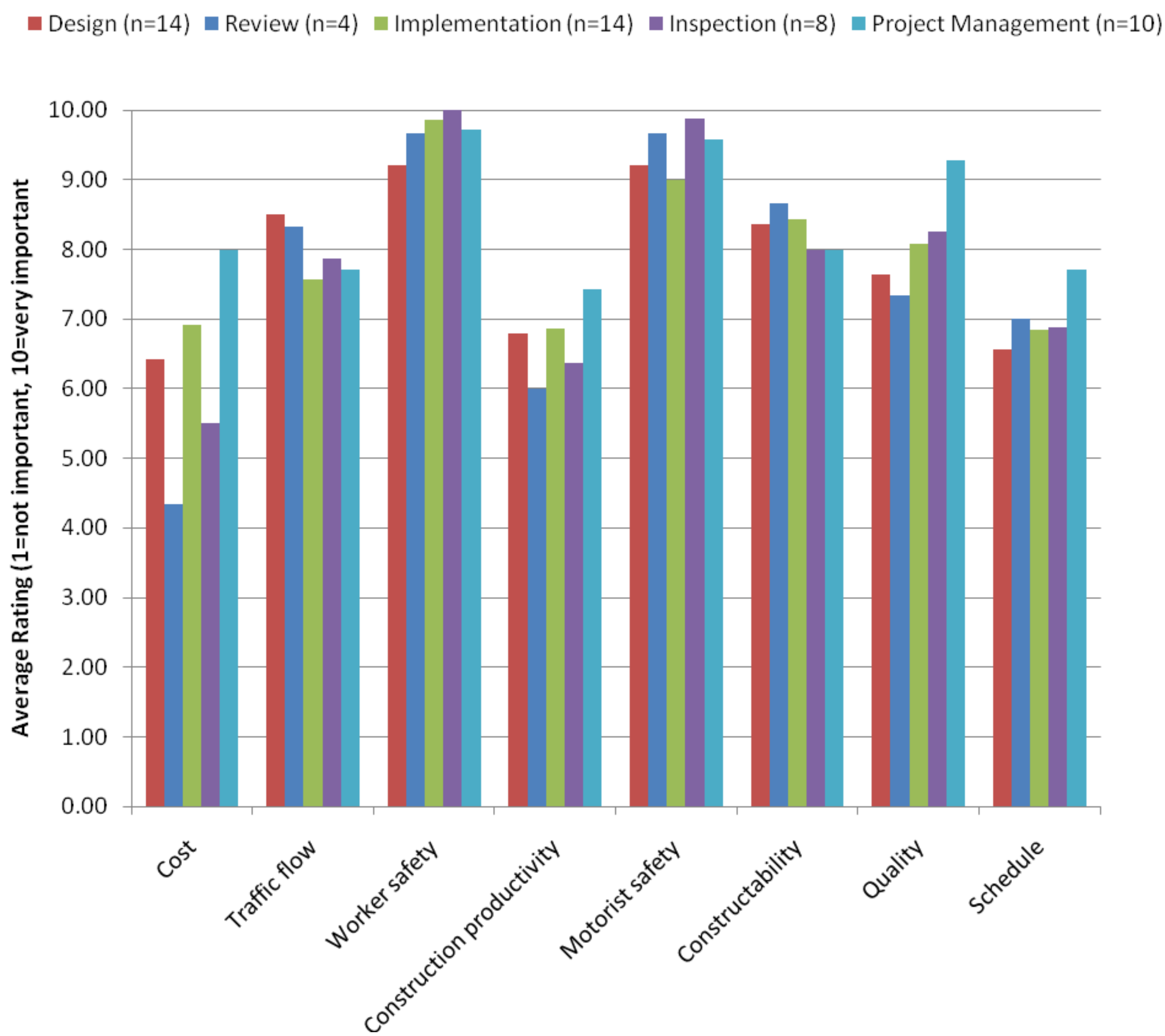

Figure 3.12: Rating of Project Objectives as Importance to Overall Project Success

The Design questionnaire also asked, “What are the top 3 concerns when creating a TCP design?” Below is a list of the common concerns in response to this question:

- Safety of the traveling public and/or construction workers (n = 7)
- Minimizing the effects on traffic flow and mobility (n = 7)
- Clear communication with motorists through signing and sufficient warning time (n = 4)

- Allowing adequate time for construction personnel to complete scheduled work (n = 4)
- Lane width (n = 2)
- Right of way (n = 1)
- Speed (n=1)

3.3.9 Quality with which the TCP Process is Managed

The survey questionnaires included several questions that provided an indication about the quality with which the TCP process is managed. Part of the continuous improvement of TCPs involves the effective collection and communication of lessons learned. How those involved collectively incorporate lessons learned into future projects is one aspect of management of the overall TCP process. As lessons learned are applied to future projects, barriers are removed and efficiency and effectiveness is enhanced. Designers, reviewers, construction personnel, inspectors, and project managers were asked, "How are lessons learned from past projects communicated for future use in TCPs?" The following is a compilation of general responses that were identified by the survey participants:

- ODOT Construction Section distributes post-project narrative to project team (n = 8)
- Word of mouth between individuals involved in varying phases of TCP process (n = 7)
- Crew and design team meetings during project development and implementation (n = 4)
- Increased experience of individuals involved in projects with TCP challenges (n = 3)
- State Traffic Control incorporates feedback into future TCP design classes (n = 2)
- Lessons learned not/seldom/occasionally communicated (n=8)

Another means to rate the degree to which the TCP process is well-managed is to determine when TCP designers are brought into the process. Early participation provides an opportunity for the designer to both give and receive feedback regarding the TCP. Designers and project managers were asked, "When in the project development phase is the Traffic Control Plan (TCP) Designer first included?" Figure 3.13 displays the array of responses received from those surveyed. As shown in the figure, TCP designers join the project at a variety of points from the original scoping effort to the Preliminary Plans Workshop. Project complexity is a consideration when determining when TCP designers are first included in the project development. TCP designers typically join the project earlier for more complex projects.

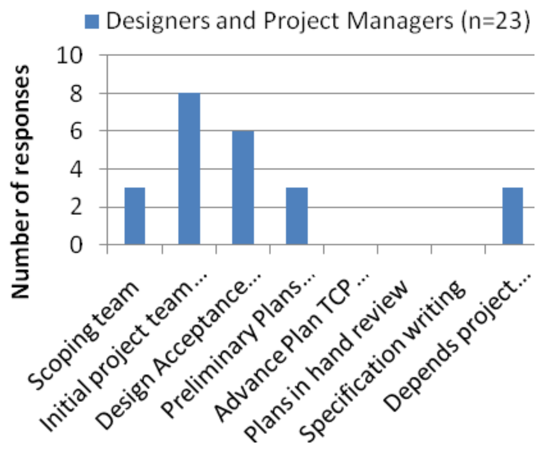

Figure 3.13: Project Phase in which TCP Designer is First Involved

3.3.10 TCP Design and Implementation Process Strengths and Enablers

In addition to the nine metrics detailed above, the current state of ODOT work zone designs and operations can be characterized by general strengths and weaknesses in the process. Designers were asked directly to state perceived strengths in the existing TCP design process. Individual responses were compiled and are listed below:

- Good support from ODOT Headquarters experts
- Close proximity to the ODOT regional office to get constructability feedback
- Focus is kept on traffic safety and not contractor profit
- Experience of ODOT designers
- Regular project team review meetings
- Quality design creates a high standard of safety
- Early involvement of TCP designers
- TCP Designers are located closer to the work and more familiar with the existing traffic issues and overall goal/plan of the project

Designers, reviewers, and construction personnel were also asked to draw on their experience in the TCP process to characterize the elements of a successful TCP, i.e., those factors that enable the successful creation and implementation of TCPs. The list below contains enablers to the TCP design and implementation process that maximize the probability of a successful TCP:

- Cooperation and buy-in from all members of the project team (n = 8)
- Working knowledge of unique site conditions such as geographical features, traffic distribution, posted speeds (n = 4)

- Clear, easily decipherable plan sheets and special provision language (n = 3)
- Designs focused on constructability of TCP (n = 2)
- Adherence to ODOT TCP design standards and MUTCD requirements (n = 1)
- Reasonable time schedule (n=1)
- Experienced TCP designers (n = 1)

3.3.11 TCP Design and Implementation Barriers and Weaknesses

The TCP ultimately exists to provide a safe environment on the roadway for both the traveling public and construction workers. The surveys that were distributed to each of the five disciplines (design, review, implementation, inspection, and project management) all contained the following questions: “How can safety be improved in work zones?”, and “What are the weaknesses and barriers within ODOT’s TCP design and implementation process?” Suggested improvements and barriers listed by participants further clarified areas of weakness that are potential causes of inefficiency or ineffectiveness within the process. The following is a compilation of general responses that were given as ways to improve safety in work zones and overcome perceived barriers and weaknesses in overall TCP design and implementation.

- Maintain the same high standard of care for implementation of TCP that is used in creating the TCP design (n = 12)
- Earlier and/or more thorough TCP constructability reviews from construction personnel (n = 9)
- Communicate more clearly with and educate the traveling public through signs, message boards, and other media available (n = 6)
- Reduce speeds of motorists in work zones through greater police enforcement (n = 4)
- Better communication between engineering disciplines/sections regarding impacts of field changes on TCP (n = 4)
- Provide positive separation between workers and traffic through use of concrete barriers (n = 3)
- Increased availability of designated TCP designers (n = 3)
- Limit unnecessary overdesign of TCP’s (n = 2)
- Earlier involvement from TCP designers (n = 2)
- Reduce motor carrier restrictions (n = 2)
- Increased field experience of TCP designers (n = 1)
- Right of way purchases to facilitate TCP design (n = 1)
- Eliminate policies created without sufficient understanding of their impacts on TCP process (n = 1)

- Limit standardization of TCP designs in situations that call for unique, common sense solutions (n = 1)

3.4 SURVEY ANALYSIS

The survey of ODOT personnel and consultants provided an opportunity to gain the perspectives of many individuals regarding TCPs (see survey instrument in Appendix A). The information gathered in the survey came from a range of individuals who varied with regards to years of experience, work location, and role on the project team. Statistical analyses (Mann-Whitney and Independent Samples t-tests) were conducted to identify relationships between the different groups of respondents.

While responses were received from all of the different disciplines (design, review, implementation, inspection, and project management), the number of responses was limited, especially in the review and inspection disciplines for which only 3 and 4 responses were received, respectively. It should be noted that a low number of responses lessens the confidence that the conclusions are representative of the entire population.

3.4.1 Quality of the TCP Design and Review

The data collected in the survey reveals findings related to the nine identified TCP outcomes (metrics). With respect to the quality of the TCP design and the TCP review, both the designers and the reviewers rated each as having above average quality. They acknowledged that the TCPs sometimes contained mistakes which included not only design errors but also inconsistencies with the construction schedule and a lack of coordination with external impacts. The presence of errors and a lack of clarity in TCP documents were identified as sources of frustration and confusion on projects. In addition, conflicts and inconsistencies between the TCP design and actual site conditions were identified as a problem. As a result, re-design and modification of the TCP is required in the field. These findings are perhaps an indication that additional time and effort should be spent to minimize TCP design errors, clearly present the design, and visit the site before work begins to verify that the design is appropriate. Visiting the site and having knowledge of the site conditions is facilitated when the TCP designers are located in close proximity to the site. However, it should be recognized as well that all work zone conditions and hazards cannot be anticipated during TCP design, especially when the construction process to be used is not fully known. Therefore, the process of designing and implementing TCPs should be planned and managed to coordinate and encourage collaboration between design and construction disciplines and allow for some field modification.

It was hypothesized that level of experience has an impact on the designer's perspective of quality. Exposure to a greater number of projects and a wider variety of projects over a career may provide the ability to distinguish level of quality on a project. When asked to rate design quality using a Likert scale (1 = low quality, 5 = high quality), the designers with more total experience (>20 years of experience) reported higher design quality on average (mean = 4.20, n = 10) than designers with less experience (mean = 3.50, n = 7)). This difference was found to be statistically significant (two sided Independent Samples t-test, p-value = 0.028). Other relationships between designer/reviewer involvement and design/review quality were also investigated, but none were found to be statistically significant.

3.4.2 Quality of TCP Implementation and Inspection on the Construction Site

The quality of implementation and inspection of the TCPs were rated by construction personnel and inspectors as above average as well. This high quality rating was due in part to frequent inspections which occurred at least once a day and often more frequently depending on the project's complexity. The quality of implementation was impacted in part by the quality of the initial TCP design. It was generally felt that greater consideration should be given to the intent of the TCP as opposed to the specific design because of unanticipated and unknown jobsite conditions during design. That is, as indicated previously, respondents recognized that the initial TCP design is high quality but that in some cases can be improved even further once construction begins and jobsite conditions are better known. As a result, simply implementing the original design may not be possible and may not provide for a safe work zone. To do so, a process should be in place to allow for modification and review of the TCP during construction. However, this does not relieve the initial TCP design of the need to be of the highest quality possible. The respondents also indicated that the quality of TCP implementation can be improved by greater enforcement of traffic control measures.

A variety of relationships to quality of TCP implementation and inspection were tested. Below are relationships that were found to be statistically significant (two-sided Independent Samples t-test):

- Implementers who identified that the TCP cannot be constructed as designed to be a frustration reported a lower average quality of inspection (mean = 3.44, n = 8) than implementers who did not identify it as a frustration (mean = 4.67, n = 6) (p-value = 0.001).
- Implementers and inspectors who gave a higher importance on productivity reported a lower average quality of inspection (mean = 3.65, n = 13) than those who indicated a lower importance on productivity (mean = 4.67, n = 9) (p-value = 0.001).

Other relationships that were hypothesized but not found to be statistically significant included:

- Implementers, inspectors, and project managers with more total years of experience reported a different quality of implementation than those with less experience.
- Implementers that identified constructor involvement in design as important reported a different quality of implementation than implementers who did not identify it as important.

3.4.3 Consistency of TCP Quality from Project-to-Project

Based on the distribution of responses to various questions, the survey revealed that the quality of TCPs varied from project-to-project, i.e., the level of quality is not consistent. The consistency of TCP design was rated highest in Region 2, followed by Regions 1, 5, 4, and 3 in order of decreasing consistency. With regards to TCP implementation, Region 1 was given the highest rating for consistency, followed by Regions 2, 3, and 5 (no responses were received regarding Region 4). Overall, the respondents assessed consistency as above average. Inspectors rated implementation with the greatest degree of consistency while construction personnel rated inspection with the least degree of consistency. Relationships between region and the reported level of quality consistency, and between discipline and the level of quality consistency, were tested for significance, however none were found to be statistically significant (two-sided t-tests).

3.4.4 Efficiency and Effectiveness of the TCP Design and Review Process

The TCP design process involves a sequence of steps through which the TCP is designed and reviewed. The survey respondents feel that each step of the process could use some improvement, with the task of creating the Advance Plan TCP packages needing the most improvement. It was commonly felt that the initial project team meeting was good and needs the least improvement. The responses to this question came only from designers, reviewers, and project managers. Given the low number of responses from reviewers compared to designers and project managers, additional responses from reviewers is needed to provide more accurate results. Statistical analyses of the data that focused on efficiency and effectiveness of the TCP process were tested, and the following found to be statistically significant (two-sided Independent Samples t-test):

- Designers and project managers who identified an early start of the TCP design as being important to the TCP design and review process reported a higher average need for improvement in the TCP process (mean = 4.46, n = 9) than designers and project managers who did not identify an early start as important (mean = 2.55, n = 6) (p-value = 0.02).
- Designers, reviewers, and project managers who work for ODOT indicate that there is a greater need for improvement in the TCP process (mean = 4.16, n = 15) than those in similar positions who did not work for ODOT (mean = 2.43, n = 5) (p-value = 0.021).
- Designers who identified construction involvement as a concern reported a greater need for improvement in the TCP process (mean = 5.00, n = 4) than designers who did not identify construction involvement as a concern (mean = 2.90, n = 7) (p-value = 0.07).

Other relationships were hypothesized but not found to be statistically significant, including:

- Designers and project managers who identified significant TCP designer involvement in scoping report a different need for improvement in the TCP process than those who indicated insignificant involvement.

3.4.5 Understanding of the TCP Design, Review, and Implementation Process

The survey data indicated that most people involved in the TCP design, review, and implementation process have received some related training. Nine out of the 13 designers and reviewers (69%) had taken the Traffic Control Design class. Training of those on the implementation side varied with no specific training in TCP implementation. Continued efforts should be made to have designers and reviewers take the Traffic Control Design class. Additional efforts should be considered to develop a class for construction personnel and inspectors to understand why TCPs are designed in a certain way and how best to implement the TCP on a project.

As part of the data analysis, it was hypothesized that those who have gone through the training have a different understanding of the TCP process and recognition of the level of quality. When implementers and inspectors were asked about the quality of implementation using a scale of 1-5 (1 = low quality, 5 = high quality), those who have the TC Supervisor training reported a lower quality of implementation on average (mean = 2.40, n = 5) than those who have not had the training (mean = 3.00, n = 8). This relationship was found to be of interest, but not statistically significant at the 0.05 level (two-sided Independent Samples t-test, p-value = 0.077).

The implementers and inspectors were also asked to rate different project priorities (e.g., cost, schedule, motorist safety, worker safety, etc.) using a scale of 1-10 (1 = low priority, 10 = high priority). The implementers and inspectors who had the TC Supervisor training rated gave cost as a lower priority (mean = 6.08, n = 12) than those who do not have the training (mean = 6.78, n = 9). This relationship was found to be statistically significant (two-sided Independent Samples t-test, p-value = 0.027).

3.4.6 Availability of Resources to Design, Review, Implement, and Inspect TCPs

According to the survey responses, the amount and availability of resources was sufficient in all phases of the TCP process. However, with regards to whether they have sufficient time for their role in the process, designers were close to neutral in their responses (mean rating = 3.3). As indicated above, additional time is warranted in the design phase to ensure high quality TCPs. In addition, further utilization of construction personnel as a resource to provide additional assistance with designing the TCPs is needed. The involvement of construction personnel early in the design phase will lead to TCPs that more closely accommodate site conditions and anticipated construction means and methods, and help to minimize the amount of modifications required in the field. Relationships between the level of resources (time, money, etc.) and the TCP process and TC quality were tested for significance using the survey data collected, however none were found to be statistically significant (two-sided t-tests).

3.4.7 Level of Worker and Motorist Safety Provided by TCPs

While the survey did not include questions about specific numbers of work zone crashes and worker injuries, the findings from several questions can be used to infer the current level of safety in work zones. With regards to their perception of the level of risk on construction sites, one-third of the construction personnel surveyed (33%) indicated that TCPs did not provide a safe work environment. The number of safety violations in TCP implementations can indicate how safe a site is as well. The number of work zones with safety violations according to the inspectors ranged significantly, from 5% to 90% of work zones, with an average of approximately one-third of the work zones containing safety violations. This percentage can be reduced through a variety of means including increased training and ensuring that TCPs accommodate the jobsite conditions.

Analyses of the survey data found one relationship related to work zone safety to be statistically significant. When asked about the quality of implementation using a scale of 1-5 (1 = low quality, 5 = high quality), implementers who indicated that the design does not provide a safe work zone reported a lower quality of implementation on average (mean = 3.20, n = 5) than implementers who did not indicate that the design does not provide a safe work zone (mean = 4.06, n = 9) (p-value = 0.01).

3.4.8 Priority of Work Zone Safety with Respect to Other Project Parameters

All respondents placed motorist and worker safety as high priorities on projects. In addition, when comparing safety to other project objectives such as cost, productivity, and construction quality, motorist and worker safety received the highest ratings by all respondents on average except for the inspectors. For the small group of inspectors who responded to this portion of this survey, they, on average, placed construction productivity as the highest priority. While safety rated lower, the findings indicate that safety is important when compared to other objectives throughout the TCP process.

Analyses of the data revealed numerous statistically significant relationships related to project priorities. The following are relationships that were found to be statistically significant (p-value ≤ 0.05) and of interest (0.05 < p-value < 0.10) using two-sided t-tests:

Cost:

- When asked to rate the priorities on a scale of 1-10 (1 = low priority, 10 = high priority), ODOT employees gave cost a lower priority (mean = 6.10, n = 30) than non-ODOT employees (mean = 7.33, n = 15) (Independent Samples t-test, p-value = 0.063).
- Region 2 respondents placed a higher priority on cost (mean = 7.19, n = 21) than respondents from other regions (mean = 5.92, n = 24) (Mann-Whitney t-test, p-value = 0.039).
- Region 2 respondents reported a higher cost-to-safety priority ratio (mean = 0.79, n = 21) than respondents in the other regions (mean = 0.64, n = 24) (Mann-Whitney t-test, p-value = 0.043).

Constructability:

- ODOT employees reported a lower constructability-to-safety priority ratio (mean = 0.88, n = 30) than non-ODOT employees (mean = 0.98, n = 15) (Mann-Whitney t-test, p-value = 0.065).
- Region 1 respondents placed a higher priority on constructability (mean = 8.81, n = 16) than respondents from other regions (mean = 8.00, n = 30) (Mann-Whitney t-test, p-value = 0.056).

- Region 1 respondents reported a higher constructability-to-safety priority ratio (mean = 1.04, n = 16) than respondents in the other regions (mean = 0.85, n = 30) (Mann-Whitney t-test, p-value = 0.004).

Productivity:

- Region 5 respondents placed a higher priority on productivity (mean = 7.91, n = 11) than respondents from other regions (mean = 6.43, n = 35) (Mann-Whitney t-test, p-value = 0.016).
- Region 1 respondents reported a higher productivity-to-safety priority ratio (mean = 0.86, n = 16) than respondents in the other regions (mean = 0.68, n = 30) (Mann-Whitney t-test, p-value = 0.038).

Schedule:

- Region 5 respondents placed a higher priority on schedule (mean = 7.91, n = 11) than respondents from other regions (mean = 6.59, n = 34) (Mann-Whitney t-test, p-value = 0.084).

3.4.9 Quality with which the TCP Process is Managed

The survey provided some insights into the quality with which the TCP process is managed as well. The survey respondents indicated that designers are brought into the TCP process early, predominantly at the initial project team meeting. Early involvement of the designers is a key aspect to high quality TCPs. When designers are involved early, they are able to add their experience into the project plan and have additional time to develop the TCPs. Late involvement can lead to incomplete designs and TCP designs that are more of an "add-on" to the project as opposed to integrated into the work. Part of the management of the TCP process involves coordinating and managing resources, including lessons learned from past projects. The survey responses indicated that a lessons-learned/knowledge management process is in place for the project team, which is both written and oral/informal, that present the project team with lessons learned after the project is complete. None of the respondents indicated, however, that a program exists which distributes lessons learned between projects and throughout ODOT. A lessons-learned/knowledge management program that extends across the organization could expand and facilitate the learning that takes place, thereby benefiting a wider array of ODOT projects. Relationships between the quality of the TCP and management of the TCP process were tested for significance using the survey data collected, however none were found to be statistically significant (two-sided t-tests).

3.4.10 TCP Design and Implementation Process Strengths and Enablers

There are many strengths of the current TCP process have enabled its success. The respondents felt that the ability to get feedback and support from ODOT Headquarters is a benefit. It also has helped when the designers are located in a regional office that is close to the project site so that they can easily access the site and may have some familiarity with it. Living and working closer to the project generally leads to a better understanding of the project and the traffic affected. The TCP process is strengthened by the inclusion of designers with extensive experience and through peer reviews. However, in order for the benefits of this experience to be realized, there must be a robust TCP designer network through which sharing of ideas and information can occur. A focus on constructability enables successful TCPs as well as having extensive experience as the designer.

3.4.11 TCP Design and Implementation Barriers and Weaknesses

In terms of barriers and weaknesses, it was generally felt that constructability reviews needed to be more thorough and conducted earlier in the design phase. The reviews should also include input from construction personnel or people with construction site experience. Involving the right people at the right time is critical to the success of a TCP. Another barrier identified is a difference in standard of care between design and implementation. For example, designers may place a high level of importance on a particular aspect of the design while less importance is giving to the feature by the construction and inspection personnel. Clear communication of the design and the design intent is needed. Clear and constant communication of ODOT's project objectives are needed as well. Lastly, public awareness of the work zone and traffic control features was identified as in need of improvement. Additional efforts are needed to alert the public of the work zone and safe means of travel through the work zone.

3.4.12 Survey of ODOT Personnel and Consultants Summary

The survey of ODOT personnel and consultants provided a wide-ranging perspective on current ODOT policy and practices along with examples from practice of the enablers and barriers to successful design and implementation of TCPs. This perspective came from a diverse sample of people involved in ODOT projects. Participants in the survey worked for both ODOT and private firms, and provided services related to design, review, construction, inspection, and project management. The experience of the participants was extensive in both number of years and types of projects, and the respondents were located throughout the state (region).

The survey revealed that all of the respondents participating in the TCP process felt that the quality of TCP design, review, implementation, and inspection was above average. There was also general agreement that motorist safety and worker safety are of higher priority to project success than other project objectives such as cost, schedule, and productivity. However, when there was a higher importance given to productivity, the respondents gave a lower rating to the level of quality of inspection. There were differences between the regions on the priority of cost, schedule, productivity, and safety. Regions placed different priorities on each of these project criteria, and the priority relative to safety was different as well.

Some confusion and frustration with the TCP process existed. Specifically, with respect to the design, those who implement the design stated that the greatest frustrations were when the TCP design did not match the site conditions and that the TCP design documents are unclear and/or contain errors. As a result, TCP implementers indicated that they have needed to frequently modify the TCP design because they felt it did not provide a safe work environment. In addition, implementers indicated that the most common reasons for modifying the TCP in the field was that: the TCP could not be constructed as design, traffic flow was excessively impeded through the project, motorists ignored specified turn movements, and the construction methods chosen were not compatible with the TCP design.

From the TCP designer's perspective, greater adherence to the TCP design is needed by the contractors. This requires an increased level of enforcement of the TCP design. Inspectors reported that almost 20% of projects have some kind of safety violation, although this percentage varied to a great extent amongst the inspectors (1% - 90%). The most commonly cited problems with implementation of the TCP were: improper transition lengths, incorrect degree of curve, over-signing the work zone, leaving gaps in traffic control measures, unknown utility schedules and locations, inadequate separation of traffic and work areas, and improper allowances for drainage. In regards to the phasing of the work, not integrating the TCP with the construction schedule was recognized as a problem as well.

There was no clear consensus on the level of TCP consistency between projects. With respect to individual phases of the process (design, review, implementation, and inspection), the designers indicated a greater level of inconsistency in the TCP design review. Similarly, the contractors saw inconsistency in the quality of the inspections. The ratings of consistency of the TCP quality were fairly uniform across all regions.

The respondents provided input on what project development phases need the most improvement in order to improve the quality of the TCP process. Implementation of the final TCP design was identified as needing the most improvement base on all responses combined. This was followed by the need for improvements in creating the Advance Plan TCP packages. An early start of the TCP design was also recognized as being important to the process. ODOT employees recognize a greater need for improvement in the TCP process than non-ODOT employees.

While the respondents indicated the need for improvements, the amount of resources available for the TCP process was viewed as being sufficient (no responses from Reviewers to this question). Designers felt that they had adequate time to complete a thorough TCP design. Supporting quality TCP designs is the sharing of lessons learned from past projects. It was found that lessons learned are shared, although the means of sharing varies. Commonly cited means in which lessons are shared were: ODOT post-project narrative, word of mouth between project team members, and crew and design team meetings during the project. However, there was recognition of a lack of, and need for, a project-to-project lessons learned/knowledge management system.

There were many strengths recognized within the current TCP process. The respondents recognized that the support from ODOT Headquarters was helpful to the TCP design, and that close proximity to the regional construction offices also benefited the design. Other strengths included the use of ODOT designers with extensive years of experience, and regular and early involvement of TCP designers. The entire process was enabled when there was cooperation and buy-in from all members of the project team. That meant bringing construction contractors in early to review and provide input on the designs. When asked about the extent to which they were requested to provide input on the design of a TCP, the response from contractors was neutral, some indicated not often while others indicated frequently.

Barriers and weaknesses of the TCP process were recognized as well. These were predominantly: a different standard of care between TCP design and TCP implementation; the need for earlier and more thorough TCP constructability reviews; and the need to communicate more clearly with and educate the traveling public about work zones. The identified barriers and weaknesses highlighted the importance of ODOT communicating its expectations with respect to the quality of TCP design and TCP implementation.
Amongst the survey respondents, the number of years of experience was found to be a differentiator when judging the quality of TCP designs. Those respondents with more years of experience indicated a higher level of quality. The amount of training was also found to be significant in addition to the amount of experience. Those respondents who have had TC supervisor training reported a different (lower) level of quality of implementation than those who did not have the training. In addition, those who had the training did not rate cost as high a priority.

A lower level of quality of inspection was found within those contractors who identified that the TCP cannot be constructed as design as a barrier. This result may indicate a need for better communication and coordination of the expectations related to the TCP, level of safety in the work zone, and the abilities and constraints on the contractor.

4.0 CASE STUDY PROJECTS

4.1 CASE STUDY OBJECTIVES

This section of the report presents the study of TCPs on past and current ODOT projects. Whereas the general survey described previously in Section 3.0 gathered input on typical ODOT projects from a wide spectrum of projects and perspectives, the case studies provided an opportunity for in-depth study of individual projects. The in-depth project-based focus allowed for assessment of the TCP planning, design, and implementation process across a common project environment, eliminating the confounding factors that multiple projects might bring to the study. The work included identifying a sample of study projects, collecting detailed data about each project, and then analyzing the data to identify salient findings related to TCPs. Data were gathered with respect to five specific aspects of each project in the case study:

- Key project personnel
- Traffic Control Plans
- Crash data
- Construction work zone scores
- Inspection/Traffic Control Supervisor reports

On each case study project, multiple interviews were conducted of a variety of different project team members: designers, reviewers, implementers (general contractors and trade contractors), inspectors, and project leaders and managers. The detailed project information collected and interviews allowed for examining the TCP process from start to finish of the project and from multiple perspectives. The aim of the analysis was to determine:

- the TCP features (both design and implementation) that were contributing factors to work zone crashes;
- suggested revisions to the TCP design, review, implementation, and inspection process to improve safety; and
- the impacts of ODOT's TCP design practices, including those related to in-house and outsourced designs, the quality and consistency of TCPs with respect to design standard compliance, staging methods, device usage, and drafting similarities.

As part of the case study investigations, a list of questions was created to gather the desired project information during the interviews. The interviews were conducted to gather information about the quality and performance of the TCPs and the related impacting factors. For each case study it was desired to have sufficient information from the project documents and interviews, and the statewide crash data, to identify a relationship between the TCP design and implementation process and the level of safety experienced in the work zone. In addition, a sufficient number of case study projects were included in order to identify and verify patterns associated with TCP performance across ODOT projects and regions.

The analysis conducted involved determining how specific TCP design, review, implementation, and inspection factors impact safety through the work zone. One mean of measuring safety was through the use of crash data. ODOT maintains information related to crashes in work zones in electronic databases. The Oregon Transportation Management System (OTMS) database, TripCheck, and the CAD database house information about the nature, extent, cause, location, and other characteristics of crashes on the state's roadways.

Obtaining the necessary crash information from the three databases can be difficult. While it was easy to determine whether a crash occurred in a work zone, there was no direct connection in the database regarding which work zone (i.e., which project). Connecting the crashes to a specific project required knowing the milepost and date limits of the project, and knowing at what mileposts and on what dates the crashes occurred. The crash database included the milepost locations of where the crashes occurred and the dates of occurrence, but no corresponding construction project number. This disconnect posed a difficulty in identifying whether there was a crash on a specific project and, if so, determining what aspects of the work zone traffic control measures were associated with or caused the crash. Additional efforts were taken to make the connection between crash and work zone features.

In addition to information collected from the crash databases, inspection reports were gathered to provide a description of the activities and characteristics of the project on a daily basis. If an accident occurred on a project, the inspection report should include a mention of it. If the inspector or Traffic Control Supervisor provided a sufficient description of the work zone features and conditions at the time of the crash, a connection between the crash causes and the traffic control features could be made. It was sometimes the case, however, that the reports did not contain sufficient information to make this correlation. Further review of project documents and logs was needed along with interviews of those involved in the project and on the project site.

4.2 CASE STUDY METHODS

The first step in the case study process was to develop a sample of case study projects. An important consideration was that the projects be representative of ODOT roadway construction projects, and encompass a variety of project characteristics including project type, size, type of roadway, region, safety performance, and composition of design team (in-house or consultant). An initial list of 14 projects was developed based on input from the study's Technical Advisory Committee (TAC). An additional 20 projects, included as part of ODOT's annual tour of work zones, were added to the list of the original 14 case study projects. A detailed discussion of these work zone tours is included in Section 4.2.4 of this report. Lastly, members of ODOT's Research conducted independent reviews of five more projects and requested that those projects be added to the list as well. Therefore, a total of 39 projects were included in the case study analysis. Table 4.1 provides a list of the projects.

As shown in Table 4.1, the case study projects were assigned a number for clarity in the study. Table 4.1 also shows the route number and project name as well as several defining characteristics of each project: region, project type, budget, and composition of design team (ODOT or consultant). The project list was sorted by Project Number and then by Region. Further information about each project is available in the Case Study Project Profile document and Case Study Project Map included in Appendix B.

The projects selected for the case study were representative of all ODOT roadway construction projects in several important areas. The projects were distributed in all five ODOT regions as follows:

- Region 1: 4 projects (10%)
- Region 2: 13 projects (33%)
- Region 3: 7 projects (18%)
- Region 4: 4 projects (10%)
- Region 5: 11 projects (29%)

The pool of case study projects contained 23 projects with traffic control designed by ODOT (59%) and 15 with the traffic control designed by a consultant (38%), and one project in which portions of the traffic control were designed by both ODOT and a consultant (3%). As shown in Table 4.1, a wide range of project sizes were included in the case study sample. The projects varied in size (based on budget) from approximately $59,000,000 to $325,000, with an average dollar amount of $10,764,000. A wide range of project types were also included in the study sample. Table 4.2 shows a breakdown of the case study projects by project type.

Table 4.1: List of Case Study Projects

Project Number	Route Number	Project Name	Region	Managing Firm	Budget Size ($)	Project Type
1	I-205	Willamette River Bridge – Pacific Hwy. (Unit 3) Sec.	1	ODOT	$ 32,142,892.40	Bridge repair
2	I-5	Marquam Bridge – Capitol Hwy. Sec.	1	ODOT	$ 21,200,000.00	Freeway Modernization
3	OR-219	Hillsboro-Silverton Hwy. at Farmington Road	1	ODOT	$ 3,694,860.07	Bridge replace./2 lane highway Modernization
4	US-26	Langensand Rd. – Cherryville Dr. Sec.	1	ODOT	$ 1,374,704.93	2 lane highway Preservation
5	I-5	Sodom Ditch-Calapooia (Bundle 216 (08233 and 08235))	2	OBDP	$ 16,512,000.00	Bridge Replacement
6	OR-18	Fort Hill – Wallace Bridge	2	ODOT	$ 12,180,757.00	2 Lane highway Modernization
7	OR-18	Oregon Coast HWY – Oldsville Road (megapave)	2	ODOT	$ 12,871,429.25	2 lane highway Preservation
8	OR-213	Lone Pine Corner – Hwy. 214	2	ODOT	$ 1,056,202.00	2 lane highway Preservation
9	OR-219	Springbrook Road - Wynooski Road (Newberg)	2	ODOT	$ 2,846,021.00	2 lane highway Preservation
10	OR-22	Sublimity Interchange	2	ODOT	$ 15,820,683.52	2 Lane highway Modernization
11	US-101	Jetty Creek Fish Passage	2	ODOT	$ 2,470,162.70	Bridge replacement
12	US-101	Latimer Road	2	ODOT	$ 1,365,238.52	2 Lane highway Modernization
13	US-101	Meda Loop Road - Redburg Road	2	ODOT	$ 568,653.00	2 Lane highway Modernization
14	US-101	New Youngs Bay Bridge	2	ODOT	$ 7,377,580.00	Bridge repair
15	US-101	Newport Signal Upgrades	2	ODOT	$ 747,886.40	Intersections
16	US-101	Otis Junction – Boiler Bay Sec.	2	ODOT	$ 3,010,000.00	2 lane highway Preservation
17	US-30	John Day River Bridge	2	ODOT	$ 1,297,325.47	Bridge repair
18	I-5	Azalea – Glendale Reconstruction	3	ODOT	$ 6,868,670.00	Freeway Modernization
19	I-5	Louse Creek US 199 (Bundle 304(08018))	3	OBDP	$ 24,158,000.00	Bridge replacement
20	I-5	S. Wolf Creek (Bundle 303)	3	OBDP	$ 11,723,000.00	Bridge repair
21	I-5	Seven Oaks Interchange (Bundle A06)	3	ODOT	$ 30,257,000.00	Bridge Replacement

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Project Number	Route Number	Project Name	Region	Managing Firm	Budget Size ($)	Project Type
22	I-5	South Medford Interchange	3	ODOT	$ 59,645,369.20	Freeway Modernization
23	OR-42	Lookingglass Creek - Glenhart	3	ODOT	$ 1,962,293.90	2 Lane highway Modernization
24	OR-62	Corridor Solutions - Medford	3	ODOT	N/A	2 Lane highway Modernization
25	OR-58	US 97 Overcrossing (Bundle 221)	4	OBDP	$ 4,366,000.00	Bridge Replacement
26	US-126	MP 97 – Rimrock Way	4	ODOT	$ 5,780,780.00	2 Lane highway Modernization
27	US-97	Re-route Phase 1, Unit 2	4	ODOT	$ 24,559,555.55	Multi lane highway Modernizaton
28	US-97	Re-route Phase 1, Unit 3	4	ODOT	$ 1,000,000.00	Multi lane highway Preservation
29	I-84	Burnt R. (Dixie Cr)-Lime Interchange (Bundle 203)	5	OBDP	$ 12,487,827.25	Bridge repair
30	I-84	Cabbage Hill Chain-up – Meacham	5	ODOT	$ 813,317.00	Freeway Preservation
31	I-84	Grande Ronde R./UPRR U'Xing Upper Perry Arch	5	ODOT	$ 2,834,301.00	Bridge repair
32	OR-207	MP214 Mission and OR-207: MP26.5 Madison VMS	5	ODOT	$ 324,955.50	Bridge (walkway/VMS)
33	I-84	North Ontario Interchange	5	ODOT	N/A	Bridge repair
34	I-84	Pendleton - North Powder (Bundle 205)	5	OBDP	$ 5,536,750.00	Bridge repair
35	I-84	Pleasant Valley - Durbin Creek	5	ODOT	$ 33,830,955.00	Freeway Modernization
36	I-84	Pleasant Valley Interchange Bridges Section	5	ODOT	$ 12,466,954.75	Bridge replacement
37	I-84	Stanton Blvd - Snake River (Bundle 202)	5	OBDP	$ 8,083,000.00	Bridge repair
38	OR-244	Irrigon Jct - Hilgard Interchange (Bundle 206)	5	OBDP	$ 10,470,548.61	Bridge replacement
39	US-20	Riley Jct. - Warm Springs Rd/US 395 Chip seal	5	ODOT	$ 4,568,615.02	2 lane highway Preservation

Table 4.2: Case Study Projects by Type

Project Type	Number of Projects	Percent of Projects
Bridge repair	9	23%
2 lane highway modernization	7	18%
Bridge replacement	7	18%
2 lane highway preservation	6	15%
Freeway modernization	4	10%
Bridge (walkway/VMS)	1	3%
Freeway preservation	1	3%
Intersections	1	3%
Multi lane highway modernization	1	3%
Multi lane highway preservation	1	3%
Bridge replacement / 2 lane highway modernization	1	3%
Total	39	100%

As shown in Table 4.2, the most common type of project in the study were bridge repair projects of which there were nine (23%). Several types of projects were represented only once. These include a walk-way bridge, freeway preservation, intersections, multi-lane highway modernization, multi-lane highway preservation, and bridge replacement/2-lane highway modernization, with each making up 3% of all case study projects.

Another important parameter that was considered when developing the list of projects to be included in the case study was the project management firm. Projects in the study were either managed my ODOT or by Oregon Bridge Delivery Partners (OBDP). Of the 39 projects, 31 (79%) were managed by ODOT, while the remaining eight (21%) were managed by OBDP.

4.2.1 Survey of Project Personnel

The design, review, implementation, and inspection of a TCP are a collaborative effort involving many participants throughout the evolution of a project. A survey was conducted to capture the perspective of twelve key project personnel on each project included in the case study. The twelve key participants were identified as the: Roadway/Bridge designer, Traffic Control Plan Designer, Design TCP Peer Reviewer, Field-modified TCP Reviewer, General Contractor (GC) Project Manager, GC Superintendent, Traffic Control Subcontractor Representative, Laborer, Traffic Control Supervisor, Inspector, ODOT/OBDP Design Phase Coordinator, and ODOT/OBDP Construction Phase Coordinator. Twelve different surveys were developed, one for each of the key participants. For the 39 projects included in the study, this amounted to a total of 468 potential survey participants.

4.2.1.1 Survey Participants

During the design phase of a project, the Roadway or Bridge Designer often works closely with the Traffic Control (TC) Designer to establish project staging and the corresponding Traffic Control Plan. For this reason, both the Roadway/Bridge Designer and TCP Designer were surveyed and asked similar questions regarding the role of traffic control on the project. In some cases, when there was not a TC Designer assigned to the project, the Roadway/Bridge Designer was responsible for the TC design. In these cases, only the Roadway/Bridge Designer was asked to complete the Roadway/Bridge Designer survey.

Review of the TCP's are commonly conducted multiple times and by several different people during project development. The project case studies focused on reviews that took place at two specific points during the project. The first review of interest is performed before the TCP sheets are included in the original bid documents. On the case study projects this review was usually performed by a Peer Reviewer to ensure that a quality TCP design was included in the final plans. The second review of interest is conducted immediately prior to construction. The General Contractor will sometimes suggest modifications to the original TCP design and submit these changes to the managing party for approval. The Field-Modified TCP Reviewer differed from project-to-project depending on the significance of the suggested TCP modifications. Minor modifications were approved by on-site Inspectors or ODOT/OBDP project managers. Major changes were approved by the Engineer-of-Record. In order to not survey a reviewer twice about the same project, if they were surveyed in regards to their role in the first review, only supplementary questions were asked about the second review that were not covered in the primary survey.

Once construction begins on a project, the General Contractor is responsible for implementing the approved TCP. For this reason, the GC Project Manager and the GC Superintendent on each project were surveyed. If the GC used a subcontractor for the traffic control on the project, the TCP Subcontractor Representative was surveyed as well. Some projects were required to have a Traffic Control Supervisor (TCS) on site during construction. The TCS role was sometimes filled by the GC Superintendent or the subcontracted TC Superintendent. Similar to not surveying the reviewers twice on the same project, those GC or subcontractor personnel who participated as the TCS also were only surveyed once since similar questions were asked on both surveys.

Inspectors work with construction personnel to ensure the traffic control design is implemented effectively and in accordance with the TCP documents. The managing party provides the inspector for the project. The inspectors on the case study projects were surveyed regarding the contractors' ability to implement the TCP effectively and the extent to which corrective action was required to maintain a safe work zone.

In addition to the participants discussed above, two representatives from the managing firm were surveyed as well. The first representative was the ODOT/OBDP Design Phase Coordinator. Projects managed by ODOT typically referred to this person as the Project Leader. Projects managed by OBDP typically referred to this person as the Design

Project Coordinator. In both cases, the ODOT/OBDP Design Phase Coordinator was surveyed because they are in a position to oversee the TCP design process implemented on the case study project. The second representative from the managing firm who was surveyed was an ODOT/OBDP Construction Phase Coordinator. ODOT Project Managers and Assistant Project Managers filled this role on ODOT managed projects. On OBDP projects, employees with the titles Project Manager or Construction Project Coordinator filled this role. The ODOT/OBDP Construction Phase Coordinator was surveyed because of their oversight role during construction which includes responsibility for managing the TCP implementation. The surveys for each of these representatives included a focus on their level of participation throughout the entire project and the transition of the project from the design phase to the construction phase. The initial benchmarking survey presented in Section 3.0 of this report indicated that the participation of construction personnel both throughout the initial phases of the project and during the transition to construction is potentially impacting elements to the success of the TCP.

While on the ODOT State Traffic Control annual work zone tours and other individual site visits, a survey was conducted of general laborers wherever possible. The purpose of these surveys was to gain the perspective of project personnel on site during construction. An important set of data points gathered in this survey was the general laborers' perception of safety on the project. This can be used as a measure of TCP success for each project.

4.2.1.2 Survey Methods

The survey was conducted using on-line questionnaires. The questionnaires were developed using a web-based survey software provided by Oregon State University. Participants were instructed to follow a link to the survey website, select the particular project for which they were completing a survey, and answer various questions related to the TCP for the project. A copy of the TCP Designer survey request e-mail is included in Appendix A. The content of this e-mail was the same for all participants regardless of discipline except for the link and the project title. The number of questions in the survey questionnaires ranged from 18 for the General Laborer to 30 for the ODOT/OBDP Project Manager. General questions were asked of all those surveyed for each project regarding work experience, TCP quality, resource availability, and level of safety provided by the TCP. Additionally, participants were asked specific questions related to their area of involvement on the project. For example, designers were asked about the number of site visits they made during the design phase of the project, while inspectors were asked about the extent to which field changes were made to the TCP during construction.

Completed surveys were submitted electronically by the participants. The survey responses were compiled and saved on an OSU server and later transferred to an MS Excel spreadsheet for analysis. An example of the ODOT/OBDP Project Manager survey is provided in Appendix C. Other surveys were very similar in both layout and content.

4.2.1.3 Limitations

The researchers were not able to obtain contact information for all key participants on every project. The reasons for this varied from project-to-project. In some cases, the designated participant was simply not involved in the project. For example, on projects where the general contractor implemented the TCP without the use of a subcontractor, no survey of the subcontractor TCP representative was required. In the same way, not all projects required the use of a Traffic Control Supervisor, in which case no survey was conducted. Another factor that limited the acquisition of contact information for the surveys was that key participants had retired or left the firm since working on the project. Also, an attempt was made to interview a laborer from each project as well, but at the time the surveys were conducted, several of the projects were no longer active. In most cases, contact information for these people was not acquired. As a result of these factors, in total there were 69 key participants (15%) who were identified as either unavailable or not applicable for participation in the survey, which reduced the number of possible survey candidates from 468 to 399.

4.2.2 Traffic Control Plans

One of the objectives of the project case study was to collect data regarding the different elements contained in the TCP for each project. The TCP documents for each case study project were collected with the help of Technical Advisory Committee (TAC) members and the ODOT Research Section and ODOT Regional offices. TCP documents were collected for all 39 projects. Hard copies of the TCPs were borrowed for 13 projects. The remaining 26 TCPs were provided electronically.

The researchers identified a list of TCP descriptive features to evaluate each TCP. Several of the features were simply quantities of common TCP elements used in work zones such as the number of tubular markers, impact attenuators, barricades, and directional arrow signs. Features more difficult to quantify were noted as being present or absent from the TCP. Examples of these features included concrete barriers, traffic entering/exiting within the work zone, lane closures, and flaggers. In addition, the number of TCP stages, phases, and total plan sheets were counted and recorded to help assess the complexity of the TCP. Using these descriptive features, the TCPs were reviewed manually and take-offs were performed for each TCP. It was not possible to perform take-offs for projects that used ODOT Standard Drawings only. All take-offs were recorded on an MS Excel worksheet. The spreadsheet containing this information in its entirety is attached in Appendix D.

The take-off values for each feature were then evaluated and a ‘presence factor’ was assigned. The presence factor was a qualitative evaluation of the extent to which the feature was part of the TCP. For example, in the case of temporary concrete barrier, the presence factor was a judgment of how much concrete barrier was part of the TCP. The range of values of each factor on all of the projects was divided into quartiles. If the take-off value for a particular feature fell below the first quartile point, it was assigned a low presence factor of 1. If the value fell between the first and third quartile points it was assigned a moderate presence factor of 2. If the value fell above the third quartile point it was assigned a high presence factor of 3. If the feature was not present it was assigned a presence factor of zero. If the feature was present, but not quantified (as in the case of temporary striping or pilot car), it was assigned a presence factor of 3. The spreadsheet containing this information for each of the 39 projects is attached in Appendix D.

After determining the relative presence of these TCP features on each project in the case study, an effort was made to quantify their impact on the quality of the TCP design and implementation. Results from the general survey presented in Section 3.0 of this report indicated that certain TCP features are more difficult to successfully incorporate than others. For instance, the use of lane closures in a work zone generally meant a more complex TCP design and implementation and, therefore, perhaps decreasing the quality. To better identify the impact that each feature had on the complexity of the TCP, a short TCP complexity survey was developed. The following list of TCP features was sent to 26 industry professionals (17 TCP designers and 9 construction personnel):

- Impact Attenuator
- Sequential Arrow Sign
- Portable Changeable Message Sign
- Concrete Barrier
- Pilot Car
- Flagger
- Temporary Striping
- Dense Temporary Signage
- Road Closure
- Single Lane Closure
- Multiple Lane Closure – 1 Direction
- Multiple Lane Closure – 2 Directions
- Traffic Entering the Work Zone
- Stages
- Traffic Control Supervisor
- Cost
- Setting (Urban, Sub-Urban, Rural)
- Duration
- Length

Survey participants were asked to rate the degree to which the TCP features indicate TCP complexity on a project (1 = no indication of TCP complexity, 10 = strong indication of TCP complexity). For example, if the presence of flaggers on a project site strongly indicates that the

TCP is complex, then 'flaggers' would be given a rating of 10. The average complexity factor that each feature received was recorded.

This complexity factor, along with the presence factor discussed above, were then used to quantify the contribution made by each feature to the complexity of a project. For example, if a flagger was present on a project based on the review of TCPs (presence factor = 3) and ‘flagger’ was given a complexity factor of 5.1, then the flagger contribution to complexity for that project would be 15.3 (3 x 5.1). Summing the contribution of each feature for the project yielded a complexity rating. Using this same method, a complexity rating was calculated for each of the 39 projects in the case study. TCP complexity will be examined as a possible influencing factor on design and implementation quality and safety in Section 4.4 of this report.

4.2.3 Crash Data

The number of crashes that occurred during the construction phase of the project was also collected for the analysis as another means for evaluating the TCPs. Crash data gathering and analysis was an important aspect to the data collection because it is an objective measure of safety from project-to-project. The following is a description of the methods and tools used to collect the crash data, the measures taken to normalize the crash data for the various projects in the study, and the limitations in collecting data for certain projects.

4.2.3.1 Crash Data Collection Methods

A standard set of parameters was used to capture the crash data. The three pieces of information needed to create crash data reports for each project were the Oregon Highway Number, construction start and end dates, and milepost beginning and end markers. Oregon Highway Numbers were obtained by cross-referencing the Route Number associated with each project with a list of Oregon Highway Numbers provided by ODOT Crash Data personnel. Construction start and end dates were initially obtained from the Awarded Contracts page of ODOT’s Procurement Office website. However, actual construction start and end dates usually differed from the dates listed on the website due to delays either before or during construction. Construction personnel were contacted to later verify the start and end dates within one to two weeks of the actual construction timeframe. Many of the milepost beginning and end markers were included in the original list of projects submitted to the researchers by the TAC. Other milepost markers were obtained from construction personnel or, in the case of OBDP projects, from the project update website.

Three sources of crash data were accessed for every case study project in an attempt to validate any findings. The first source was the Oregon Transportation Management System (OTMS) Crash Database. With assistance from ODOT Research and an ODOT Crash Data Analyst, data were gathered through the use of multiple Comprehensive State Highway Crash Reports. The case study project parameters discussed above (Oregon Highway Number, construction timeframe, and mileposts) were entered into a query page and the total number of crashes was recorded for each project.

Construction timeframe and mileposts were entered into the query page with a 15 day and 0.5 mile buffer at both ends of the project, respectively. This was done to capture any potential minor adjustments made to the timeframe or work zone location. The database returned any crash that occurred on the given Oregon highway and within the specified date and mile-point parameters. The researcher examined each crash for additional indicators verifying that the crash occurred in a work zone. If the record indicated that the crash did not occur in a work zone, the crash was excluded from the total number of crashes for that project. If the record indicated that the crash did occur in a work zone, the crash was included in the total. If the record made no indication regarding the presence of a work zone, it was conservatively assumed that the crash did occur in the work zone because it fell within the project timeline and highway location and was therefore included in the total. A list of all of the projects and the parameters used for the queries is shown in Table 4.3 sorted by project number.

Table 4.3: Crash Data Collection Parameters

Project Number	Project Name	Oregon HWY Number	Start MP (with .5 mile buffer)	End MP (with .5 mile buffer)	Start Date (with 15 day buffer)	End Date (with 15 day buffer)
1	Willamette River Bridge – Pacific Hwy. (Unit 3) Sec.	64	-0.60	9.30	6/16/2006	4/16/2008
2	Marquam Bridge – Capitol Hwy. Sec.	1	293.71	300.43	10/22/2003	3/15/2005
3	Hillsboro-Silverton Hwy. at Farmington Road	140	4.68	6.29	9/22/2006	1/15/2008
4	Langensand Rd. – Cherryville Dr. Sec.	26	24.62	32.97	6/15/2007	11/3/2007
5	Sodom Ditch-Calapooia (Bundle 216 (08233 and 08235))	1	219.50	222.00	8/17/2007	12/31/2008
6	Fort Hill – Wallace Bridge	39	23.32	26.78	4/11/2008	12/31/2008
7	Oregon Coast HWY – Oldsville Road (megapave)	39	26.5	40.84	6/6/2007	11/15/2007
8	Lone Pine Corner – Hwy. 214	160	24.24	30.21	5/16/2005	10/15/2007
9	Springbrook Road - Wynooski Road (Newberg)	140	20.86	22.90	4/16/2008	11/13/2008
10	Sublimity Interchange	162	11.33	14.58	5/4/2008	12/31/2008
11	Jetty Creek Fish Passage	9	48.16	46.86	5/20/2008	12/14/2008
12	Latimer Road	9	63.32	64.56	6/11/2008	12/15/2008
13	Meda Loop Road - Redburg Road	9	91.49	93.24	6/23/2008	12/31/2008
14	New Youngs Bay Bridge	9	4.26	5.55	8/6/2007	12/31/2008
15	Newport Signal Upgrades	9	138.82	140.29	10/17/2006	5/30/2007
16	Otis Junction – Boiler Bay Sec.	9	110.25	126.91	5/17/2005	11/16/2006
17	John Day River Bridge	92	91.82	93.27	4/27/2008	11/30/2008
18	Azalea – Glendale Reconstruction	1	80.90	87.80	3/17/2007	10/15/2007
19	Louse Creek US 199 (Bundle 304(08018))	1	55.08	62.22	2/15/2008	12/31/2008
20	S. Wolf Creek (Bundle 303-Bridge 08333)	1	53.57	76.52	3/17/2007	12/31/2008
21	Seven Oaks Interchange (Bundle A06)	1	34.88	37.08	3/17/2006	11/15/2008

…continued next page

Project Number	Project Name	Oregon HWY Number	Start MP (with .5 mile buffer)	End MP (with .5 mile buffer)	Start Date (with 15 day buffer)	End Date (with 15 day buffer)
22	South Medford Interchange	1	26.23	28.83	5/11/2006	12/31/2008
23	Lookingglass Creek - Glenhart	35	71.82	73.71	3/17/2006	11/15/2006
24	Corridor Solutions - Medford	22	-0.50	1.60	1/8/2004	7/30/2006
25	US 97 Overcrossing (Bundle 221 (07984))	18	85.79	86.79	3/11/2007	11/20/2007
26	MP 97 – Rimrock Way	15	96.51	111.58	5/22/2008	11/7/2008
27	Re-route Phase 1, Unit 2	4	118.35	122.65	11/16/2006	12/31/2008
28	Re-route Phase 1, Unit 3	41	-0.25	0.94	5/17/2008	12/31/2008
29	Burnt R. (Dixie Cr)-Lime Interchange (Bundle 203, 01786)	6	340.10	341.10	3/17/2008	12/31/2008
30	Cabbage Hill Chain-up – Meacham	6	225.77	238.40	3/17/2007	10/15/2007
31	Grande Ronde R./UPRR U'Xing Upper Perry Arch	6	254.50	257.00	2/15/2008	12/31/2008
32	MP214 Mission and OR-207: MP26.5 Madison VMS	320	25.90	27.00	6/28/2005	3/16/2006
33	North Ontario Interchange	6	372.50	375.50	1/17/2006	11/15/2008
34	Pendleton - North Powder (Bundle 205, 07292)	6	285.30	286.30	8/17/2007	12/31/2008
35	Pleasant Valley - Durbin Creek	6	340.05	343.41	4/16/2009	12/31/2008
36	Pleasant Valley Interchange Bridges Section	6	316.77	318.94	5/17/2004	11/15/2006
37	Stanton Blvd - Snake River (Bundle 202, 08397)	6	370.95	378.51	2/22/2007	11/29/2008
38	Irrigon Jct - Hilgard Interchange (Bundle 206, 08502)	341	46.51	47.53	1/17/2007	12/31/2008
39	Riley Jct. - Warm Springs Rd/US 395 Chip seal	7	104.06	171.64	1/17/2007	11/15/2008

It is important to note that in Table 4.3 the mile points and construction start dates include the buffers discussed above. The green shading indicates that actual construction end date occurs after the date for which crash data were available (December 31, 2008). For these 13 projects crash data were only gathered up to December 31, 2008. The blue shading indicates that both the start and end date for the project occurred after December

31, 2008 and therefore no data were collected for this project. Further explanation regarding the impact of these limitations is provided below in Section 4.2.3.3.

The second source of data was the CAD database. The CAD database is a collection of crashes reported by emergency response crews on ODOT state highways. The CAD database differs from the OTMS database in that CAD provides data that is real-time. There is no lag time associated with the data collected in this database. Project parameters identical to those used in the OTMS data collection were used to search for crashes that may have occurred on the projects in the case study.

The third source of data was the ODOT Trip Check system. TripCheck data are records of delays on the highway recorded by ODOT dispatch personnel. Generally, these delays are accumulated by Oregon State Police and other accepted inputs, such as OnStar (GM Trademark), and forwarded to ODOT for verification. Again, with the assistance of ODOT Research and an Intelligent Transportation Systems Unit Manager, reports were provided for each project. These reports listed all verified delays that had occurred within the given mile markers and timeframes by date. Each incident was categorized by source of delay. Possible sources of delay included herbicide application, weather, construction zone, and crash/hazard among others. The researchers filtered out all delays categorized as a crash/hazard delay, verified that a motor vehicle accident was the cause, and tallied the number of crashes for each project.

The method of using three data sources was implemented to capture the most accurate crash data possible. A discussion regarding the reliability and eventual application of these data sources is presented below along with their results. Examples of the Comprehensive Crash Database Reports, CAD Data Reports, and Trip Check Data Reports are attached in the Appendix E.

4.2.3.2 Steady State Data Collection

The projects included in the study were diverse in terms of size, scope, TCP complexity, and setting. The projects also varied in duration and roadway length. Additionally, traffic volumes and crash rates may be different from project-to-project when there is no work zone present. To normalize the data collected 'during construction' to the expected 'non-construction crash rate', two other 'steady state' sets of crash data were collected to allow for meaningful comparisons from project-to-project. Both sets were collected in a similar manner to the 'during construction' data discussed above. The first set of 'steady state' data collected was termed 'previous year-equal duration'. This set was intended to gather crash data from each project site without the work zone present, while maintaining similar weather/roadway conditions to those of the construction timeframe. For example, for a project with construction timeframe of April 1, 2007 to November 1, 2007, the 'previous year-equal duration' data for this project were collected from April 1, *2006* to November 1, *2006*. The second set of 'steady state' data collected was termed 'immediately prior-equal duration'. This set was intended to gather crash data from project sites without the work zone present, while accounting for similar traffic volumes to those during the construction timeframe. Using the same construction timeframe as an example, the project duration from April 1, 2007 through November 1, 2007 was 213 days. The ‘immediately prior-equal duration’ data for this project were therefore collected for 213 days immediately prior to the project from *August 26, 2006* to *April 1, 2007.*

4.2.3.3 Limitations

One limitation in collecting crash data was related to the constraints of the ODOT Crash Database. There was a seven month lag time from when a crash occurs to the date in which that crash was recorded and made available in the ODOT Crash Database. Project case study crash data were retrieved for the research study on August 1, 2009. Therefore, with the seven month lag, crashes that occurred after December 31, 2008 had not yet been added to the database. This limited availability of recent crash data affected the analysis of case study projects in two ways. One of the 39 projects had construction start dates after December 31, 2008 and therefore no crash data were available for this project (#35 – Pleasant Valley – Durbin Creek). Additionally, 13 projects had construction completion dates or expected completion dates after December 31, 2008 and, therefore, only partial crash data were available for these projects. In all, 14 projects were affected by the 7 month lag time in the OSTM Crash Database. Table 4.4 shows the 14 projects and the degree to which they were affected.

Table 4.4: Crash Data Availability

Project Number	Route Number	Project Name	Construction Start Date	Construction End Date	Crash Data Available (as of 08/01/09)
27	US-97	Re-route Phase 1, Unit 2	12/1/2006	1/31/2009	98%
20	I-5	S. Wolf Creek (Bundle 303-Bridge 08333)	4/1/2007	5/22/2009	84%
14	US-101	New Youngs Bay Bridge	8/21/2007	4/28/2009	83%
28	US-97	Re-route Phase 1, Unit 3	6/1/2008	4/30/2009	68%
5	I-5	Sodom Ditch-Calapooia (Bundle 216 (08233 and 08235))	9/1/2007	9/30/2009	66%
34	I-84	Pendleton - North Powder (Bundle 205, 07292)	9/1/2007	10/31/2009	63%
22	I-5	South Medford Interchange	5/26/2006	7/29/2010	63%
31	I-84	Grande Ronde R./UPRR U'Xing Upper Perry Arch	3/1/2008	8/30/2009	59%
29	I-84	Burnt R. (Dixie Cr)-Lime Interchange (Bundle 203, 01786)	4/1/2008	1/1/2010	45%
6	OR-18	Fort Hill – Wallace Bridge	4/26/2008	1/1/2010	43%
13	US-101	Meda Loop Road - Redburg Road	7/8/2008	9/26/2009	43%
10	OR-22	Sublimity Interchange	5/19/2008	1/1/2010	41%
19	I-5	Louse Creek US 199 (Bundle 304(08018))	3/1/2008	7/1/2010	38%
35	I-84	Pleasant Valley - Durbin Creek	5/1/2009	11/30/2010	0%

Six projects had less than 50 percent of the project crash data available. Complete (100%) crash data was available for 25 of the 39 projects in the case study. It is important to note that the steady state data collected for these projects used durations equal to those used for data collected during construction. By using equal durations, comparisons between steady state and during construction were consistent with the methods used in analysis of other projects in the case study.

4.2.4 Work Zone Scores

Each summer, ODOT hosts tours of various on-going projects around the State to assess the level of safety on the projects and provide those involved in the TCP process an opportunity to learn about issues of concern. The tours entail ODOT personnel driving to different projects over several days to take pictures and complete project evaluation forms. According to the 2008 Construction Work Zone Tour Summary Report:

> *Each participant is asked to evaluate the condition and effectiveness of a variety of devices used within the work zone. Scores are based on a simple scale of 1 (low) to 10 (high). A score of 5 warrants contact with the ODOT Project Manager's office or Inspector on-site to discuss the issue and recommend a change. Any score of 4 or less and contact with the ODOT Project Manager, Inspector or a representative of the Contractor is made immediately to correct identified deficiencies (ODOT 2008c, pg. 4).*

The tour is a valuable activity for educating TCP designers, monitoring work zone safety, and collecting lessons-learned from work zones. Multiple tours were scheduled during the summers of 2007, 2008, and 2009. An ODOT researcher participated on two tours in 2008 and also two tours in 2009. The 2008 tours were of projects located in ODOT Regions 2, 4, and 5. The 2009 tours were of projects located in ODOT Regions 2, 3, 4, and 5.

Once all of the tours were complete for each summer, a report of the findings was prepared by ODOT's Traffic Control Plans Unit and distributed to tour participants and other members of ODOT. The reports included a summary of scores associated with the quality and level of safety provided by the TCP on each project visited. Of the projects visited during the 2007 work zone tour, 9 projects were included in this project case study. In 2008, 23 projects in the case study were visited, and in 2009, eight projects included in the case study were visited. In total, 27 of the 39 projects (69%) involved in the case study were visited and received scores as part of the 2007, 2008, and/or 2009 construction work zone tours. Fifteen of the 39 (38%) were visited just one year, eleven (28%) were visited two years, and one (3%) was visited each of the three years.

4.2.5 Inspection Reports and Traffic Control Supervisor Reports

During the course of construction, inspectors prepare daily reports of the progress of the work. These inspection reports are intended to document the work environment, quality of work, contractor's daily progress, and any other project information affecting contractual obligations. Information about the nature and characteristics of the traffic control measures may also be included in the inspection reports if identified by the inspector as being of importance to the project.

The inspection reports from three of the case study projects were collected. Initial reviews of the reports were conducted to get a sense of the typical information included in the reports. None of the daily reports for the projects included information about or related to the TCPs. The absence of TCP-related information in the inspection reports was also confirmed by ODOT inspectors in informal conversations. Therefore, no effort to collect and review inspection reports from additional projects was made. It is not expected that these reports will provide useful data for the research study.

Another possible source of information related to traffic control measures on the case study projects were the Traffic Control Supervisor reports. In some cases, the Traffic Control Plan for a project calls for the presence of a Traffic Control Supervisor (TCS) to direct and inspect the implementation of the TCP. When a TCS is included as a pay item in the bid documents, the general contractor is required to submit TCS reports to the ODOT Construction Section for the days the TCS is on site. The general contractor is usually limited to the number of hours for which they can bill for a TCS and therefore reports are not available for every day of the project. However, the reports include some information related to the nature of work taking place and any significant traffic control measures taken that day.

Of the 39 projects, 16 (41%) had a Traffic Control Supervisor assigned to them. With the help of ODOT Construction Section, Contracts Administration Unit, reports were collected for 14 (88%) of the 16 projects. Using the previously determined crash dates for each project as a reference, TCS reports for the day of each crash, and the day prior to each crash, were collected. Reports were reviewed to verify that a crash took place on the project, to collect any information related to the cause of the crash, and to note any possible impacts due to the TCP in place. Information related to the type of work being done on each day was also recorded.

4.3 CASE STUDY RESULTS

4.3.1 Surveys

The first step of the survey involved identifying and contacting each of the 399 key personnel who were involved in the case study projects. The researchers were able to obtain contact information for 278 (70%) of those key personnel. Each person was sent an e-mail requesting that they participate in the survey that matched their role on the project. A total of 142 (51%) of those contacted completed and returned the survey. Figure 4.1 shows the distribution of those who were contacted and those who responded to the survey across the 12 key participant groups (identified here as ‘Project Roles’). Viewing the data in this way allows for comparisons between different participant groups, and between different phases of the work (e.g., planning/design vs. construction).

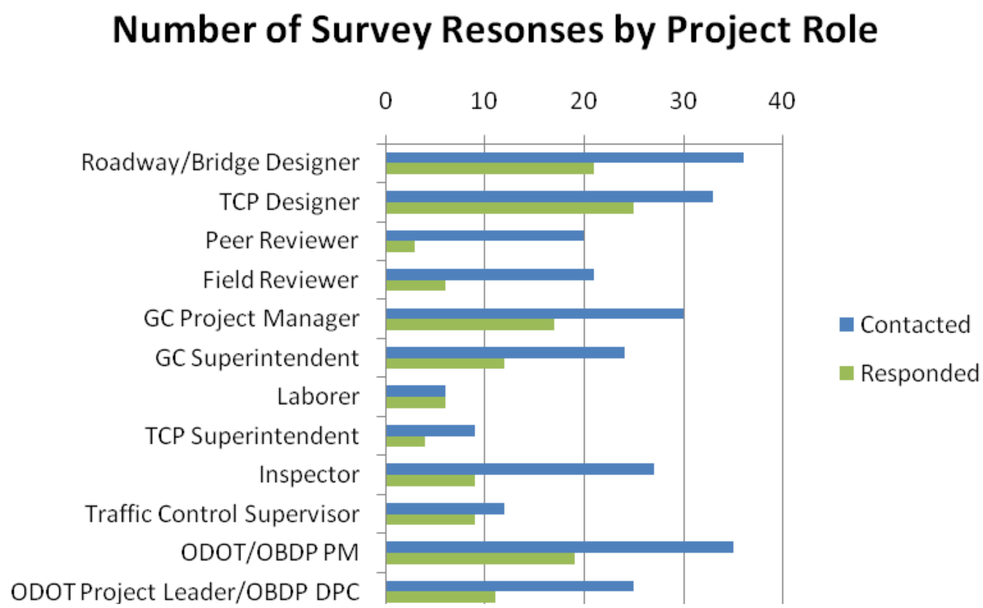

Figure 4.1: Number of Survey Responses by Project Role

As shown in Figure 4.5, the greatest number of responses came from TCP Designers, Roadway/Bridge Designers, ODOT/OBDP Construction Phase Coordinators and GC Project Managers. These project roles also contained the most people contacted. In terms of response rates, the highest response rates came from the following project roles: Laborer (100%), Traffic Control Designers (76%), Traffic Control Supervisors (75%), Roadway/Bridge Designers (58%), GC Project Mangers (57%) and ODOT/OBDP Construction Phase Coordinators (54%).

Figure 4.2 shows the distribution of those who were contacted and those who responded to the survey across the 39 case study projects. On none of the projects did all of those who were contacted respond to the survey. The most responses (11) were received on the Pendleton-North Powder project. No responses were received on one project (Seven Oaks Interchange).

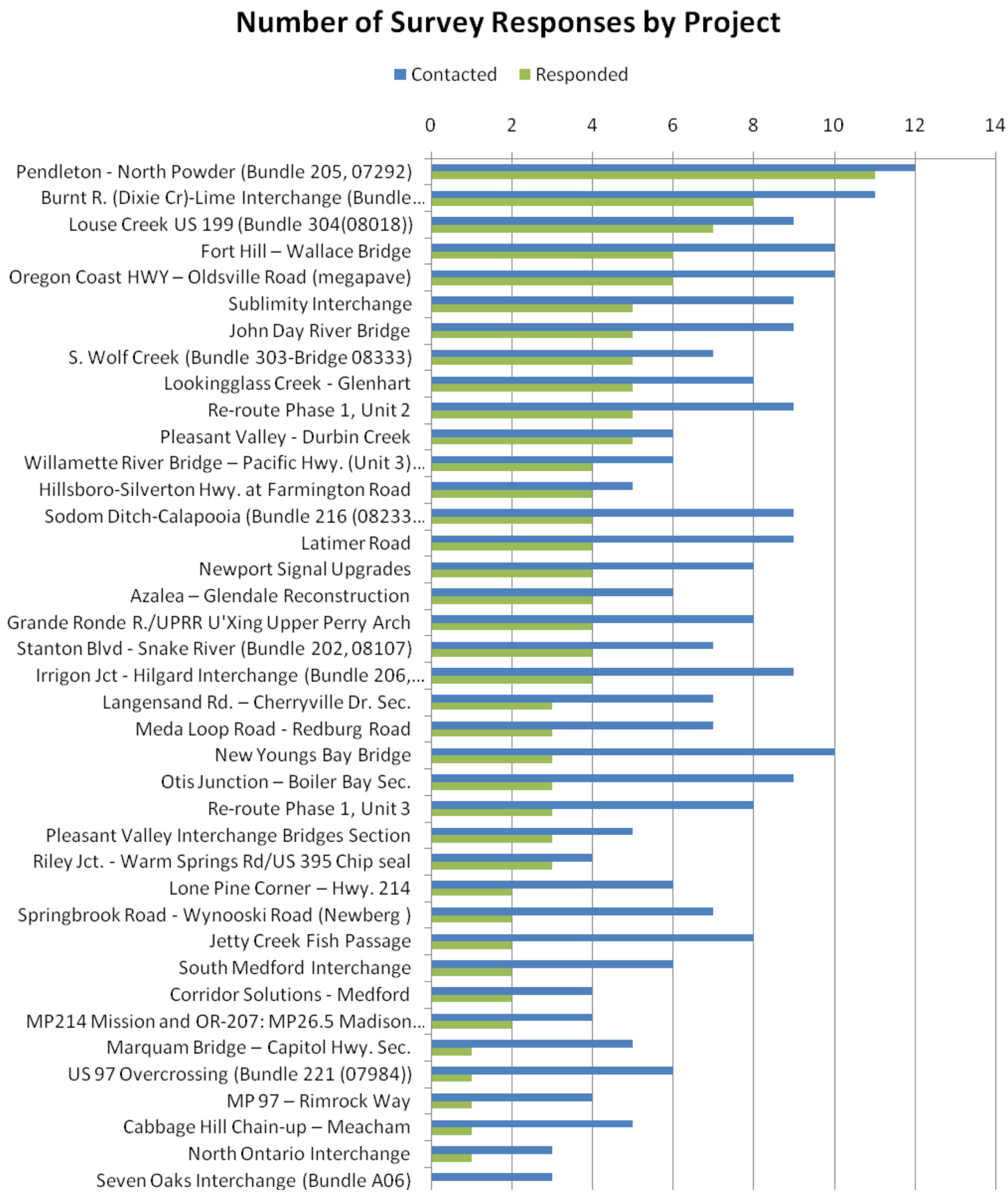

Figure 4.2: Number of Survey Responses by Project

The case study process used a project as the ‘unit of measurement’. That is, analyses of the data were conducted in which comparisons were made between individual projects or groups of projects. As a result, each project was given equal weight in the analyses. However, the number of survey responses received was not consistent between projects. More responses were received on some projects than others. As a result, when average survey responses were calculated per project, there was more uncertainty that the combined response was an accurate reflection of the project when the number of responses for the project was less. This concern was especially true if responses were received from only one discipline such as only design personnel or only construction personnel (for example, in the case of projects 1-4, no designers responded).

For this reason, it was important to report the distribution of responses on each project by discipline. Table 4.5 shows each of the 39 projects, the corresponding region, and the number of responses by each discipline group. Two of twelve possible project respondents were grouped as ‘Designers’ (Roadway/Bridge and TCP designers). The two ‘Reviewers’ on each project were the peer reviewer and the field reviewer. The GC project manager, superintendent, laborer and subcontracted TCP representative were considered ‘Constructors’. Those grouped as ‘Inspectors’ included the ODOT/OBDP inspector and the traffic control supervisor. The ODOT/OBDP project manager and project leaders were considered ‘Management’. On two projects (29 and 34) a representative from all discipline groups responded. An additional 4 projects (6, 7, 12, and 19) had a respondent in 4 out the 5 discipline groups. Note that on 9 projects there were no responses from either designers or reviewers and that on 16 projects there were no responses from constructors or inspectors.

Table 4.5: Survey Responses by Discipline

Project Number	Route Number	Project Name	Region	Designers (2)	Reviewers (2)	Constructors (4)	Inspectors (2)	Management (2)
1	I-205	Willamette River Bridge – Pacific Hwy. (Unit 3) Sec.	1	0	0	2	1	1
2	I-5	Marquam Bridge – Capitol Hwy. Sec.	1	0	0	0	0	1
3	OR-219	Hillsboro-Silverton Hwy. at Farmington Road	1	0	0	1	2	1
4	US-26	Langensand Rd. – Cherryville Dr. Sec.	1	0	0	2	0	1
5	I-5	Sodom Ditch-Calapooia (Bundle 216 (08233 and 08235))	2	2	1	0	0	1
6	OR-18	Fort Hill – Wallace Bridge	2	2	0	2	1	1
7	OR-18	Oregon Coast HWY – Oldsville Road (megapave)	2	2	0	2	1	1
8	OR-213	Lone Pine Corner – Hwy. 214	2	2	0	0	0	0
9	OR-219	Springbrook Road - Wynooski Road (Newberg)	2	2	0	0	0	0
10	OR-22	Sublimity Interchange	2	2	0	1	0	2
11	US-101	Jetty Creek Fish Passage	2	1	0	0	0	1
12	US-101	Latimer Road	2	1	0	1	1	1
13	US-101	Meda Loop Road - Redburg Road	2	1	0	0	0	2
14	US-101	New Youngs Bay Bridge	2	1	0	0	0	2
15	US-101	Newport Signal Upgrades	2	1	0	2	0	1
16	US-101	Otis Junction – Boiler Bay Sec.	2	1	0	0	1	1
17	US-30	John Day River Bridge	2	2	0	1	0	2
18	I-5	Azalea – Glendale Reconstruction	3	2	1	0	1	0
19	I-5	Louse Creek US 199 (Bundle 304(08018))	3	2	0	3	1	1
20	I-5	S. Wolf Creek (Bundle 303-Bridge 08333)	3	2	1	0	0	2
21	I-5	Seven Oaks Interchange (Bundle A06)	3	0	0	0	0	0
22	I-5	South Medford Interchange	3	0	0	1	0	1
23	OR-42	Lookingglass Creek - Glenhart	3	2	0	3	0	0
24	OR-62	Corridor Solutions - Medford	3	2	0	0	0	0

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Project Number	Route Number	Project Name	Region	Designers (2)	Reviewers (2)	Constructors (4)	Inspectors (2)	Management (2)
25	OR-58	US 97 Overcrossing (Bundle 221 (07984))	4	1	0	0	0	0
26	US-126	MP 97 – Rimrock Way	4	0	0	0	0	1
27	US-97	Re-route Phase 1, Unit 2	4	2	0	2	1	0
28	US-97	Re-route Phase 1, Unit 3	4	2	0	1	0	0
29	I-84	Burnt R. (Dixie Cr)-Lime Interchange (Bundle 203, 01786)	5	2	1	2	1	2
30	I-84	Cabbage Hill Chain-up – Meacham	5	1	0	0	0	0
31	I-84	Grande Ronde R./UPRR U'Xing Upper Perry Arch	5	0	0	2	2	0
32	OR 207	MP214 Mission and OR-207: MP26.5 Madison VMS	5	1	1	0	0	0
33	I-84	North Ontario Interchange	5	1	0	0	0	0
34	I-84	Pendleton - North Powder (Bundle 205, 07292)	5	2	2	4	1	2
35	I-84	Pleasant Valley - Durbin Creek	5	2	0	3	0	0
36	I-84	Pleasant Valley Interchange Bridges Section	5	0	0	1	1	1
37	I-84	Stanton Blvd - Snake River (Bundle 202, 08107)	5	0	1	0	1	2
38	OR-244	Irrigon Jct - Hilgard Interchange (Bundle 206, 08502)	5	0	1	2	1	0
39	US-20	Riley Jct. - Warm Springs Rd/US 395 Chip seal	5	2	0	0	1	0

For each project, several questions were posed to the key participants involved related to the quality and consistency of the TCP and the safety it provided to workers and motorists on-site. Project personnel were asked to rate both the quality and consistency of the TCP design, review, implementation, and inspection associated with the project on a scale of 1 to 10 with 1 representing the lowest quality and consistency rating and 10 being the highest rating. The participants were also asked to rate the level of safety provided by the TCP to both workers and motorists using the same scale. All responses to each of these questions on a project were averaged together to determine a per project rating. For example, each project was taken to have one design quality rating, one implementation rating, one motorist safety rating, etc.

Figures 4.3 through 4.5 show the average quality, consistency, and safety ratings for all 39 projects included in the case study. The average quality ratings of design, review, implementation, and inspection displayed in Figure 4.3 were very similar. Implementation was rated highest with an average per project rating of 8.03 while design was rated lowest with a rating of 7.68. Design quality ratings ranged from 10 (4 projects) to 4 (Willamette River Bridge-Pacific Highway), while implementation quality ratings ranged from 10 (2 projects) to 3.4

(Looking Glass Creek – Glenhart). Quality of review and inspection were given average per project ratings of 7.89 and 7.93, respectively. Review ratings ranged from 10 (Sodom Ditch – Calapooia Bundle 216) down to 5 (2 projects), while the highest inspection rating on a project was 10 (2 projects) and the lowest inspection rating was 5.25 (Willamette River Bridge – Pacific Highway).

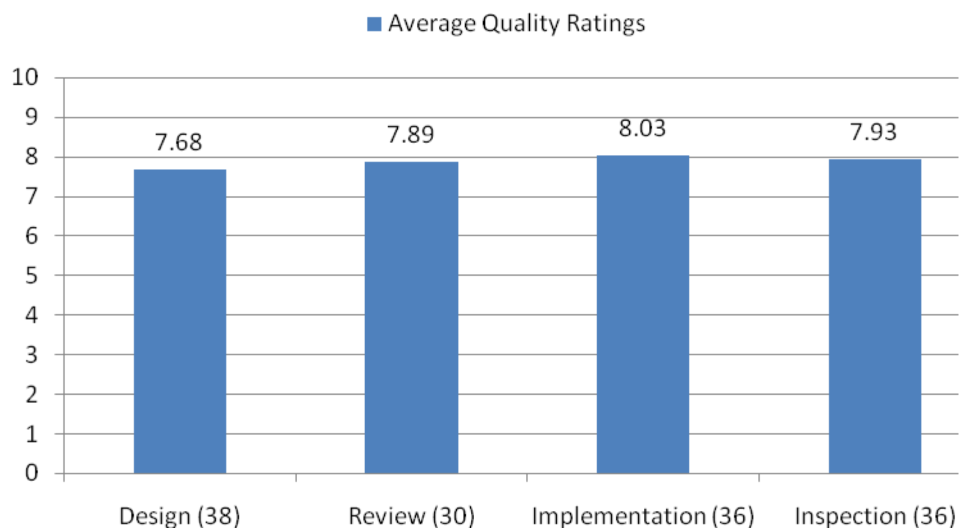

Figure 4.3: Average Quality Ratings for Case Study Projects

Figure 4.4 shows the average consistency ratings for projects included in the case study. Consistency was rated lower than quality on average for all four discipline areas related to traffic control. Disciplines in the area of construction (implementation and inspection) were rated as having the greatest consistency (7.39 and 7.66, respectively) while design and review of TCP's were rated as having the least consistency (6.87 and 6.79, respectively). The highest consistency rating on a project for all four disciplines was 10.0. The lowest project consistency ratings in the four disciplines were: design = 5.33 (Riley Jct. – Warm Springs Rd), review = 4.00 (3 projects), implementation = 5.00 (Marquam Bridge – Capitol Hwy. Sec.), inspection = 3.00 (Riley Jct. – Warm Springs Rd).

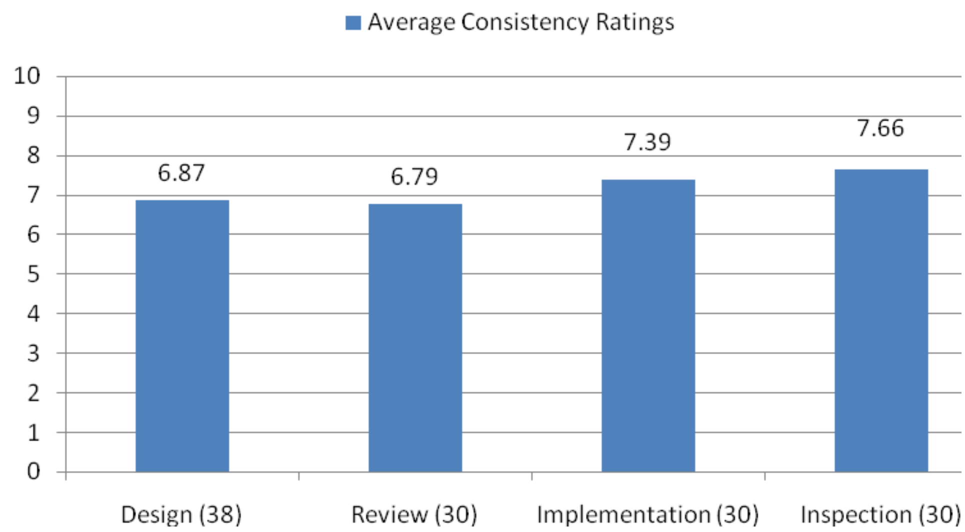

Figure 4.4: Average Consistency Ratings for Case Study Projects

Motorist and worker safety levels were rated higher than quality and consistency and are displayed below in Figure 4.5. The average level of motorist safety provided by the TCP's on projects in the case study was 8.68. Projects reported an average level of worker safety provided by the TCP's to be slightly lower than motorist safety with a rating of 8.55. Six projects rated the level of motorist safety highest (10.0) while the Pleasant Valley – Durbin Creek project rated the level of motorist safety lowest (5.60). The highest rating for level of worker safety was also 10.0 (5 projects) and the lowest rating for level of worker safety was 6.50 (Willamette River Bridge – Pacific Hwy.).

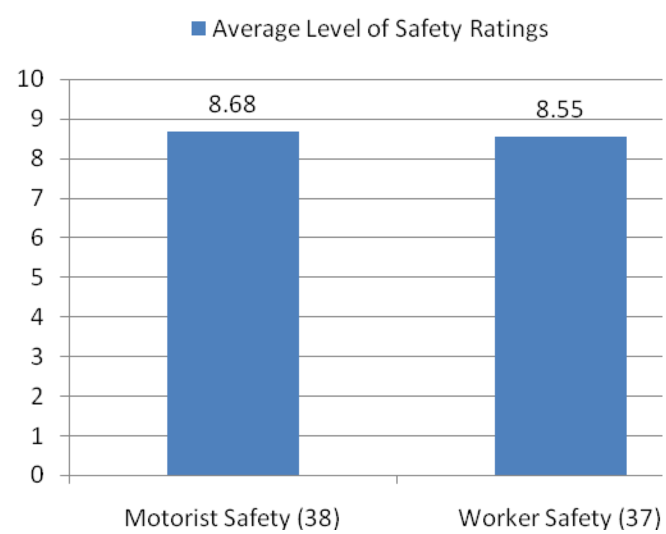

Figure 4.5: Average Level of Safety Ratings for Case Study Projects

4.3.2 Traffic Control Plans

Each traffic control plan was reviewed and different features of the TCP were noted in an MS Excel Spreadsheet. Values were obtained for 30 (77%) of the 39 project plans reviewed. Nine (23%) contained various ODOT standard drawings for traffic control and therefore no quantities were recorded. However, the designated standard drawing sheets included in the plans were noted and listed in the attached spreadsheet that can be found in Appendix D.

In addition to the plans review, a survey was conducted to determine the degree to which certain TCP features indicated a complex TCP. Of the 26 designers and construction personnel contacted, 13 (50%) responded. Three respondents were construction personnel while 10 respondents were TCP designers. Below in Figure 4.6 are the survey results.

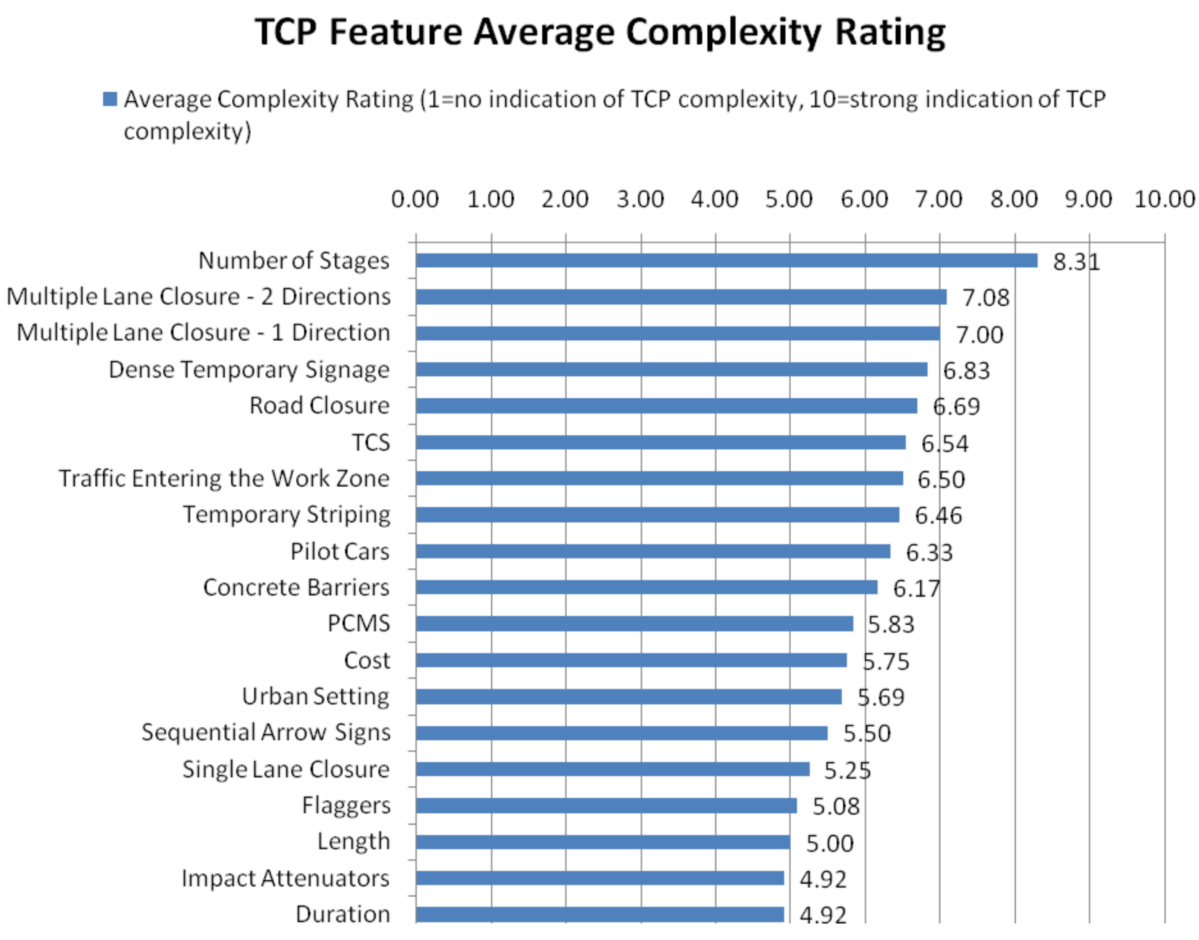

Figure 4.6: TCP Feature Average Complexity Rating

Respondents rated 'Number of Stages' as being the highest indicator of complexity with an average complexity rating of 8.31. Multiple lane closures, both in two directions and one direction, were next highest with average complexity ratings of 7.08 and 7.00, respectively.

Duration (4.92), Impact Attenuators (4.92), and Length (5.00) were rated as being the lowest indicators of TCP complexity.

4.3.3 Crash Data

4.3.3.1 OTMS Crash Data Results

The OTMS crash data collection effort provided crash data for each case study project as shown in Table 4.6. The number of crashes per project ranged from 0 to 400. Of those projects on which crash data could be obtained (38 projects), six did not have any crashes during the construction (16%). Two sets of steady state data are also provided below. The first set is the total number of crashes during a timeframe equal to that of construction but one calendar year prior. The number of crashes per project for this set of data ranged from 0 to 259. The second set is the total number of crashes during a timeframe equal to that of construction but just prior to the start of construction. The number of crashes per project for this set of data ranged from 0 to 178. In the last column of Table 4.6 is the steady state average, which is the average of the two sets of steady state data collected ('construction time-previous years' and 'equal duration prior to construction').

Table 4.6: Crash Data Total (OTMS)

Project Number	Route Number	Project Name	# of Crashes (during construction)	# of Crashes (construction time-previous years)	# of Crashes (equal duration prior to construction)	Steady State Average
1	I-205	Willamette River Bridge – Pacific Hwy. (Unit 3) Sec.	195	158.0	142.0	150.0
2	I-5	Marquam Bridge – Capitol Hwy. Sec.	400	259.0	149.0	204.0
3	OR-219	Hillsboro-Silverton Hwy. at Farmington Road	15	14.0	11.0	12.5
4	US-26	Langensand Rd. – Cherryville Dr. Sec.	4	13.0	7.0	10.0
5	I-5	Sodom Ditch-Calapooia (Bundle 216 (08233 and 08235))	3	3.0	1.0	2.0
6	OR-18	Fort Hill – Wallace Bridge	8	5.0	7.0	6.0
7	OR-18	Oregon Coast HWY – Oldsville Road (megapave)	25	20.0	16.0	18.0
8	OR-213	Lone Pine Corner – Hwy. 214	21	20.0	21.0	20.5
9	OR-219	Springbrook Road - Wynooski Road (Newberg)	11	6.0	8.0	7.0
10	OR-22	Sublimity Interchange	3	1.0	2.0	1.5
11	US-101	Jetty Creek Fish Passage	0	1.0	0.0	0.5
12	US-101	Latimer Road	4	0.0	0.0	0.0
13	US-101	Meda Loop Road - Redburg Road	2	0.0	0.0	0.0
14	US-101	New Youngs Bay Bridge	11	10.0	13.0	11.5
15	US-101	Newport Signal Upgrades	13	27.0	35.0	31.0
16	US-101	Otis Junction – Boiler Bay Sec.	171	172.0	153.0	162.5
17	US-30	John Day River Bridge	1	0.0	0.0	0.0
18	I-5	Azalea – Glendale Reconstruction	2	0.0	2.0	1.0
19	I-5	Louse Creek US 199 (Bundle 304(08018))	6	8.0	11.0	9.5

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Project Number	Route Number	Project Name	# of Crashes (during construction)	# of Crashes (construction time-previous years)	# of Crashes (equal duration prior to construction)	Steady State Average
20	I-5	S. Wolf Creek (Bundle 303-Bridge 08333)	38	155.0	143.0	149
21	I-5	Seven Oaks Interchange (Bundle A06)	17	16.0	13.0	14.5
22	I-5	South Medford Interchange	16	20.0	26.0	23.0
23	OR-42	Lookingglass Creek - Glenhart	7	7.0	5.0	6.0
24	OR-62	Corridor Solutions - Medford	207	228.0	108.0	168.0
25	OR-58	US 97 Overcrossing (Bundle 221 (07984))	0	0.0	0.0	0.0
26	US-126	MP 97 – Rimrock Way	17	6.0	8.0	7.0
27	US-97	Re-route Phase 1, Unit 2	79	132.0	178.0	155.0
28	US-97	Re-route Phase 1, Unit 3	2	0.0	0.0	0.0
29	I-84	Burnt R. (Dixie Cr)-Lime Interchange (Bundle 203, 01786)	0	0.0	0.0	0.0
30	I-84	Cabbage Hill Chain-up – Meacham	3	2.0	8.0	5.0
31	I-84	Grande Ronde R./UPRR U'Xing Upper Perry Arch	0	3.0	2.0	2.5
32	OR207	MP214 Mission and OR-207: MP26.5 Madison VMS	0	0.0	0.0	0.0
33	I-84	North Ontario Interchange	8	7.0	7.0	7.0
34	I-84	Pendleton - North Powder (Bundle 205, 07292)	1	1.0	1.0	1.0
35	I-84	Pleasant Valley - Durbin Creek	no data	no data	no data	no data
36	I-84	Pleasant Valley Interchange Bridges Section	11	9.0	3.0	6.0
37	I-84	Stanton Blvd - Snake River (Bundle 202, 08397)	10	5.0	5.0	5.0
38	OR-244	Irrigon Jct - Hilgard Interchange (Bundle 206, 08502)	0	0.0	0.0	0.0
39	US-20	Riley Jct. - Warm Springs Rd/US 395 Chip seal	24	14.0	23.0	18.5

A total of 1,335 crashes were recorded during construction for all 38 projects in the case study. No data were available for one project (I-84 Pleasant Valley – Durbin Creek). A total of 1,215 crashes were recorded as the steady state average for those same 38 projects. Collectively for all projects combined, there was a 10% increase in the number of crashes during construction compared to the number of steady state crashes. When comparing the average percent increase/decrease on a per project basis, there was a 34% average increase in the number of crashes during construction compared to the steady state per project.

It is important to remember that the number of crashes used in the analysis above is dependent on the information provided in the database as described previously. Some crashes that were found in the database to have occurred between the project mileposts and within the project duration were not coded to have occurred in a work zone. As noted above, the researcher examined each crash for additional indicators verifying that the crash occurred in a work zone. If the record positively indicated that the crash did not occur in a work zone, the crash was excluded from the total number of crashes for that project. If the record positively indicated that the crash did occur in a work zone, the crash was included in the total. Lastly, if the record made no indication regarding the presence of a work zone, it was conservatively assumed that the crash did occur in the work zone because it fell within the project timeline and highway location, and was therefore included in the total. The number of crashes positively identified (Y) as Work Zone crashes was 218. The number of crashes not positively identified (blank) as Work Zone crashes was 1,117. The number of crashes identified as NOT (N) Work Zone crashes but occurred within project case study construction timeframe/milesposts was 460.

4.3.3.2 Trip Check Crash Data Results

The TripCheck crash data collection effort resulted in the crash data for each case study project. A set of preliminary data was collected using the TripCheck database on January 28, 2009. The same parameters available to the OTMS database were used to provide a direct comparison in total crashes for each project. On January 28, 2009, data were available in the OTMS database through April 30, 2008. Therefore only crashes in TripCheck that occurred before April 30, 2008 were tallied. The number of crashes per project in TripCheck ranged from 0 to 111. After comparing the two data sets, it was determined that the TripCheck data were significantly less comprehensive than the data provided by the OTMS database. For this reason, the TripCheck data were not useful in verifying the OTMS data and were not considered in the analysis portion of this study.

4.3.3.3 CAD Crash Data Results

In an effort to validate the OTMS crashes from a second database source, data were collected using the CAD database. With the help of an ITS Operations Coordinator, a text delimited file that listed all crashes in Oregon on state highways from October 22, 2003 to July 31, 2009 was obtained. October 23, 2003 was the earliest start date for any of the projects included in the study, and July 31, 2009 was the most recent date that data were available for the OTMS data. CAD data were sorted by date of the crash. For most crash entries, the county in which the crash occurred was specified. However, the description of the roadway and specific location for each crash varied in content. The roadway was identified by the Oregon highway number, Oregon highway name, or route number. Location on the roadway was identified by mile point or street intersection. Some entries did not specify a location on the roadway. Also, the roadway and location information was recorded in one column and not entered in a standardized fashion. Separating and organizing the data would have been extremely labor intensive. For this reason, crashes for each project could not be determined by using the CAD data independently. Instead, an attempt was made to match the known individual crashes in OTMS data with crashes in the CAD data. The CAD data were first sorted by county (those with no county listed were conservatively included) and then by date of entry. Using a crash date, county, roadway and milepost identified in the OTMS data, that same date, county, roadway and milepost were sought in the list of CAD data. If all four parameters matched (given a 5 mile range) then the crash were verified. A detailed record of matching parameters was recorded for 14 (36%) of the 39 projects which accounted for 303 (23%) of the 1,335 total crashes in the case study. After some preliminary comparisons between the two data sets, it was also determined that the CAD data were less comprehensive than the data provided by the OTMS database. For this reason, the CAD data were not useful in verifying the OTMS data and were not considered in the analysis portion of this study.

4.3.4 Work Zone Scores

Table 4.7 shows the list of the projects on which work zone tours were performed along with the corresponding scores they received each year. For those projects that were visited multiple times, a single average score was calculated and is listed to the right of each set of scores in the table. The single average scores were used later in the analysis portion of this study. As shown in the table, the scores ranged from 6.8 to 8.5, with an average of 7.7.

Table 4.7: 2007/2008/2009 Average Work Zone Scores

Project Number	RTE Number	Project Name	Average Work Zone Tour Scores (*2007 **2008 ***2009)	Single Average Work Zone Tour Scores
1	I-205	Willamette River Bridge – Pacific Hwy. (Unit 3) Sec.	7.4*	7.4
2	I-5	Marquam Bridge – Capitol Hwy. Sec.	N/A	N/A
3	OR-219	Hillsboro-Silverton Hwy. at Farmington Road	7.6*	7.6
4	US-26	Langensand Rd. – Cherryville Dr. Sec.	N/A	N/A
5	I-5	Sodom Ditch-Calapooia (Bundle 216 (08233 and 08235))	7.4**/7.7***	7.6
6	OR-18	Fort Hill – Wallace Bridge	8.3**	8.3
7	OR-18	Oregon Coast HWY – Oldsville Road (megapave)	8.5**	8.5
8	OR-213	Lone Pine Corner – Hwy. 214	N/A	N/A
9	OR-219	Springbrook Road - Wynooski Road (Newberg)	7.9**	7.9
10	OR-22	Sublimity Interchange	6.9**/7.8***	7.4
11	US-101	Jetty Creek Fish Passage	8.5**	8.5
12	US-101	Latimer Road	7**	7.0
13	US-101	Meda Loop Road - Redburg Road	N/A	N/A
14	US-101	New Youngs Bay Bridge	8.4**	8.4
15	US-101	Newport Signal Upgrades	N/A	N/A
16	US-101	Otis Junction – Boiler Bay Sec.	N/A	N/A
17	US-30	John Day River Bridge	7.8**	7.8
18	I-5	Azalea – Glendale Reconstruction	N/A	N/A
19	I-5	Louse Creek US 199 (Bundle 304(08018))	7.1***	7.1
20	I-5	S. Wolf Creek (Bundle 303-Bridge 08333)	7.6**	7.6
21	I-5	Seven Oaks Interchange (Bundle A06)	7.1*/6.8**	7.0
22	I-5	South Medford Interchange	7.3*/7.8**/7.4***	7.5
23	OR-42	Lookingglass Creek - Glenhart	N/A	N/A
24	OR-62	Corridor Solutions - Medford	N/A	N/A
25	OR-58	US 97 Overcrossing (Bundle 221 (07984))	N/A	N/A
26	US-126	MP 97 – Rimrock Way	8.1**	8.1
27	US-97	Re-route Phase 1, Unit 2	7.1*/8.2**	7.7
28	US-97	Re-route Phase 1, Unit 3	7.9**	7.9

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Project Number	RTE Number	Project Name	Average Work Zone Tour Scores (*2007 **2008 ***2009)	Single Average Work Zone Tour Scores
29	I-84	Burnt R. (Dixie Cr)-Lime Interchange (Bundle 203, 01786)	7.3**/7.6***	7.5
30	I-84	Cabbage Hill Chain-up – Meacham	N/A	N/A
31	I-84	Grande Ronde R./UPRR U'Xing Upper Perry Arch	8.3**/7.0***	7.7
32	OR 207	MP214 Mission and OR-207: MP26.5 Madison VMS	N/A	N/A
33	I-84	North Ontario Interchange	7.2*/7.8**	7.5
34	I-84	Pendleton - North Powder (Bundle 205, 07292)	7.8**/7.8***	7.8
35	I-84	Pleasant Valley - Durbin Creek	8**/7.2***	7.6
36	I-84	Pleasant Valley Interchange Bridges Section	7.3*	7.3
37	I-84	Stanton Blvd - Snake River (Bundle 202, 08397)	7.6*/7.6**	7.6
38	OR-244	Irrigon Jct - Hilgard Interchange (Bundle 206, 08502)	8.1*/7.8**	8.0
39	US-20	Riley Jct. - Warm Springs Rd/US 395 Chip seal	6.8**	6.8

It should be noted that, as indicated in the work zone tour report, the data from the tours were not normalized across the State. As a result, this could possibly artificially bolster the average scores given by each tour participant. Given this limitation, the ODOT Traffic Control Plans Unit is considering adjustments to the work zone tour score process for following years to rectify the data and the collection process.

4.3.5 Traffic Control Supervisor Reports

Of the fourteen projects for which Traffic Control Supervisor (TCS) reports were obtained, two projects did not have any crashes during construction. The remaining twelve were reviewed for details related to the crashes that were captured in the OTMS database. These reports indicate standard project information such as project name, contract number, TCS name, and date of the report. The TCS generally describes t he daily operations with a few brief words or phrases such as ‘concrete pour’ or ‘grading’. The TCS indicates the TCP standard drawings being referenced for the implementation and the location that traffic control measures are in place. In some cases, the reports indicate the number of traffic control devices in use.

When reviewing the TCS reports (or TP & DT Daily Report) for details related to crashes on the project, it was discovered that TCS reports were not available for the majority of crash dates. Also, in many cases where a TCS report was available for the date of the crash, there was no indication in the report that a crash had occurred in the work zone. Table 4.8 shows the number of crashes recorded for each of the twelve projects (according to the OTMS database), the number of TCS reports available for the dates on which those crashes occurred, and the number of TCS reports that verified that a crash had taken place.

Table 4.8: Record of Crashes on TCS Reports

Project Number	Route Number	Project Name	Crashes (during construction)	TCS report completed for crash date	TCS report verified crash
1	I-205	Willamette River Bridge – Pacific Hwy. (Unit 3) Sec.	195	111	15
2	I-5	Marquam Bridge – Capitol Hwy. Sec.	400	140	7
5	I-5	Sodom Ditch-Calapooia (Bundle 216 (08233 and 08235))	3	0	0
7	OR-18	Oregon Coast HWY – Oldsville Road (megapave)	25	8	0
8	OR-213	Lone Pine Corner – Hwy. 214	21	0	0
9	OR-219	Springbrook Road - Wynooski Road (Newberg)	11	6	2
10	OR-22	Sublimity Interchange	N/A		
16	US-101	Otis Junction – Boiler Bay Sec.	171	4	0
19	I-5	Louse Creek US 199 (Bundle 304(08018))	6	1	0
20	I-5	S. Wolf Creek (Bundle 303-Bridge 08333)	38	10	6
22	I-5	South Medford Interchange	N/A		
23	OR-42	Lookingglass Creek - Glenhart	7	4	0
27	US-97	Re-route Phase 1, Unit 2	79	9	0
29	I-84	Burnt R. (Dixie Cr)-Lime Interchange (Bundle 203, 01786)	0	0	0
34	I-84	Pendleton - North Powder (Bundle 205, 07292)	1	0	0
38	OR-244	Irrigon Jct - Hilgard Interchange (Bundle 206, 08502)	0	0	0

Of the 957 crashes recorded by the OTMS database on these projects, a TCS report was available on the day of the crash for 293 (31%). Of the 293 reports, 30 (10%) verified that a crash took place. The low percentage of reports available is likely due to a number of reasons including: the work zone was not active even though the date fell within the construction timeframe and mile posts; the TCS was not present for all days of operation; or the crash occurred on a non-work day such as a weekend and the TCS was not present. The low percentage of verified crashes may be due to various reasons such as: the crash being a minor accident and TCS was not aware of it; the intent of the report is not to record crashes (TP & DT Daily Report form does not request the information); or the TCS forgot to include it in his/her report.

In the instances where the TCS report did provide verification that a crash occurred, limited details were provided. The most common statements and information provided were the location of the crash (mile point), number of vehicles involved, and that the traffic control devices were correct and visible. Below is a list of the types of statements recorded on the reports that were used to describe the crash or the traffic control measures in place on the project at the time of the crash:

- Location of the crash (mile point)
- Number of vehicles involved
- Traffic control devices were correct and visible
- Failure to stop for flagging line leading to rear end collision
- Failure to merge leading to rear end collision
- Failure to merge, vehicle collided with concrete barrier
- Vehicle tried to pass in lane closure, drove into dig out
- Vehicle collided with sign truck
- Accident did not occur in lane closure
- Collision with barrier
- Collision with barricade
- No injuries

4.4 CASE STUDY ANALYSIS

Many different pieces of data were collected for the case study analysis from a handful of sources (survey, TCP review, crash data, and work zone scores). For the analyses, comparisons based on simple statistical measures (mean, sum, range, etc.) were made based on the findings from the initial benchmarking survey conducted in Task 3. These comparisons are described below.

Similar to survey analysis performed in Section 3.4, an in-depth statistical analysis of the project case study data was conducted using commercial statistical software (PASW Statistics 17).

Several different types of tests were used to compare the relationships between project characteristics. Below is a short description of each of the types of tests used and their purpose:

- Levene's test for equality of variance - Analyzed for independent samples t-test to ensure the variables have equal variances. When variances were not equal ($p<0.05$), the appropriate adjusted p-value was utilized.
- Kolmogorov-Smirnov test – Tested a set of variables for normal distribution.
- Independent Samples t-test – Used to compare the relationship between two normally distributed variables.
- Mann-Whitney U-test - Nonparametric test to the independent samples t-test. It was used when the dependent variable was not normally distributed.
- Analysis of Variance (ANOVA) test – Used to compare the relationship among three or more normally distributed variables.
- Kruskall Wallis test - The nonparametric test to the Analysis of Variance (ANOVA) test. It was used when the dependent variables were not normally distributed.
- Pearson Correlation coefficient - Utilized when correlations were made using variables that were normally distributed.
- Spearman's rho correlation – Used when correlations were made using variables that were not normally distributed.

4.4.1 Project List

As described above, Task 4 entailed developing a representative sample of roadway construction projects to study that includes a combination of both current and past projects. The project characteristics to be considered when developing the study sample include: type of project, type of highway, regional representation, and managing firm (ODOT or consultant). In addition, projects in which the TCPs were designed by ODOT staff and those designed by hired consultants were included. The case study contains projects that fit all of these categories. In addition, survey responses were collected on projects within all of these categories.

4.4.2 Regions

The projects in the case study were analyzed to identify relationships related to several different project parameters. Table 4.9 displays the average quality, consistency, and safety ratings by region. The number of projects (n) that responded within each category is shown to the right of the rating in the table.

Table 4.9: Average Quality, Consistency and Safety Ratings by Region

	Average Quality Ratings								Average Consistency Ratings								Average Safety Ratings			
Region	Design	n	Review	n	Implementation	n	Inspection	n	Design	n	Review	n	Implementation	n	Inspection	n	Motorist	n	Worker	n
1	**5.44**	4	n/a	0	7.35	4	6.79	4	**5.58**	4	n/a	0	**5.73**	4	6.73	4	7.69	4	6.94	3
2	8.26	13	8.04	13	8.36	13	8.61	13	7.58	13	6.69	13	8.17	11	8.65	11	9.13	13	8.83	13
3	7.96	6	8.17	6	7.63	6	7.57	6	6.27	6	7.89	6	8.06	4	7.75	4	8.62	6	8.57	6
4	7.32	4	7.00	3	7.15	4	6.80	4	6.43	4	5.33	3	7.00	3	7.78	3	8.62	4	8.32	4
5	7.81	11	7.77	8	8.51	9	8.19	9	6.98	11	6.66	8	6.98	8	6.67	8	8.55	11	8.73	11

Analysis of the data indicated that there were several regional differences in perceived design quality (ANOVA, p-value = 0.028), implementation consistency (ANOVA, p-value = 0.018), and level of worker safety (ANOVA, p-value = 0.075). Perceived differences in design quality were most notable in Regions 1, 2, and 3 where the means reported were 5.44 (n = 4), 8.26 (n = 13), and 7.96 (n = 6), respectively. Average design quality in Region 1 was low compared to Region 2 (two-sided Independent Samples t-test, p-value = 0.013) and Region 3 (two-sided Independent Samples t-test, p-value = 0.074). However, it is important to note that all respondents that rated design quality on Region 1 projects were construction personnel which may introduce a bias in the average response. Regions also tended to rate design quality and consistency similarly. For example, projects in Region 2 rated design quality and consistency highest (mean quality = 8.26, n = 13, and mean consistency = 7.58, n = 13), while Region 1 projects reported the lowest ratings for design (mean quality = 5.44, n = 4 and mean consistency = 5.58, n = 4). Review quality and consistency were rated highest by Region 3 (mean = 8.17, n = 6, and mean = 7.89, n = 6, respectively) while Region 4 reported the lowest review ratings (mean quality = 7.00, n = 3, and mean consistency = 5.33, n = 3).

Implementation quality was rated highest for projects in Region 5 (mean = 8.51, n = 9). Average implementation consistency varied greatly by region (ANOVA, p-value = 0.018). Projects in Region 1 reported lower average implementation consistency than Region 2 (mean = 8.17, n = 11) and Region 3 (mean = 8.06, n = 4) (two-sided Independent Samples t-tests, p-values = 0.016 and 0.079, respectively). Inspection quality and consistency were rated highest in Region 2 (mean = 8.19, n = 13, and mean = 8.65, n = 11, respectively) while inspection quality was rated lowest in Region 1 (mean = 6.79, n = 4) and inspection consistency was rated lowest in Region 5 (mean = 6.67, n = 8).

Motorist safety and worker safety levels were rated highest in Region 2 (mean = 9.13, n = 13, and mean = 8.83, n = 13, respectively) and were rated lowest in Region 1 (mean = 7.69, n = 4, and mean = 6.94, n = 3). Regional differences with regard to level of worker safety were established through the ANOVA test (p-value = 0.075). The average level of worker safety in Region 1 was low compared to Region 2 and Region 5 (mean = 8.73, n = 11) (two-sided Independent Samples t-tests, p-values = 0.043 and 0.067, respectively)

Table 4.10 presents the average work zone scores, average overall quality rating, and the percent increase of crashes during construction for projects within each region. The number of projects in each region that reported scores is shown in the column to the right of each mean value in the table. An overall quality rating was first calculated for each project by averaging the design, review, implementation, and inspection quality ratings on the project. A regional overall quality rating was then calculated for all the projects in the region. Projects in Region 2 were rated as having the highest overall quality (mean = 8.32, n = 13) and highest average work zone score (mean = 7.93, n = 9). Region 1 projects rated overall quality lowest (mean = 6.53, n = 4). Region 3 projects had the lowest average percent increase of crashes during construction (2%, n = 7). A Spearman's rho correlation test was performed for average work zone scores and average percent increase of crashes, and no statistically significant results were revealed.

Table 4.10: Work Zone, Overall Quality and Percent Crash Increase by Region

Region	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
1	7.50	2	6.53	4	22%	4
2	7.93	9	8.32	13	63%	13
3	7.28	4	7.83	6	2%	7
4	7.88	3	7.09	4	73%	4
5	7.52	9	7.96	11	9%	10

4.4.3 Management Firm

Similar to Table 4.9 above, Table 4.11 displays quality, consistency, and safety ratings, except that the data are grouped by the organization which managed the project (ODOT or OBDP). Design ratings on projects managed by ODOT (mean quality = 7.64, n = 30, and mean consistency = 6.87, n = 30) were very similar to design ratings on projects managed by OBDP (mean quality = 7.86, n = 8, and mean consistency = 6.87, n = 8). Average review consistency (mean = 7.82, n = 7) was rated higher for projects managed by OBDP compared to projects managed by ODOT (mean = 6.47, n = 23) (two-sided Independent Samples t-tests, p-value = 0.069). Average review quality was rated higher on projects managed by OBDP (mean = 8.88, n = 7) than those managed by ODOT (mean = 7.59, n = 23) (two-sided Independent Samples t-tests, p-value = 0.025)

Projects managed by ODOT were rated highest with respect to inspection quality and consistency (mean = 7.97, n = 28, and mean = 7.86, n = 23, respectively). Implementation quality was rated highest for projects managed by OBDP (mean = 8.49, n = 8) while projects managed by ODOT were rated as having greater implementation consistency (mean = 7.57, n = 23).

Table 4.11: Average Quality, Consistency and Safety Ratings by Managing Firm (No documents containing best practices related to peer and constructability reviews for TCP's were discovered in the literature review)

	Average Quality Ratings								Average Consistency Ratings								Average Safety Ratings			
Managing Firm	Design	n	Review	n	Implementation	n	Inspection	n	Design	n	Review	n	Implementation	n	Inspection	n	Motorist	n	Worker	n
ODOT	7.64	30	7.59	23	7.90	28	7.97	28	6.87	30	6.47	23	7.57	23	7.86	23	8.56	30	8.47	29
OBDP	7.86	8	8.88	7	8.49	8	7.78	8	6.87	8	7.82	7	6.83	7	7.01	7	9.11	8	8.82	8

Additional analyses of the data were conducted to determine if there were any other differences between ODOT and OBDP projects with regards to other parameters besides safety. Two differences were found to be of interest:

- Projects managed by OBDP gave higher average priority to productivity (mean = 8.17, n = 8) than projects managed by ODOT (mean = 7.05, n = 29) (two-sided Independent Samples t-test, p-value = 0.059).
- Projects managed by OBDP gave higher average priority to traffic flow (mean = 9.17, n = 8) than projects managed by ODOT (mean = 8.09, n = 29) (two-sided Independent Samples t-test, p-value = 0.054).

Table 4.12 presents the average work zone scores, average overall quality rating, and the percent increase of crashes during construction for projects managed by ODOT and OBDP. The overall quality ratings were calculated in a manner similar to that done for regions as described above. Projects managed by OBDP were rated as higher in terms of overall quality (mean = 8.23, n = 8) than ODOT projects (mean = 7.71, n = 30). Both ODOT and OBDP projects received approximately the same average work zone scores. ODOT projects had a higher average percent increase of crashes during construction (42%, n = 30) than OBDP projects (mean = 5%, n = 8). A Spearman's rho correlation test was performed for average work zone scores and average percent increase of crashes, and no statistically significant results were revealed.

Table 4.12: Work Zone Scores, Overall Quality, and Percent Crash Increase by Managing Firm

Managing Firm	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
ODOT	7.68	20	7.71	30	42%	30
OBDP	7.58	7	8.23	8	5%	8

4.4.4 TCP Design Firm

The case study projects were grouped according to whether they were designed by ODOT staff or an outside consultant. Table 4.13 shows the quality, consistency, and safety ratings from the survey responses. Projects where there was an ODOT TCP designer were rated slightly higher in terms of design quality and design consistency (mean = 7.69, n = 22, and mean = 6.95, n = 22, respectively) than those designed by consultants (mean = 7.59, n = 13, and mean = 6.69, n = 13, respectively). Projects on which there was a consultant TCP designer rated review highest for both quality and consistency (mean quality = 8.41, n = 9, and mean consistency = 7.25, n = 9).

Table 4.13: Average Quality, Consistency and Safety Ratings by Design Firm

	Average Quality Ratings								Average Consistency Ratings								Average Safety Ratings			
Design Firm	Design	n	Review	n	Implementation	n	Inspection	n	Design	n	Review	n	Implementation	n	Inspection	n	Motorist	n	Worker	n
ODOT	7.69	22	7.81	18	7.84	21	7.95	21	6.95	22	6.41	18	7.71	17	7.93	17	8.64	22	8.48	22
Consultant	7.59	13	8.41	9	8.26	12	7.83	12	6.69	13	7.25	9	6.51	10	7.13	10	8.86	13	8.80	12

Implementation quality was rated highest for projects on which there was a consultant TCP designer (mean = 8.26, n = 12). ODOT TCP designers were rated as having greater implementation consistency (mean = 7.71, n = 17). This relationship was found to be statistically significant (two-sided Independent Samples t-test, p-value = 0.027). Inspection quality and consistency were also rated higher on projects where there was an ODOT TCP designer (mean quality = 7.95, n = 21, and mean consistency = 7.93, n = 17 for ODOT, mean quality = 7.83, n = 12, and mean consistency = 7.13, n = 10 for consultant-designed projects). Motorist safety and worker safety were both rated higher on projects where there was a consultant TCP designer (mean = 8.86, n = 13, and mean = 8.80, n = 12, respectively).

Table 4.14 presents the average work zone scores, average overall quality rating, and the percent increase of crashes during construction for projects design by ODOT and designed by outside consultants. The average work zone scores were similar for both groups of projects. The average overall quality rating was slightly higher for consultant projects, yet this was not found to be statistically significant. ODOT projects had a higher average percent increase of crashes during construction (46%, n = 23) than consultant-designed projects (mean = 17%, n = 15). A Spearman's rho correlation test was performed for average work zone scores and average percent increase of crashes, and no statistically significant results were revealed.

Table 4.14: Work Zone Score, Overall Quality and Percent Crash Increase by TCP Design Firm

TCP Design Firm	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
ODOT	7.67	14	7.72	23	46%	23
Consultant	7.65	12	8.00	14	17%	15

4.4.5 Project Type

A total of ten different project types were included in the project case study. This provided a good representative sample of Oregon highway construction projects and useful data for making general comparisons. However, with only 39 projects in the case study, statistically significant results were not obtained related to project type due in large part to the low number of projects represented by each project type. Five of the ten project types were represented by only one project. Table 4.15 shows the average ratings that each project type for work zone scores, overall quality, and percent increase of crashes during construction. Bridge repair projects and two-lane highway modernization projects were rated with the highest overall quality (means = 8.25). Freeway preservation projects were rated with the lowest overall quality (mean = 5.0, n = 1), however the accuracy of this result is suspect given only one response. The range of percent increase of crashes during construction was from a 200% *increase* on Multi-lane highway preservation projects (n = 1) to a 58% *decrease* on Intersection projects (n = 1). Work zone tour scores rated the projects very similarly across project type with a range from 7.53 (Freeway Modernization, n = 1) to 7.9 (Multi-lane highway preservation projects, n = 1). The low number of projects for some project types limits generalization of the results beyond the study sample.

Table 4.15: Work Zone Scores, Overall Quality, Percent Crash Increase by Project Type

Project Type	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
Multi lane highway preservation	7.90	1	7.17	1	200%	1
Bridge replace./2 lane highway Modernization	7.60	1	6.58	1	20%	1
Intersections	n/a	0	7.50	1	-58%	1
Multi lane highway modernization	7.65	1	6.85	1	-49%	1
Bridge repair	7.69	9	8.25	9	7%	9
Freeway modernization	7.53	2	7.53	4	55%	3
Bridge replacement	7.56	6	8.20	6	2%	7
2 lane highway preservation	7.73	3	7.49	6	12%	6
Freeway preservation	n/a	0	5.00	1	-40%	1
2 Lane highway modernization	7.69	4	8.25	7	131%	7
Bridge (walkway/VMS)	n/a	0	7.75	1	0%	1

4.4.6 Project Size

The case study projects were grouped based on size using the dollar value of the project as an indicator of size. Table 4.16 displays the quality, consistency, and safety ratings for the projects grouped by project size. In terms of average design quality, medium-sized projects ($5,000,000-$20,000,000) were rated as having the highest quality by all of the respondents. The lowest average design quality was given for large projects (>$20,000,000) except by the implementers. In terms of consistency and safety, medium-sized projects scored well also. The highest ratings overall were received by medium-sized projects for both motorist safety and worker safety (mean = 9.05, n = 13, and mean = 8.80, n = 13, respectively). The lowest ratings overall were received by large-sized projects. In fact, large-sized projects received the lowest average ratings for 8 out of the 10 survey questions.

Table 4.16: Average Quality, Consistency and Safety Ratings by Project Size ($)

	Average Quality Ratings								Average Consistency Ratings								Average Safety Ratings			
Size (thousands)	Design	n	Review	n	Implementation	n	Inspection	n	Design	n	Review	n	Implementation	n	Inspection	n	Motorist	n	Worker	n
$0-$5,000	7.54	17	7.89	14	7.62	15	7.78	15	6.61	17	5.79	14	7.33	12	7.92	12	8.59	17	8.48	17
$5,001-$20,000	8.00	13	8.37	10	8.43	13	8.51	13	7.31	13	8.01	10	7.58	12	7.74	12	9.05	13	8.80	13
$20,001+	6.66	6	6.63	4	7.78	6	7.03	6	5.95	6	7.00	4	7.15	6	6.96	6	7.83	6	7.66	5

Table 4.17 presents the average work zone scores, average overall quality rating, and the percent increase of crashes during construction for the projects according to project size. In terms of quality, the average overall quality was highest for medium-sized projects (mean = 8.31, n = 13) and lowest for large-sized projects (mean = 6.98, n = 6). Work zone scores were fairly consistent across all three size categories with medium-sized project rating slightly higher (mean = 7.83, n = 12) and large-sized projects receiving the lowest scores on average (mean = 7.36, n = 6). It is interesting to note that while the work zone scores and quality ratings were higher on small and medium-sized projects than on large-sized projects, the average percent increase of crashes during construction was lowest on large-sized projects (5%, n = 6). A Spearman's rho correlation test was performed for average work zone scores and average percent increase of crashes, and no statistically significant results were revealed.

Table 4.17: Work Zone Scores, Overall Quality, Percent Crash Increase by Project Size ($)

Size (thousands)	**Average Work Zone Score and Number of Projects (n)**		**Average Overall Quality Rating and Number of Projects(n)**		**Average Percent Increase of Crashes During Construction and Number of Projects(n)**	
$0-$5,000	7.65	8	7.62	17	40%	17
$5,001-$20,000	7.83	12	8.31	13	44%	13
$20,001+	7.36	6	6.98	6	5%	6

4.4.7 Constructability and Peer Review

Analysis of the general survey of ODOT personnel (presented in Section 3.0 of this report) indicated that the nature and extent of the review of the TCP design at different stages and by different project personnel were possible indicators of TCP quality and work zone safety. As part of the case study process, attempts were made to identify a peer reviewer of the TCP design for each project before being let and also a field reviewer for each project in which TCP designs were modified on site. The case study projects were analyzed in many ways regarding the quality and nature of the review process on each project.

Efficiency and productivity of the TCP design review process was examined through questions in the case study survey. Roadway designers, TCP designers, peer reviewers, and project leaders on each project were asked to rate the efficiency of the TCP design review process from 1 to 10 (1 = not efficient, 10 = efficient). Below is a list of the significant findings related to review efficiency and productivity:

- Projects that rated review efficiency as high also rated design quality as high (Pearson correlation, $r = 0.534$, p-value = 0.002).
- The TCP design quality rating on projects where the review was rated as being more efficient (6-10) (mean = 8.24, n = 24) was higher than for projects where the review was rated as being less efficient (1-5) (mean = 6.79, n = 6) (two-sided Independent Samples t-test, p-value = 0.032)
- The average level of worker safety priority rating on projects where the review was rated as being more efficient (6-10) (mean = 8.84, n = 24) was higher than for projects where the review was rated as being less efficient (1-5) (mean = 7.97, n = 6) (Mann-Whitney U-test, p-value = 0.038)
- Projects where productivity was rated as a high priority also rated review quality as high priority (Pearson correlation, $r = 0.379$, p-value = 0.039)

The impact of peer reviews on safety was also investigated. Peer reviewers were identified on 20 (51%) of the 39 projects (i.e. name and contact information for the peer reviewer on the project was confirmed and requests for survey participation were made). For 19 (49%) of the projects, the peer reviewer was not positively identified. In these cases, the TCP designer was not able to provide the name and contact information for a peer reviewer on the projects or the TCP designer was not available. Comparisons were made between projects on which the peer reviewer was identified and those projects on which the peer reviewer was not identified. One measure of safety on the case study projects is the number of phone calls from the travelling public received by construction personnel regarding frustration with the TCP. On projects where the peer reviewer was identified, the average number of critical phone calls from the travelling public (mean = 1.87, n = 16) was lower than for projects where no peer reviewer was identified (mean = 3.04, n = 14) (two-sided Independent Samples t-test, p-value = 0.060).

Field review of TCP designs as they are modified by the general contractor is another important aspect to TCP design quality and work zone safety. Field reviewers were identified for 21 (54%)

of the 39 projects (i.e. name and contact information for the field reviewer on the project was confirmed and requests for survey participation were made). On projects where the field reviewer was identified, the average implementation quality rating (mean = 8.45, n = 16) was higher than for projects where no field reviewer was identified (mean = 7.25, n = 14) (two-sided Independent Samples t-test, p-value = 0.014). Additionally on projects where the field reviewer was identified, the average work zone score rating (mean=7.89, n=15) was higher than for projects where no field reviewer was identified (mean = 7.36, n = 12) (two-sided Independent Samples t-test, p-value = 0.001).

Constructability reviews were identified as a possible enabler of TCP design quality and work zone safety in the general survey of ODOT personnel (described in Section 3.0). Both the timing and extent of these constructability reviews were investigated. The following relationships related to the extent of constructability reviews on the projects were found to be statistically significant:

- On projects where the extent of constructability review was rated as high, the average inspection quality was also rated as high (Pearson correlation, r = 0.556, p-value = 0.004).
- On projects where the extent of constructability review was rated as high, the average level of worker safety was also rated as high (Pearson correlation, r = 0.497, p-value = 0.013).

These correlations can be seen categorically in Table 4.18. Projects with significant constructability reviews (1-5 = insignificant, 6-10 = significant) had a mean inspection rating of 8.35 (n = 18) compared to those with insignificant constructability reviews (mean = 7.51, n = 18). Projects with significant constructability reviews rated the level of worker safety (mean = 8.75, n = 19) higher than those with insignificant constructability reviews (mean = 8.34, n = 18).

Table 4.18: Average Quality, Consistency and Safety Ratings by Constructability Review

	Average Quality Ratings								**Average Consistency Ratings**								**Average Safety Ratings**			
Constructability Review	Design	n	Review	n	Implementation	n	Inspection	n	Design	n	Review	n	Implementation	n	Inspection	n	Motorist	n	Worker	n
Early in Design	6.55	4	8.00	3	7.89	4	6.96	4	5.84	4	6.83	3	6.94	4	6.19	4	8.15	4	8.13	4
Late in Design	7.91	15	8.61	11	8.37	15	8.34	15	7.16	15	7.11	11	7.28	15	7.94	15	8.93	15	8.78	14
Significant	8.05	19	7.95	18	8.14	18	8.35	18	6.89	19	6.65	18	7.62	15	8.13	15	8.84	19	8.75	19
Insignificant	7.32	19	7.79	12	7.92	18	7.51	18	6.85	19	6.99	12	7.17	15	7.18	15	8.51	19	8.34	18

When constructability was rated as a high priority on a project, several different correlations were found to be significant:

- On projects where constructability priority was rated as high, the average quality of implementation was also rated as high (Spearman's rho correlation, r = 0.493, p-value = 0.003).
- On projects where constructability priority was rated as high, the average level of worker safety was also rated as high (Spearman's rho correlation, r = 0.579, p-value = 0.000).
- On projects where constructability priority was rated as high, the average level of motorist safety was also rated as high (Spearman's rho correlation, r = 0.606, p-value = 0.000).

Table 4.19 shows the average work zone score, overall quality rating, and average percent increase of crashes during construction as they relate to timing and extent of constructability review. Correlations were examined between these indicators and no statistically significant relationships were found.

Table 4.19: Work Zone Scores, Overall Quality, Percent Crash Increase by Constructability Review

Constructability Review	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
Early in Design	7.36	3	7.19	4	-19%	4
Late in Design	7.67	11	8.23	15	62%	15
Significant	7.73	14	8.13	19	20%	19
Insignificant	7.63	12	7.51	19	50%	18

4.4.8 Formal Training

The impact of TCS and TCP design training was investigated also. Table 4.20 presents the quality, consistency, and safety ratings from each of the different disciplines for various levels of training. On all of the projects except one, the designers surveyed have had formal TCP design training. As a result, comparisons between those projects whose designers have had training and those projects whose designers have not were not possible. On some projects the GC superintendent on-site had TCS training while on other projects the superintendent did not. A test was conducted to determine whether there was a difference in the quality, consistency, and safety ratings between these two groups, but nothing statistically significant was found. A similar comparison was made for projects on which the TCS was a pay item compared to projects without a TCS pay item, yet no statistically significant difference was found.

Table 4.20: Average Quality, Consistency and Safety Ratings by Formal Training

	Average Quality Ratings								Average Consistency Ratings								Average Safety Ratings			
Formal Training	Design	n	Review	n	Implementation	n	Inspection	n	Design	n	Review	n	Implementation	n	Inspection	n	Motorist	n	Worker	n
TCS	7.34	16	7.97	13	7.80	16	7.69	16	6.46	16	7.33	13	7.06	14	7.37	14	8.54	16	8.28	15
No TCS	7.73	20	7.80	15	8.10	18	8.14	18	6.98	20	6.26	15	7.69	16	7.91	16	8.71	20	8.63	20
TCP Design Class	7.58	23	7.75	19	7.79	21	7.74	21	6.82	23	6.57	19	7.15	19	7.55	19	8.26	23	8.38	22
No TCP Design Class	6.00	1	n/a	0	7.67	1	8.67	1	6.33	1	n/a	0	6.67	1	8.67	1	9.00	1	7.33	1

Table 4.21 presents the average work zone scores, average overall quality rating, and the percent increase of crashes during construction for the projects according to the extent of training and whether TCS was a pay item. In terms of quality, the average overall quality ratings were very similar regardless of whether a TCS was a pay item on the project. A similar result was found for work zone scores (no difference based on whether a TCS was a pay item on the project). It is interesting to note that while the work zone scores and quality ratings were very similar, the average percent increase of crashes during construction on projects in which there was not a TCS as a pay item (53%, n = 20), was higher than on projects in which a TCS was a pay item (13%, n = 16). As mentioned above, the number of projects on which designers did not have formal TCP training was so low that comparisons based on amount of TCP training were not possible. A Spearman's rho correlation test was performed for average work zone scores and average percent increase of crashes, and no statistically significant results were revealed.

Table 4.21: Work Zone Scores, Overall Quality, Percent Crash Increase by Formal Training

Formal Training	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
TCS as Pay Item	7.65	12	7.64	16	13%	16
No TCS as Pay Item	7.68	14	7.86	20	53%	20
TCP Design Class	7.64	17	7.65	23	11%	23
No TCP Design Class	n/a	0	7.44	1	-60%	1

4.4.9 Experience of Project Personnel

One of the enablers to TCP design success identified in the previous benchmarking survey (see Section 3.0) was the involvement of experienced project personnel on a project. This was investigated in greater detail across the projects in the case study. Average quality, consistency, and safety ratings are shown below in Table 4.22. The projects are grouped according to those projects with TCP designers who had 20 or more years of design experience and those projects with designers who had less than twenty years of design experience. Average design quality and consistency ratings on projects where the TCP designer had twenty or more years experience (quality mean = 8.75, n = 12, and consistency mean = 7.92, n = 7.92) were higher than those where the TCP designer had less than twenty years of experience (quality mean = 7.31, n = 13, and consistency mean = 6.45, n = 13). This difference was found to be statistically significant (two sided Independent Samples t-test, quality p-value = 0.007, consistency p-value = 0.010).

Table 4.22: Average Quality, Consistency and Safety Ratings by TCP Designer Experience

	Average Quality Ratings								Average Consistency Ratings								Average Safety Ratings			
TCP Designer Experience (years)	Design	n	Review	n	Implementation	n	Inspection	n	Design	n	Review	n	Implementation	n	Inspection	n	Motorist	n	Worker	n
Less than 20	7.31	13	8.06	12	7.69	12	8.02	12	6.45	13	7.11	12	7.50	11	7.96	11	8.23	13	8.18	13
20 or more	8.75	12	7.96	12	8.37	12	8.19	12	7.92	12	6.69	12	7.96	9	8.09	9	9.01	12	8.95	12

Also, average levels of motorist safety rating and worker safety rating on projects where the TCP designer had twenty or more years of design experience (motorist safety mean= 9.01, n = 12, and worker safety mean = 8.95, n = 12) were higher than those projects where the TCP designer had less than twenty years of experience (motorist safety mean = 8.23, n = 13, and worker safety mean = 8.18, n = 13). These differences were also found to be statistically significant (two sided Independent Samples t-test, motorist safety p-value = 0.088, worker safety p-value = 0.042).

Analyses also showed relationships between TCP designers and project priorities. Below is a list of those findings:

- The priority given to cost on projects in which the GC superintendents had 20 or more years of experience (mean = 5.65, n = 5) was higher than on projects in which the GC superintendent had less than 20 years experience (mean = 7.89, n = 7) (two sided Independent Samples t-test, p-value = 0.011).
- The ratio of schedule priority to safety priority on projects in which TCP designers had 20 or more years of design experience (mean = 0.860, n = 11) was higher than on projects in which the TCP designer had less than 20 years of experience (mean = 0.736, n = 8) (two sided Independent Samples t-test, p-value = 0.039).
- The ratio of productivity priority to safety priority on projects in which TCP designers had 20 or more years of experience (mean = 0.838, n = 12) was higher than on projects in which the TCP designer had less than 20 years of experience (mean = 0.723, n = 8) (two sided Independent Samples t-test, p-value = 0.054).

Additionally, projects on which the general contractor superintendent had 20 or more years of experience rated motorist safety priority higher (mean = 8.95, n = 5) than projects on which the GC superintendent had less than 20 years of experience (mean = 8.02, n = 7) (Mann-Whitney U-test, p-value = 0.006). Below in Table 4.23 are the average work zone scores, overall quality ratings, and average percent increase of crashes during construction grouped according to the amount of designer experience. No statistically significant relationships between the two groups were found.

Table 4.23: Work Zone Scores, Overall Quality, Percent Crash Increase by TCP Design Experience

TCP Designer Experience (years)	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
Less than 20	7.65	9	7.67	13	55%	12
20 or more	7.86	8	8.32	12	32%	12

4.4.10 TCP Site Detail

If the TCP design does not match the field conditions, construction personnel will often make field adjustments in an attempt to improve the quality of the TCP and safety in the work zone. In some cases, the TCP design may be modified in the field at the start of construction by the contractor to meet the contractor's planned construction sequence and methods. In other cases, changes to the TCP may be needed due to insufficient site detail provided in the TCP design, or a TCP design that does not accurately reflect the site conditions. In each case, a field-modified TCP design is created and submitted for review. Analyses were conducted to examine the impact of several factors related to site detail and on-site TCP design modifications.

Tables 4.24 and 4.25 show average work zone scores, overall quality ratings, and average percent increase of crashes during construction for the case study projects grouped in terms of TCP designer site visits and design detail. Projects on which the TCP designer visited the site less than two times report slightly lower average work zone score (mean = 7.76, n = 7) and average overall quality rating (mean = 7.82, n = 12) than those projects on which the TCP designer visited the site two or more times (mean work zone score = 7.79, n = 9, and mean overall quality rating = 8.08, n = 12). The average percent increase of crashes during construction for projects on which the TCP designer visited less than two times (mean = 49%, n = 12) is higher than those projects on which two or more site visits by the TCP designer were made (mean = 34%, n = 11).

Table 4.24: Work Zone Scores, Overall Quality, Percent Crash Increase by TCP Designer Site Visits

TCP Designer Site Visits	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
Less than 2	7.76	7	7.82	12	49%	12
2 or more	7.79	9	8.08	12	34%	11

The use of site specific TCP designs and standard drawings on projects was also examined. Thirty of the case study projects (77%) included TCP drawings that were specific to the project site along with the applicable ODOT TCP standard drawings. Nine projects (23%) provided only ODOT TCP standard drawings in the bid documents. Table 4.25 below shows that for projects on which there were only standard drawings, the average work zone score (mean = 7.88, n = 4) was slightly higher than on those projects that used site specific designs (mean = 7.62, n = 23). The opposite was true for the average overall quality rating (standard plans mean = 7.72, n = 9, and site specific plans mean = 7.85, n = 29). The average percent increase of crashes during construction was slightly lower (mean = 28%, n = 9) for projects that used standard plans compared to those that used site specific plans (mean = 36%, n = 29).

Table 4.25: Work Zone Scores, Overall Quality, Percent Crash Increase by Design Detail

Design Detail	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
Standard Plans	7.88	4	7.72	9	28%	9
Site Specific	7.62	23	7.85	29	36%	29

Fifteen (38%) of the projects confirmed that the General Contractor (GC) submitted a modified TCP design for approval. Thirteen (33%) of the projects confirmed that the general contractor did not submit a modified TCP design. Nine (23%) of the projects provided conflicting reports as to whether or not a modified design was submitted. For the analysis, a conflict was recorded only if there was a discrepancy among construction personnel (generally between the general contractor and the managing firm project manager). In some cases, the TCP designer reported that the design was not modified but construction personnel indicated otherwise. In these instances, the designer may have been unaware that minor changes were submitted for approval and a conflict was not recorded. Table 4.26 shows the average work zone score, overall quality rating, and percent increase of crashes during construction for the projects grouped according to whether the TCP design was modified.

Table 4.26: Work Zone Scores, Overall Quality, Percent Crash Increase by GC Design Modification

General Contractor Design Modifications	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
Yes	7.48	8	7.41	15	61%	15
No	7.85	11	8.15	13	15%	13
Conflict Reported	7.64	7	8.03	9	27%	9

On those projects where design modifications were made to the TCP design, the level of motorist safety was rated lower (mean = 8.33, n = 15) than on those projects where design modifications were not made (mean = 9.32, n = 13) (two sided Independent Samples t-test, p-value = 0.045). In addition, managing firm project managers and assistant project managers on projects where the extent of TCP field changes was significant (rating of 6-10) report a lower average implementation quality (mean = 6.86, n = 7) compared to projects where field changes were insignificant (rating of 1-5) (mean = 8.86, n = 17) (two sided Independent Samples t-test, p-value = 0.003).

4.4.11 Sub-contracting the TCP Implementation

The practice of subcontracting the traffic control implementation on a project was identified as a possible enabler for safe work zones in the literature review and survey of state DOT personnel across the country. The impact of this practice on safety was investigated for projects in the case study. General contractors for each project were asked whether or not traffic control implementation was subcontracted. In many cases, contractors reported that TCP devices were acquired through a subcontractor. On four (10%) of the projects, only the flagging operations were subcontracted, and on three projects (8%) the entire TCP implementation was subcontracted. Sixteen projects (41%) reported that the entire TCP implementation was performed in-house. The seven projects that subcontracted at least some portion of the TCP implementation rated implementation quality higher (mean = 8.81, n = 7) compared to those on which TCP implementation was performed in-house (mean = 7.59, n = 15) (two sided Independent Samples t-test, p-value = 0.06). It should be noted that one of the sixteen projects where implementation was subcontracted did not report an implementation quality rating. Table 4.27 reports the average quality, consistency, and safety ratings used in those comparisons.

Table 4.27: Average Quality, Consistency and Safety Ratings by Traffic Control Subcontracted

	Average Quality Ratings								Average Consistency Ratings								Average Safety Ratings			
Traffic Control Subcontracted	Design	n	Review	n	Implementation	n	Inspection	n	Design	n	Review	n	Implementation	n	Inspection	n	Motorist	n	Worker	n
Yes	7.25	3	8.00	1	8.58	3	7.08	3	7.00	3	8.00	1	7.00	2	5.71	2	8.83	3	8.00	3
No	7.40	16	7.97	12	7.59	15	7.98	15	6.74	16	7.57	12	7.16	13	8.09	13	8.34	16	8.29	15
Flagging Only	8.63	4	8.38	4	8.98	4	7.94	4	7.55	4	7.13	4	8.42	3	8.00	3	9.08	4	8.50	4

Table 4.28 presents the average work zone scores, average overall quality rating, and the percent increase of crashes during construction for the projects according to the different levels of subcontracting of the TCP implementation (all in-house, all subcontracted, and only flagging subcontracted). In terms of quality, the projects in which only the flagging was subcontracted received the highest average overall quality ratings (mean = 8.48, n = 4). When compared using the average work zone scores, each group received approximately the same average score. Based on the average percent increase of crashes during construction, however, those projects in which the traffic control was all done by the GC had the lowest average increase in crashes (mean = 15%, n = 4). Comparisons were made among all in-house, all subcontracted, and only flagging subcontracted projects, but no statistically significant results were found.

Table 4.28: Work Zone Scores, Overall Quality, Percent Crash Increase by GC Design Modification

Traffic Control Subcontracted	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
Yes	7.45	4	7.53	3	15%	4
No	7.61	10	7.62	16	27%	15
Flagging Only	7.53	3	8.48	4	36%	4

4.4.12 TCP Complexity

As described previously in the Research Methods Section 4.2.2, a complexity factor was determined for each case study project as a reflection of the complexity of the TCP design. The complexity factor was calculated based on the magnitude and nature of the TCP features on a project, and the complexity ratings for each type of feature that were received from ODOT personnel. The intent of creating and using a complexity factor was to develop an objective means to compare projects with different TCP designs according to how complex the design and implementation of the TCP was. Table 4.29 presents the average work zone scores, average overall quality rating, and average percent increase in crashes during construction for the project grouped according to their complexity (simple, moderate, or complex). Simple projects are those with complexity ratings below 105.4. Moderate projects were those with complexity ratings between 105.4 and 215.1, and complex projects are those with complexity ratings above 215.1. As shown in the table, the simple projects had the highest average work zone scores (mean = 7.88, n = 4). The moderately complex projects were rated with the highest average overall quality rating (mean = 7.92, n = 22), yet also had the highest average percent increase in crashes during construction (mean = 40%, n = 22). Statistically analyses of the data to evaluate the relationships did not reveal any statistically significant results.

While the results were not found to be statistically significant, the complexity rating provides an objective means to plan, monitor, and manage projects. The rating could be incorporated into planning efforts to identify which projects are more complex and may need additional resources or additional oversight for the TCP design. Of the 33 projects in the case study that were rated for complexity by the TCP designer, 20 (60%) were given the same rating using the numerical complexity rating. This comparison can be seen for all the projects in the TCP complexity matrix included in Appendix D. Further research may be needed to validate the complexity rating and perhaps modify its formulation.

Table 4.29: Work Zone Scores, Overall Quality, Percent Crash Increase by TCP Complexity

TCP Complexity (Numerical Rating)	Average Work Zone Score and Number of Projects (n)		Average Overall Quality Rating and Number of Projects(n)		Average Percent Increase of Crashes During Construction and Number of Projects(n)	
Simple	7.88	4	7.72	9	28%	9
Moderate	7.67	17	7.92	22	40%	22
Complex	7.46	6	7.63	7	25%	7

4.4.13 Other Correlations

Numerous other statistical comparisons of the data were performed as part of the analysis. While many did not reveal statistically significant results, some relationships were verified. Those that were found to be statistically significant (p-value < 0.05) were primarily relationships directly between ratings of quality, implementation, inspection, and/or safety. Statistically significant relationships are listed below:

- Projects which were rated highly for *design* quality were also rated highly for implementation quality (Pearson correlation, r =0.536, p-value =0.001), motorist safety (Pearson correlation, r = 0.522, p-value = 0.001), and worker safety (Pearson correlation, r = 0.555, p-value = 0.000).
- Projects which were rated highly for *implementation* quality were also rated highly for motorist safety (Pearson correlation, r = 0.642, p-value = 0.000) and worker safety (Pearson correlation, r = 0.525, p-value = 0.000).
- Projects which were rated highly for *inspection* quality were also rated highly for motorist safety (Pearson correlation, r = 0.450, p-value = 0.006) and worker safety (Pearson correlation, r = 0.428, p-value = 0.010).
- Respondents who indicated a high priority of constructability also reported high quality of implementation ratings (Pearson correlation, r = 0.334, p-value = 0.050).

4.5 CASE STUDY SUMMARY

The 39 project case studies provided useful information for the research study. Data from each case study project were collected via a survey of project personnel, review of crash databases, review of the project TCPs, review of TCS reports, and work zone tours. A detailed analysis of the data collected was conducted to identify: the TCP features that contributed to work zone crashes; potential revisions to the TCP design and review process to improve safety; and the impacts of ODOT's TCP design practices on the quality and consistency of TCPs. Below are brief descriptions of the salient findings from this analysis.

Design-phase personnel and construction-phase personnel tended to have different perspectives of the quality of TCP designs and implementations. In general, design-phase personnel rated the TCP designs included in the bid documents as having higher quality than those modified in the field and approved for construction. Construction-phase personnel rated field-modified TCPs higher than those included in the bid documents. The discrepancy between the two versions of the TCP is due in part to the original TCP not matching the field conditions. Construction-phase personnel indicated that the original TCPs did not match the field conditions more often than the design-phase personnel. In addition, construction-phase personnel rated the quality of actual implementation higher than design-phase personnel. There is a difference between design-phase and construction-phase personnel with regards to what constitutes a quality TCP design in the bid documents and what is quality implementation of the TCP.

On some of the case study projects the TCP design was modified during construction. The case study revealed that when significant modification of the design occurred, the project suffered (lower motorist safety rating and lower implementation quality rating). One reason why the designs may be modified is when only standard drawings were included and details specific to the project site are needed. When asked, "What were the most challenging aspects regarding the TCP design for this project?", 10 of the 39 projects (27%) had one or more respondents state that specific details were most challenging. However, in the case study projects, no conclusive relationship was found for those projects in which the design was modified because it did not meet the site conditions. More site visits and/or a more detailed design may not improve the implementation. On the other hand, it may be that improvements can be attained through better communication with the TCP designers during construction.

When comparing the case study projects by region, the data revealed that there are some regional differences in design quality, implementation consistency, and worker safety. In general, the TCP process in Region 2 was recognized as having higher quality than the other regions, while Region 5 was rated highly for its implementation consistency. Other regional differences were tested, but nothing was found to be statistically significant. The crash ratios ranged widely from region to region. This may be due to a number of factors including the type, size, and location of the typical projects in each region along with the project surroundings. It may also be due to the processes used and cultures existing in the regional offices.

The results indicated that review of the TCP, whether it is done during design or construction, was significant in a number of ways. In general, when the review was rated highly with regards to efficiency and/or quality, the design quality and worker safety were rated highly. When comparing OBDP projects and ODOT projects, review quality was identified as higher on OBDP projects.

It should be noted, however, that the review process did not appear to be tracked or measured in terms of efficiency and effectiveness. The review process was found by the survey participants to be ambiguous and many project team members were not confident in their responses regarding who conducted the review and when it was completed. When locating case study project personnel for the study, reviewers (both peer design and in the field) were the most difficult to locate. In some cases a self-review was conducted, and in some cases conversations with the respondents indicated that the review was more of an overview of the TCP design, or they felt unqualified to adequately answer the survey questions. When a reviewer for a project was located and identified, the projects tended to be rated higher in terms of quality.

Constructability reviews during the design phase are beneficial to both the TCP design and its implementation. When the extent of constructability review was highly rated, inspection quality and worker safety were better. Additionally, when constructability was given a high priority, the average quality of implementation, worker safety, and motorist safety all improved. It was evident that constructability reviews were important to TCP design and implementation. Although constructability reviews should be done early in the design process to gain the biggest value, the timing of the review was not as important as the quality of the constructability review. Ensuring input from construction personnel during the design phase of a project led to better overall quality of the TCP design and better implementation on the project site.

The experience of the designer and the GC superintendent play a significant part in the TCP design and implementation. The TCP process benefits when designers and the GC superintendent have more years of experience. More years of experience by the TCP designer correlated to higher average design quality and consistency, and a higher rating for worker safety. Also, a higher priority on safety was given by those superintendents who had more years of experience.

Subcontracting of some portion of the traffic control implementation may in some cases benefit the project. For those projects in which the work zone flagging was subcontracted, the overall quality of the TCP implementation was rated higher. However, the TCS reports noted a handful of rear-end crashes in flagging line-ups. Flagging stations, locations, and procedures should be evaluated to determine if improvements can be made. Rather than the implementation, the TCP design may also be contracted out to a consultant. A comparison between those projects designed by ODOT designers and those designed by consultants indicated that ODOT-designed TCPs have a higher implementation consistency than those designed by hired consultants.

The complexity of the TCP was not necessarily an indication of actual TCP design quality, TCP implementation, and safety performance during construction. TCPs that contained more features and temporary signage may have provided drivers more warning than for complex TCPs.

5.0 CONCLUSIONS

The process of designing, reviewing, implementing, and inspecting traffic control measures in construction work zones is complicated and extensive. It involves different disciplines, some of which may work for different firms or at different locations. Traffic Control Plan (TCP) design requires in-depth knowledge of design standards, construction processes, the construction project, and the jobsite features. Implementation of TCP designs requires knowledge and experience in construction means and methods, and an understanding of safety management in work zones. In addition, review and inspection of TCP designs and implementation ensures a high quality product from project-to-project. The entire TCP process is needed. Without any of these areas of expertise and quality assurance measures, the quality and safety of work zones would be compromised.

The objectives of this study were to: identify ways to modify TCPs to improve their quality and consistency; identify how the process of designing and reviewing TCPs can be modified to improve their quality and consistency; and identify effective processes and practices for implementing and inspecting work zones for compliance with the TCPs. The research study was successful in meeting these objectives through the use of a review of literature, a benchmarking survey of ODOT personnel, and project case studies that involved detailed analysis of ODOT projects.

There was a general consensus throughout project personnel (both ODOT personnel and others) that the quality of TCP design, review, implementation, and inspection is high. There was also general agreement that motorist safety and worker safety are of higher priority to project success than other project objectives such as cost, schedule, and productivity. The support from ODOT Headquarters is beneficial to the TCP process, and close proximity of the design teams to the regional construction offices also benefit the TCP design. Other strengths are the use of designers with extensive years of experience, and regular and early involvement of TCP designers. The entire process is enabled when there is early cooperation and buy-in from all members of the project team.

Literature is available both within ODOT and nationally to guide the design of traffic control plans for work zones. These documents provide guidance on the elements to include in work zones to control traffic and on the layout and sequencing of work zones. Each project and work zone, however, is different. TCPs need to be tailored to each project, and the TCP process should accommodate the need to create project-specific TCPs.

Barriers and weaknesses of the TCP process exist as well. There is a different standard of care between those involved in TCP design and those involved in TCP implementation. The expectation on what is sufficient to provide a safe work zone differs between these groups. This can affect the importance placed on specific aspects of a TCP design and the ultimate level of safety in a work zone. There is a need for earlier and more thorough TCP constructability reviews, and a need to communicate more clearly with and educate the traveling public about work zones on a project by project basis. The identified barriers and weaknesses highlight the importance of ODOT communicating its expectation with respect to the quality of TCP design and TCP implementation.

The study revealed that there are some distinctions between regions in regards to TCP quality, and some features of the TCP process that impact the quality, consistency, and safety of TCPs. In regards to the TCP design, as stated previously the number of years of experience was found to be a differentiator when judging the quality of TCP designs. On those projects in which the TCP designers had more years of experience, the projects had a higher level of quality. Designers who have significant experience are more knowledgeable about proper TCP designs and standards, and are better able to recognize how to tailor a design to meet specific site conditions or anticipated construction sequence and procedures.

Solely using standard TCP design drawings can be a detriment to the quality of the TCP and safety in the work zone. Standard drawings may not provide sufficient detail, and may not convey the importance of the TCP to the contractor. While this conclusion was not found to be statistically significant, on approximately 25% of the projects accommodation of site detail was listed as a challenging part of implementing the TCP. If no site specific detail is provided, TCP design modifications made during construction may not be appropriate. A lack of a full review of site modified TCPs, which is sometimes the case, may result in inappropriate traffic control measures and less safe work zones. One example is over-signing, which was noted by both designers and implementers because it desensitizes drivers to important traffic control information. Using only standard TCP design drawings also makes communicating and maintaining the intended standard of care more difficult. This difficulty was noted by designers as a concern.

Some confusion and frustration with the TCP process exists. Specifically, with respect to the design, those who implement the design stated that the greatest frustrations were that the TCP design does not match the site conditions and that the TCP design documents are unclear and/or contain errors. As a result, TCP implementers indicated that they need to frequently modify the TCP design because they felt it does not provide a safe work environment. In addition, implementers indicated that the most common reasons for modifying the TCP in the field is that: the TCP cannot be constructed as designed, traffic flow is excessively impeded through the project, motorists ignore specified turn movements, and the construction methods chosen are not compatible with the TCP design.

The review function in the TCP process is critical to its success. Reviews, both peer design reviews and reviews of field modified TCPs, provide a means to assure quality in the TCP design. The lowest review ratings were given for ODOT Regions 3 (see benchmarking survey results in Section 3.3.3) and 4 (see case study results in Section 4.4.2). Additional efforts and/or resources should be implemented to improve the reviews in these regions. The points in the process that were identified as needing the most improvement were in the Advance Plans TCP Package and the Plans-in-Hand Review phase. These occur later in the design process which indicates that the timing of the review is less important than the quality of the review and the availability of project information in order to complete the review. It is also important to ensure that the right people participate in the reviews. Incorporating both personnel who have TCP design experience and personnel who are knowledgeable about construction means and methods is critical to conducting a quality review. Further research on this topic may provide guidance toward developing a formal and effective TCP review process.

The implementation function of the TCP process requires interpretation of the TCP design and application of the design to the site. It also requires recognition of when the TCP needs to be modified to accommodate unforeseen site conditions and changes in the construction sequence and methods. To do so, the implementers need to have TCP training and experience in TCP implementation. Requiring a TC Supervisor on projects, or during critical construction activities on projects, is one means to ensure that this experience and oversight is present on projects. For example, night time construction or stage changes are critical activities that impact safety in work zones and the presence of a TC Supervisor on-site would provide additional experience and expertise to mitigate potential hazards. A TC Supervisor is used more frequently in other states, while being rated as having a high impact on work zone safety (see Figures 2.1 and 2.2).

From the TCP designer's perspective, greater adherence to the TCP design is needed by the contractors. This requires an increased level of enforcement of the TCP design. Inspectors report that on almost 20% of projects there is some kind of problem in the implementation of the TCP, although this percentage varies to a great extent amongst the inspectors (1% - 90%). The most commonly cited problems with implementation of the TCP were: improper transition lengths, incorrect degree of curve, over-signing the work zone, leaving gaps in traffic control measures, unknown utility schedules and locations, inadequate separation of traffic and work areas, and improper allowances for drainage. In regards to the phasing of the work, not integrating the TCP with the construction schedule was recognized as a problem as well.

The amount of training was also found to be important in addition to the amount of experience. Those respondents who have had TC supervisor training reported a different (lower) level of quality of implementation than those who do not have the training. In addition, those who have the training do not rate project cost as high a priority. Training helps to communicate the expected standard of care to the implementers, an issue that is especially important on complex projects and on projects in which the TCP needs to be modified to accommodate changed site conditions or construction methods.

The research study revealed that the frequency and quality of inspection during construction was sufficient. Inspection quality from one project to another, and between regions, however, was not consistent and should be improved. This was reflected in the lack of detailed information provided in the inspection reports and the TCS reports on some projects, especially on the days when a crash occurred on the project. Inspection methods and levels of expectation (for the contractor as well as for the inspector) should be standard across all projects and effectively communicated.

The research study revealed that some improvements can be made in management of the project as well. Sharing lessons learned from past projects supports the design of high quality TCPs. . It was found that lessons learned are shared, although the means of sharing varies. Commonly cited means in which lessons are shared were: ODOT post-project narrative, word of mouth between project team members, and crew and design team meetings during the project. However, there was recognition of a lack of, and need for, a project-to-project lessons learned/knowledge management system. This lessons-learned system should be accessible across all regions and to consultants.

6.0 GUIDELINES AND RECOMMENDATIONS

Comments received from the benchmarking and case study surveys, along with the analysis of the study data, indicated that there are many positive aspects of the Traffic Control Plan (TCP) process and other areas in which modifications would improve the quality and consistency of TCPs and safety in work zones. Numerous conclusions were drawn from the research study as was described in Section 5.0 of the report. Generalization of the conclusions to the entire ODOT design and construction program depends on the accuracy of the data and how well the projects, data, and personnel included in the study samples are representative of ODOT overall. Studying a complex process, such as that associated with TCPs, was difficult because of the multi-variable nature of TCP quality, consistency, and safety, and a lack of objective and reliable data. While each data set may not provide generalizable findings individually, analyses from multiple data sets that provide common results offer greater confidence in the conclusions and recommendations. In this study, conclusions have been drawn from multiple data sources including the literature review, benchmarking survey, and case studies (survey, crash data, TCS reports, work zone scores, and review of TCPs). A description of the recommendations from multiple data sources are further described below.

Provided below are recommendations for continuing current efforts along with suggestions for modifications to the TCP process. The recommendations were grouped into three tiers based on the extent to which each were supported by the research conducted. Tier 1 recommendations include those based on research findings that were verified through multiple statistically reliable comparisons and abundant anecdotal references within the literature review, benchmarking survey, and case studies. These are considered the highest priority for ODOT to improve TCPs. Tier 2 recommendations are based on research findings that were verified through a single statistically reliable comparison and a notable number of anecdotal references. Tier 3 recommendations are based on findings that were supported by a considerable number of anecdotal references, but not necessarily quantifiable or statistically significant. The recommendations included in Tiers 2 and 3 are important, and should not be disregarded, but are considered less reliable and of lower priority than those in Tier 1.

Tier 1 Recommendations

- *Identify and/or place capable peer reviewers within each region*. The amount of resources provided to support TCP review should be sufficient to conduct thorough reviews of all projects as needed. Traffic control is a specialized discipline, and in some regions TCP reviewers with the appropriate skills were hard to find. Provide resources to enable additional TCP review training.
- *Formally communicate the TCP design/review process, and the names of the TCP reviewers assigned to the project, to the project team members*. This should be done for both the designers, especially external consultants, at the beginning of design, and for the contractors in the bid package or at the pre-construction meeting. By doing so, there will

be less ambiguity regarding TCP reviews and it will clarify who to contact for review and approval if field modifications to the TCP are desired.

- *Maintain and enhance connections between the design teams and the regional construction offices (both in location and in communication channels).* The ability to readily communicate and discuss the planned TCP with those who have construction expertise is beneficial to the quality of the TCP. Encourage designers to seek input from construction personnel about construction site impacts to the TCP.
- *Emphasize the importance of designer experience and training.* The study revealed that projects on which the designers had more experience designing TCPs resulted in better TCP quality. In addition, TCP training of designers helps to enhance quality. For some regions, this could be done using remote or distance education tools. This can additionally be facilitated by incorporating sessions co-led by Project Managers or other construction staff into the formal TCP design training.
- *Formalize the review process for TCP designs that are field modified.* When the TCP is modified in the field, a thorough review of the TCP should be conducted as part of the approval process. Ensure that those in the field know who to contact for the review and approval. The review should also be done by a qualified TCP designer.
- Establish a formal process for identifying projects that have unique project features and therefore warrant greater attention to the TCP. Some projects that do not require a complex TCP and are located on a roadway with slow traffic speeds and low volumes still require an extensive TCP process, despite perception to the contrary. However, a more detailed and extensive TCP process is needed on 'significant' projects and hazardous roadways (e.g., more and earlier reviews, specialized training, focused TCP meetings, etc.). The process could be used as a planning tool for setting up the TCP process on each project. While this recommendation is not specifically supported by the analyses, it is provided to practically address and integrate all of the Tier 1 recommendations.

Tier 2 Recommendations

- *Require designers to visit the site prior to preparing the TCP design.* The quality of implementation suffers, and extra review effort is needed, when the TCP design does not take into account unique site impacts. Site visits should be conducted to record existing roadway and future project features that are unique and need to be addressed in the TCP design.
- *Tailor the TCP design to the project.* Those case study projects which did not solely use standard TCP drawings were found to have higher quality, especially with respect to implementation of the TCP. Including more than just standard TCP drawings should be emphasized where warranted. The TCP process should be structured to accommodate the need to create project-specific TCPs, and allow for modification of the TCP in the field where required to accommodate unforeseen site conditions and changes to the construction means and methods.

- *Maintain a seamless transition between design and construction*. When possible, have those who participated in the TCP design provide support during construction. Those who created the design are most familiar with the design issues and are valuable to the contractor when questions arise and modifications are suggested. Similarly, utilize construction personnel who will be involved in the construction phase for constructability reviews during the design.
- *Communicate to the contractor and inspectors the expected level of quality of TCP implementation and the intent of the TCP to ensure a common standard of care*. This could initially be done through standard training, and then augmented with site specific information on each project. A meeting between the TCP designer, contractor representatives, Traffic Control Supervisor (TCS), and inspector prior to the start of construction regarding the TCP features and expectations is needed to reinforce the designer's intent, explain the design, and coordinate the design with construction means and methods as needed.
- *Promote TC supervisor training of General Contractor's superintendents*. The TC supervisor training is a means to communicate the importance of traffic control and the expectations that ODOT has regarding implementation of TCPs.
- *Ensure early and regular involvement of TCP designers in the project design phase*. Including TCP designers early on and regularly in the design allows for integrating the traffic control issues with the roadway design as opposed to the traffic control being an "add-on" prepared hastily at the end of the design.

Tier 3 Recommendations

- *Continue to provide TCP design support from the ODOT Headquarters*. Both peer design reviews and review of field-modified TCPs are critical to assuring quality of the TCP design and its implementation. The expertise available in ODOT Headquarters is recognized as a valuable resource. This need is especially important when the TCP design is subcontracted to consultants who may not have extensive years of design experience or understand the standard of care expected by ODOT.
- *Seek to get early cooperation and buy-in from all members of the project team*. Alignment of responsibilities and expectations early on in the project from all involved helps to alleviate conflicts and ambiguities later on. It also provides ODOT with an opportunity to establish expectations for the quality of TCP design documents and implementation standards. This may require using alternative contracting methods involving integrated project delivery (e.g., design-build and CM/GC) that more readily allow for collaboration between the design team and the contractors.
- *Improve the Advance Plans TCP Package and the Plans-in-Hand Review phases of the TCP design process*. Improvements at these stages can alleviate many issues that potentially would arise during construction. Plans that are too complete, or not complete enough, make review at these stages difficult. In addition, constructability reviews prior to these stages facilitate the efficiency of the design.

- *Establish a formal lessons learned/knowledge management process to share project experiences across all ODOT projects.* While some means are currently employed to provide project feedback to the project team, additional processes should be in place to share lessons learned from project-to-project.
- *Enhance the amount and type of information recorded by the inspectors and TC supervisors.* Close monitoring and recording of field conditions facilitates improvements. The type of information collected by inspectors and TC supervisors should be reviewed such that it facilitates field oversight, captures lessons-learned for future projects, and supports crash data management.

Additional recommendations and lessons learned were suggested by the ODOT TAC committee following its preliminary review of the research results. A summary of these are provided below:

- Incorporate 'documentation quality' as a performance measure for Traffic Control Supervisors and Inspectors
- Communicate the importance of constructability reviews to ODOT Project Leaders and Office of Major Projects
- Communicate the importance of TCP designer experience to Region Traffic Managers and Design Managers for consideration when assigning TCP designers to projects
- A recommendation of a required review of the TCP by ODOT Headquarters for projects identified as 'significant' from items within the Tier 1 recommendations.
- Include at least one field review by the TCP designer during the construction phase of the project
- The TAC recognized ODOT needed to improve the quality and consistency of crash data collection methods, so as to support further data analysis.

The research study revealed that when certain project characteristics are present, providing safety and effective traffic control is particularly challenging. Those features which had a significant impact on traffic control, in order of decreasing impact, were:

- Numerous or frequent stage changes
- High speeds through the work zone
- Multiple lane closures
- Dense existing signage
- Unique site features (i.e. horizontal or vertical curves in/before work zone)
- Traffic entering/leaving the work zone (intersections/ramps)
- Urban or night setting
- Flagging and/or pilot car operation

- Use of temporary striping
- Multi-lane highways

While the type of roadway is another characteristic that distinguishes projects, it was not supported by the research data as a factor that significantly impacted TCP quality and consistency or work zone safety. The rated roadway speed, included in the list above, implies the type of roadway to some degree. However, multi-lane highways were included in the list above because they were commonly rated as the most complex and are an indicator of traffic volume. Traffic volume, while not considered in the research study, may also be an impacting factor that creates a hazardous environment and should be taken into consideration.

Further research is recommended to develop a quantitative measure which reflects the extent to which these factors are present on projects, similar to the complexity factor used in this study. Such a rating could then be used to guide ODOT in assigning resources to a project and managing a project to ensure a high quality TCP. For example, the rating might be used to determine whether to subcontract out the design to a consultant, utilize solely standard TCP drawings, conduct additional constructability reviews, hold additional pre-construction meetings specific to the TCP, utilize a more experienced designer, or require a TCS on a project. Categories of projects could be developed to guide management of the project, identify critical projects, and utilize resources affectively. Below is a general structure for a guideline that relates the project characteristics to the TCP process features:

- When *none* of the significant project characteristics are present, the following procedures may be followed:
    - Use of only standard TCP drawings
    - Special provisions include language that communicates the intent of design
    - Self-review by qualified designer
- When *some* of the significant project characteristics are present, the following procedures must be followed:
    - Site specific TCP design plus standard drawings where appropriate
    - Constructability review during design
    - Focused TCP review
- When *more* of the significant project characteristics are present, the following procedures must be followed:
    - Site specific TCP design plus standard drawings where appropriate
    - Constructability reviews conducted at multiple points during design
    - Focused, multi-disciplinary TCP reviews at multiple points during design
    - TCS present for construction activities critical to TCP

- When *most* of the significant project characteristics are present, the following procedures must be followed:
  - Site specific TCP design plus standard drawings where appropriate
  - Constructability reviews conducted at multiple points during design and at beginning of construction
  - TCP designer involved throughout the design
  - Focused, multi-disciplinary TCP reviews at multiple points during design
  - TCS assigned to the project during construction and present daily
  - GC superintendent and TCP designer with extensive experience

The structure presented above is an example of a general TCP program structure that could be used as a guideline for addressing risks associated with varying TCP components. The following is an example of a more detailed program that further defines, and attempts to quantify, the risks associated with a particular TCP and provides guidelines for addressing those risks with appropriate mitigation measures. Figure 6.1 below contains a checklist for identifying various TCP and project characteristics potentially present and calculating a risk factor associated with the individual characteristic and overall TCP. Those characteristics listed in the first category are considered relatively low risk characteristics and are therefore assigned a risk factor of 1. Those listed in the second category are considered moderate risk characteristics and are assigned a risk factor of 2. Those listed in the third category are considered high risk characteristics and are assigned a risk factor of 3. By identifying the characteristics present on a particular project and summing the corresponding risk factors, the user can quantify the level of risk associated with the TCP. The cumulative risk value associated with the hypothetical TCP example in Figure 6.1 is nineteen.

An appropriate TCP mitigation program can be determined using the quantified level of risk associated with the TCP. Four categories of TCP mitigation programs – Required, Limited, Moderate, and Extensive – are presented below in Table 6.1. Certain basic TCP program components are recommended for all projects even when none of the risk checklist items are present. These are listed under the 'Required' TCP Program Components in Table 6.1. For projects with calculated risk checklist values from 1 to 11, a 'Limited' program is recommended. For projects with calculated risk checklist values from 12 – 22, a 'Moderate program is recommended. Lastly, for projects with calculated risk checklist values from 23 – 33, an 'Extensive' program is recommended. For example, for the calculated risk checklist value of 19 shown in Figure 6.1, a 'Moderate' TCP mitigation program would be selected.

TCP Risk Checklist with Example Project

Category I	Present?
Number of Stage Changes - 1	☐
Frequency of Stage Changes - Single	☐
Flagging and/or pilot car operation	☑
Temporary Striping	☑
Right of way required	☑

Count		Risk Factor		Total
3	x	1	=	3

Category II	Present?
Number of Stage Changes - 2	☐
Frequency of Stage Changes - Regular	☑
Number of Lane Closures - 1	☐
Lane Closure - Single Direction	☐
Signage - Dense existing signage	☑
Site Features - Unique, Horizontal, Vertical curves	☑
Traffic entering/leaving work zone	☑
Construction Setting - Urban	☐
Freeway or Multi-Lane Highway	☑
Modernization or Bridge Work	☐

Count		Risk Factor		Total
5	x	2	=	10

Category III	Present?
Number of Stage Changes - 3+	☑
Frequency of Stage Changes - Daily	☐
Posted Speed - 50 MPH+	☑
Number of Lane Closures - 2+	☐
Lane Closure - Multiple Directions	☐
Construction Time - Night	☐

Count		Risk Factor		Total
2	x	3	=	6

Sum of Risk Factors **19**

Figure 6.1: TCP Risk Checklist and Example

Table 6.1: TCP Program Components

Required (All TCPs)	*Limited (Risk Factor 1-11)*	*Moderate (Risk Factor 12-22)*	*Extensive (Risk Factor 23-33)*
• Identify Peer Reviewer • Identify Constructability Reviewer • Identify Modified Field Reviewer • TCP Designer with Formal Training • GC Representative with Formal Training • Standard TCP Drawings • TCP Designer Virtual Site Visit	• Identify Peer Reviewer • Peer Review at 60% • Identify Constructability Reviewer • Constructability Review at 60% • TCP Designer with Formal Training • TCP Designer with 5+ Years Experience • GC Representative with Formal Training • GC Superintendent with 5+ Years Experience • TCS - Present for Stage Changes Only • Identify Modified Field Reviewer • Construction Office Review of Field Modifications • Standard TCP Drawings • Special Provisions indicating Standard of Care • TCP Designer Virtual Site Visit	• Identify Peer Reviewer • Peer Reviews at 30% and 60% • Identify Constructability Reviewer • Constructability Reviews at 30% and 60% • TCP Designer with Formal Training • TCP Designer with 10+ Years Experience • GC Representative with Formal Training • GC Superintendent with 10+ Years Experience • TCS - Present for all Critical Activities • Identify Modified Field Reviewer • Construction Office Review of Field Modifications • TCP Designer Office Review of Field Modifications • Standard TCP Drawings • Site Specific TCP • Special Provisions indicating Standard of Care • At least one TCP Designer Site Visit	• Identify Peer Reviewer • Peer Reviews at 30%, 60%, and 90% • Peer Review - ODOT Headquarters • Identify Constructability Reviewer • Constructability Reviews at 30%, 60%, and 90% • TCP Designer with Formal Training • TCP Designer with 20+ Years Experience • GC Representative with Formal Training • GC Superintendent with 20+ Years Experience • TCS - Present Daily • Identify Modified Field Reviewer • Construction Office Review of Field Modifications • TCP Designer Site Visit and Office Review of Field Modifications • Standard TCP Drawings • Site Specific TCP • Special Provisions indicating Standard of Care • Pre-Construction Meeting to discuss Standard of Care • Multiple (2+) TCP Designer Site Visits

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APPENDIX A:
SURVEY EMAIL AND SURVEY INSTRUMENT

E-MAIL TO SURVEY PARTICIPANTS

The following e-mail was used to transmit the questionnaire to the survey participants and ask for their participation in the survey. A similar e-mail, without the attached questionnaire, was sent to those individuals identified for an interview.

Dear Sir or Madam:

OSU Construction Engineering Management is conducting a research study for the Oregon Department of Transportation titled "Work Zone Design and Operation Enhancements". We respectfully request your help in this study through your completion of a short survey. The survey is attached and includes some general background information questions along with additional questions related to Work Zone Design and Operation within your area of expertise. The primary purpose of the study is to enable improved safety performance through work zones on state roadways.

Five surveys are being used in this research to reflect the different disciplines involved: Project Management, Design, Design Review, Implementation (Construction), and Inspection. If the survey which we have sent to you does not match your discipline, please contact me and I will send you the appropriate survey.

Please respond to only those questions that you feel qualified to answer. All individual responses will be kept confidential and not be used for anything unrelated to this study. Summarized data will not identify individual participants or companies. In appreciation for your participation, we would be pleased to send you a summary of the survey results.

If you have any questions about this study, please contact Dr. John Gambatese (Principal Investigator) at john.gambatese@oregonstate.edu, or Michael Johnson at johnson@engr.orst.edu.

Thank you very much for taking the time to participate in this important study.

Sincerely,

Michael Johnson
OSU Construction Engineering Management
Graduate Research Assistant

DESIGNER SURVEY QUESTIONNAIRE

INTERVIEW: WORK ZONE DESIGN AND OPERATION ENHANCEMENTS

DESIGN

Regional TCP Designers, Region Tech Center Roadway Designers, OBDP, Consultants

If you have any questions about this interview or about the research project in general, please do not hesitate to contact us at: johnson@engr.orst.edu or john.gambatese@oregonstate.edu. All survey responses will be kept anonymous.

BACKGROUND INFORMATION

1. What is your title? ____
2. Are you an ODOT employee? ___ Yes ___ No
3. How long have you worked at ODOT/your firm? ______ years
4. How many years of experience do you have in each of the following areas:

_________ Design ___ Traffic Control Design ___ Testing
_________ Construction ___ Inspection ___ Construction Management
_________ Other: _____________________________________

5. In what regions do you perform work? Select all that apply.

_________ 1 ___ 2 ___ 3 ___ 4 ___ 5 ___ OBDP

6. Approximately what percent of your department's/firm's work is on each of the following types of projects?

_________ Transportation ___ Industrial/Manufacturing ___ Buildings: Residential
_________ Energy ___ Water/Wastewater ___ Buildings: Commercial/Office
_________ Other: _____________________________________

7. Approximately what percent of your department's/firm's projects are for ODOT? ______ %
8. If your firm is a consultant to ODOT:
   a. What is your firm's approximate annual revenue? ____________ dollars
   b. What is the approximate distribution between public and private work within your firm? ______ % public ______ % private
9. Approximately what percent of the services that your department/firm provides is each of the following services?

_________ Design ___ Traffic Control Design ___ Testing
_________ Construction ___ Inspection ___ Construction Management

_________ Other: ___________________________

10. What is your role in the Traffic Control Planning process?

TRAFFIC CONTROL PLAN (TCP) DESIGN POLICY AND PROCESS

11. When in the project development phase is the Traffic Control Plan (TCP) Designer first included?
12. Who selects the TCP designer for a project?
13. Please rate each of the following criteria from 1-10 (1 = low priority and 10 = high priority) on whether it is considered in the selection of the TCP designer for a project.
    ___ Design experience ___ Cost ___ Efficiency
    ___ Availability ___ Skill ___ Quality of work
    ___ Other: ________________________ ___ I don't know

14. Please rate each of the following criteria from 1-10 (1 = low priority and 10 = high priority) on whether it is considered when determining if a TCP will be designed 'in-house' by ODOT or by a hired consultant?
    ___ Design experience ___ Complexity of project ___ Expertise available
    ___ Work load of ODOT designers ______________________ Project budget
    ___ Project schedule
    ___ Other: ________________________ ___ I don't know

15. Approximately what percent of the following ODOT project classifications do you most often design?

_________ Major Freeway modernization ___________________ Frwy. preservation ______ Bridge replacement
_________ Multi lane highway ___ 2 lane hwy. widening ___ 2 lane hwy. preservation
_________ Other: ______________________________ ___ Intersections

16. Please rate the complexity (1 = very simple, 10 = very complex) of the TCP designs for each of the following types of ODOT project classifications.

_________ Major Freeway modernization ___________________ Frwy. preservation ______ Bridge replacement
_________ Multi lane highway ___ 2 lane hwy. widening ___ 2 lane hwy. preservation
_________ Other: ______________________________ ___ Intersections

17. Please rate each of the following criteria from 1-10 (1 = low priority, 10 = high priority) on whether it is used to determine if a project calls for a "Written + Plan" or just a "Written" TCP?

_________ Complexity of the design ___ Construction office needs ______ Project size
_________ Design time constraints ___ Significance of the project ______ Project schedule
_________ Other: _________________________________ ___ I don't know

18. When during the project development phase is the TCP design started?
19. How involved are you as a member of the Scoping Team? Use: 1 = Not involved, 5 = Very involved.
    ___ 1 ___ 2 ___ 3 ___ 4 ___ 5
20. How many revisions do you typically make before arriving at a final TCP design? ______

21. Who typically initiates changes to the TCP design? Select all that apply.
__________ Roadway designer ___ Bridge designer ___ Construction staff
__________TCP designer ____TCP reviewer ___ Project Manager
__________ Other: ___________________________________ ___ I don't know

22. Please rate each of the following steps in the TCP design process in terms of the improvement needed in order to improve overall TCP design. Use: 1 = no improvements needed, 10 = significant improvements needed.
    ___ Initial project team meetings
    ___ Creating the Design Acceptance Package
    ___ Preliminary Plans Workshops
    ___ Creating the Advance Plan TCP Packages
    ___ Plans-in-hand review
    ___ Specification writing
    ___ Implementation of the final design

23. How can the TCP design process be improved?
24. How can safety be improved in work zones?

TCP DESIGN RESOURCES

25. What are the top 3 sources of information used in the design of a TCP?
__________ Roadway ___ Bridge ___ MCTD Mobility Manager
__________TCP Standard Drawings ____Work Zone Analysts ___ Project Manager
__________ Other: ___________________________________

26. What information from the Work Zone Analyst is most critical to designing a successful TCP?
27. How thorough is the TCP information obtained from the Work Zone Analyst? Use: 1 = Not very thorough, 5 = Very thorough.
    ___ 1 ___ 2 ___ 3 ___ 4 ___ 5
28. How timely is the TCP information obtained from the Work Zone Analyst? Use: 1 = Not very timely, 5 = Very timely.
    ___ 1 ___ 2 ___ 3 ___ 4 ___ 5
29. Is there updated work zone analysis that takes place once the TCP is in place?
    ___ Yes ___ No
30. What information from the contractor is most critical to designing a successful TCP?
31. How thorough is the TCP information typically obtained from the contractor? Use: 1 = Not very thorough, 5 = Very thorough.
    ___ 1 ___ 2 ___ 3 ___ 4 ___ 5
32. How timely is the TCP information typically obtained from the contractor? Use: 1 = Not very timely, 5 = Very timely.
    ___ 1 ___ 2 ___ 3 ___ 4 ___ 5
33. How many site visits by TCP designers are typically a part of the TCP design process? ________
34. Indicate whether you agree or disagree with this statement: Designers are given enough time to complete a thorough TCP design. Use: 1 = Strongly **disagree** with this statement, 5 = Strongly **agree** with this statement.
    ___ 1 ___ 2 ___ 3 ___ 4 ___ 5

35. Do you have sufficient resources available to complete an effective design? Use: 1 = Insufficient, 5 = Sufficient.
    ___ 1 ___ 2 ___ 3 ___ 4 ___ 5

TCP DESIGN TRAINING

36. What TCP design training have you received? Select all that apply.
    ___ Traffic Control Design Plans Workshop
    ___ Work Zone Analysis
    ___ Other: ______________________________________

GENERAL TCP DESIGN

37. What TCP design elements do you believe work best in terms of safety?
38. What are the top 3 concerns when creating a TCP design?
39. What are the common TCP design mistakes?
40. What are the strengths of ODOT's TCP design process?
41. What are the weaknesses of ODOT's TCP design process?
42. What makes a successful TCP design?
43. What are the barriers in the ODOT TCP design process?
44. Are lessons learned from past projects communicated for future use in TCP's? If so, how?
45. What is the quality of the typical TCP design? Use: 1 = Poor quality, 5 = Excellent quality.
    ___ 1 ___ 2 ___ 3 ___ 4 ___ 5
46. What is the quality of the typical TCP design review? Use: 1 = Poor quality, 5 = Excellent quality.
    ___ 1 ___ 2 ___ 3 ___ 4 ___ 5
47. Please rate each of the following project objectives in terms of their importance to project success. Use: 1 = not important, 10 = very important.
    ___ Cost
    ___ Traffic flow
    ___ Worker safety
    ___ Construction productivity
    ___ Motorist safety
    ___ Constructability
    ___ Quality
    ___ Schedule

APPENDIX B:
PROJECT LIST WITH DETAILS

Project Number	Route Number	Project Name	Contract No.	Key No.	Region	Oregon HWY Number	Type of Roadway	Start MP	Finish MP	Construction Time Frame	Project Delivery Method	Managing Firm	TCP Design Firm
1	I-205	Willamette River Bridge – Pacific Hwy. (Unit 3) Sec.	13237	12874	1	64	Freeway	-0.10	8.80	07/01/06 to 04/01/08	Design Bid Build	ODOT	ODOT
2	I-5	Marquam Bridge – Capitol Hwy. Sec.	12901	n/a	1	1	Freeway	294.21	299.93	11/06/2003 to 2/28/05	Design Bid Build	ODOT	W & H Pacific
3	OR-219	Hillsboro-Silverton Hwy. at Farmington Road	13274	11931	1	140	2 Lane Highway	5.18	5.79	10/7/2006 to 12/31/07	Design Build	ODOT	ODOT
4	US-26	Langensand Rd. – Cherryville Dr. Sec.	13370	14593	1	26	2 Lane Highway	25.12	32.47	6/30/07 to 10/19/07	Design Bid Build	ODOT	ODOT
5	I-5	Sodom Ditch-Calapooia (Bundle 216 (08233 and 08235))	13366	14037	2	1	Freeway	220.00	221.50	09/01/2007 to Sept 2009	Design Bid Build	OBDP	JRH
6	OR-18	Fort Hill – Wallace Bridge	13422	14291	2	39	2 Lane Highway	23.82	26.28	04/26/2008 to 2010	Design Bid Build	ODOT	ODOT
7	OR-18	Oregon Coast HWY – Oldsville Road (megapave)	13344	15173	2	39	2 Lane Highway	-0.22	40.34	06/21/07 to 10/31/07	Design Bid Build	ODOT	Kittleson and Associat es
8	OR-213	Lone Pine Corner – Hwy. 214	13101	11860	2	160	2 Lane Highway	24.74	29.71	5/31/05 to 9/31/05	Design Bid Build	ODOT	ODOT
9	OR-219	Springbrook Road - Wynooski Road (Newberg)	13409	9274	2	140	2 Lane Highway	21.36	22.40	05/01/2008 to 10/29/08	Design Bid Build	ODOT	ODOT

Project Number	Route Number	Project Name	Contract No.	Key No.	Region	Oregon HWY Number	Type of Roadway	Start MP	Finish MP	Construction Time Frame	Project Delivery Method	Managing Firm	TCP Design Firm
10	OR-22	Sublimity Interchange	13439	13658	2	162	2 Lane Highway	11.83	14.08	05/19/2008 to 2010	Design Bid Build	ODOT	ODOT
11	US-101	Jetty Creek Fish Passage	13342	13807	2	9	2 Lane Highway	Z 47.66	Z 47.36	06/04/08 to 11/29/08 (Comp. Time Est.)	Design Bid Build	ODOT	ODOT
12	US-101	Latimer Road	13440	11667	2	9	2 Lane Highway	63.82	64.06	06/26/08 to 11/30/08 (Comp. Time Est.)	Design Bid Build	ODOT	ODOT
13	US-101	Meda Loop Road - Redburg Road	13452	15329	2	9	2 Lane Highway	91.99	92.74	07/08/08 to 09/26/09 (Comp. Time Est.)	Design Bid Build	ODOT	ODOT
14	US-101	New Youngs Bay Bridge	13362	11792	2	9	2 Lane Highway	4.51	5.31	08/21/07 to 04/28/09 (Comp. Time Est.)	Design Bid Build	ODOT	ODOT
15	US-101	Newport Signal Upgrades	13271	12673	2	9	Intersection	139.32	139.79	11/1/2006 - 5/15/2007	Design Bid Build	ODOT	ODOT
16	US-101	Otis Junction – Boiler Bay Sec.	13121	13657	2	9	2 Lane Highway	110.75	126.41	6/1/2005 to 11/1/2006	Design Bid Build	ODOT	ODOT
17	US-30	John Day River Bridge	13423	11798	2	92	2 Lane Highway	92.32	92.77	05/12/08 to 11/15/08 (Comp. Time Est.)	Design Bid Build	ODOT	ODOT
18	I-5	Azalea – Glendale Reconstruction	13326	12721	3	1	Freeway	81.40	87.30	4/2007-9/2007	Design Bid Build	ODOT	ODOT
19	I-5	Louse Creek US 199 (Bundle 304(08018))	13413	14043	3	1	Freeway	55.58	61.72	3/1/08 to 7/1/2010	Design Bid Build	OBDP	HW Lochner
20	I-5	S. Wolf Creek (Bundle 303-Bridge 08333)	13330	14042	3	1	Freeway	54.07	76.02	4/01/2007 to 5/22/2009	Design Bid Build	OBDP	Exeltech Consulting Services, Inc

Project Number	Route Number	Project Name	Contract No.	Key No.	Region	Oregon HWY Number	Type of Roadway	Start MP	Finish MP	Construction Time Frame	Project Delivery Method	Managing Firm	TCP Design Firm
21	I-5	Seven Oaks Interchange (Bundle A06)	13201	13541	3	1	Freeway	35.38	36.58	04/2006 to 10/2008	Design Bid Build	ODOT	DKS
22	I-5	South Medford Interchange	13227	10964	3	1	Freeway	26.73	28.33	05/26/2006 to 07/29/2010 (Comp. Time Est.)	Design Bid Build	ODOT	ODOT
23	OR-42	Lookingglass Creek - Glenhart	13209	12731	3	35	2 Lane Highway	72.32	73.21	4/2006-10/2006	Design Bid Build	ODOT	ODOT
24	OR-62	Corridor Solutions - Medford	12914	10838	3	22	2 Lane Highway	0.00	1.10	1/23/2004 to mid july 2006	Design Bid Build	ODOT	ODOT
25	OR-58	US 97 Overcrossing (Bundle 221 (07984))	13311	14258	4	18	2 Lane Highway	86.29	86.29	3/26/2007 to 11/5/2007	Design Bid Build	OBDP	Falconi Consulti ng Services
26	US-126	MP 97 – Rimrock Way	13449	14190	4	15	2 Lane Highway	97.01	111.08	06/06/2008 to 10/23/2008	Design Bid Build	ODOT	URS
27	US-97	Re-route Phase 1, Unit 2	13302	13940	4	4	Multi Lane Highway	118.85	122.15	12/1/2006 to 1/31/2009	Design Bid Build	ODOT	ODOT
28	US-97	Re-route Phase 1, Unit 3	13471	15203	4	41	Multi Lane Highway	0.25	0.44	06/01/2008 to 4/2009	Design Bid Build	ODOT	ODOT
29	I-84	Burnt R. (Dixie Cr)-Lime Interchange (Bundle 203, 01786)	13406	12547	5	6	Freeway	340.60	340.60	04/01/2008 to 01/01/2010	Design Bid Build	OBDP	HDR
30	I-84	Cabbage Hill Chain-up – Meacham	13359	15127	5	6	Freeway	226.27	237.90	04/0107 to 09/30/07	Design Bid Build	ODOT	ODOT
31	I-84 connectio n	Grande Ronde R./UPRR U'Xing Upper Perry Arch	13420	11852	5	6	Freeway	255.00	256.50	march 2008 to aug 2009	Design Bid Build	ODOT	DKS

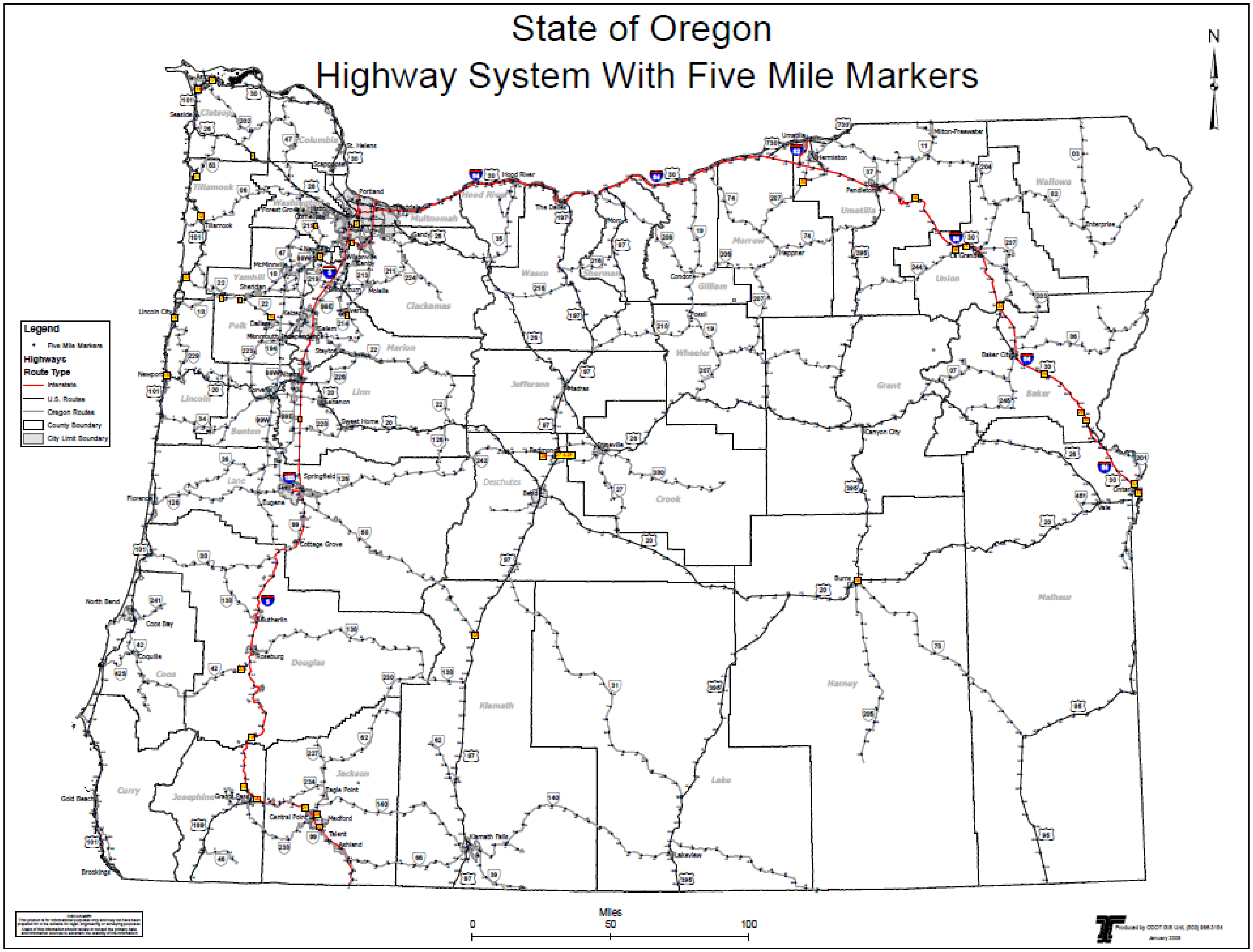
Project Number	Route Number	Project Name	Contract No.	Key No.	Region	Oregon HWY Number	Type of Roadway	Start MP	Finish MP	Construction Time Frame	Project Delivery Method	Managing Firm	TCP Design Firm
32	OR207	MP214 Mission and OR-207: MP26.5 Madison VMS	13140	14167	5	320	Freeway	26.40	26.50	7/13/05 to 3/1/06	Design Bid Build	ODOT	Std Drawing s
33	I-84	North Ontario Interchange	13320	n/a	5	6	Freeway	373.00	375.00	2/1/2006 - 10/31/08	Design Bid Build	ODOT	Kittleson and Associat es
34	I-84	Pendleton - North Powder (Bundle 205, 07292)	13396	14027	5	6	Freeway	285.80	285.80	09/01/07 to 10/31/09	Design Bid Build	OBDP	Quincy Enginee ring
35	I-84	Pleasant Valley - Durbin Creek	13410	15464	5	6	Freeway	340.55	342.91	may 2009 to nov 2010	Design Bid Build	ODOT	ODOT and DKS
36	I-84	Pleasant Valley Interchange Bridges Section	13110	10473	5	6	Freeway	317.27	318.44	june 2004 oct 2006	Design Bid Build	ODOT	ODOT
37	I-84	Stanton Blvd - Snake River (Bundle 202, 08107)	13315	14024	5	6	Freeway	371.45	378.01	3/9/07 to 11/14/08	Design Bid Build	OBDP	DKS
38	OR-244	Irrigon Jct - Hilgard Interchange (Bundle 206, 08502)	13298	14028	5	6 341	2 Lane Highway	47.01	47.03	feb 2007 to dec 2008	Design Bid Build	OBDP	KPFF
39	US-20	Riley Jct. - Warm Springs Rd/US 395 Chip seal	13465	15176	5	7	2 Lane Highway	104.56	171.14	2/1/2007- 10/31/08	Design Bid Build	ODOT	ODOT

Project Number	Route Number	Project Name	Project Size ($)	Project Scope	Project Type	Setting	TCP Complexity (Designer Rating)	TCP Drawings	TCS Pay Item	Date Awarded
1	I-205	Willamette River Bridge – Pacific Hwy. (Unit 3) Sec.	$ 32,142,892.40	Grading, drainage, structures, paving, signing, and illumination	Bridge repair	Suburban	Complex	yes - H	yes	5/9/2006
2	I-5	Marquam Bridge – Capitol Hwy. Sec.	$ 21,200,000.00	Grading, drainage, structure, paving, signal, and illumination	Freeway Modernization	Urban	Complex	yes - H	yes	n/a
3	OR-219	Hillsboro-Silverton Hwy. at Farmington Road	$ 3,694,860.07	Grading, drainage, structure, paving, signing, and roadside development	Bridge replacement and 2 land highway Modernization	Rural	Complex	yes - H	no	7/27/2006
4	US-26	Langensand Rd. – Cherryville Dr. Sec.	$ 1,374,704.93	Paving, pavement markers, and cable barriers	2 lane highway Preservation	Rural	Simple	yes - H	no	5/22/2007
5	I-5	Sodom Ditch-Calapooia (Bundle 216 (08233 and 08235))	$ 16,512,000.00	n/a	Bridge Replacement	Rural	Simple	yes - E	yes	6/7/2007
6	OR-18	Fort Hill – Wallace Bridge	$ 12,180,757.00	Grade, structures, paving, signing, illumination, roadside development	2 Lane highway Modernization	Rural	Complex	yes - E	no	2/22/2008
7	OR-18	Oregon Coast HWY – Oldsville Road (megapave)	$ 12,871,429.25	Structures and paving	2 lane highway Preservation	Rural	Moderate	yes - E	yes	4/25/2007
8	OR-213	Lone Pine Corner – Hwy. 214	$ 1,056,202.00	Grading, drainage, structure, paving, and signing	2 lane highway Preservation	Urban	Simple	yes - H	yes	3/11/2005
9	OR-219	Springbrook Road - Wynooski Road (Newberg)	$ 2,846,021.00	Grading, paving, and signal	2 lane highway Preservation	Urban	Moderate	yes - E	yes	10/24/2007
10	OR-22	Sublimity Interchange	$ 15,820,683.52	Grade, drainage, structures, paving, signing, signals, illumination	2 Lane highway Modernization	Suburban	Complex	yes - E	yes	4/16/2008
11	US-101	Jetty Creek Fish Passage	$ 2,470,162.70	Culvert replacement with a bridge	Bridge replacement	Rural	Moderate	yes -E	no	4/26/2007
12	US-101	Latimer Road	$ 1,365,238.52	Install new traffic signals, paving	2 Lane highway Modernization	Urban	Moderate	yes - E	no	3/25/2008
13	US-101	Meda Loop Road - Redburg Road	$ 568,653.00	Passing lane construction	2 Lane highway Modernization	Suburban	Simple	yes - E	no	4/1/2008

Project Number	Route Number	Project Name	Project Size ($)	Project Scope	Project Type	Setting	TCP Complexity (Designer Rating)	TCP Drawings	TCS Pay Item	Date Awarded
14	US-101	New Youngs Bay Bridge	$ 7,377,580.00	Refurbish drawbridge (paint, electrical, mechanical)	Bridge repair	Suburban	Moderate	yes - E	no	5/21/2007
15	US-101	Newport Signal Upgrades	$ 747,886.40	Signals	Intersections	Urban	Simple	yes - H	no	7/21/2006
16	US-101	Otis Junction – Boiler Bay Sec.	$ 3,010,000.00	Grading, drainage, structures, paving, and signals	2 lane highway Preservation	Rural	Moderate	yes -E	yes	4/7/2005
17	US-30	John Day River Bridge	$ 1,297,325.47	Reconstruct bridge end panels, paving	Bridge repair	Rural	Moderate	yes - E	no	n/a
18	I-5	Azalea – Glendale Reconstruction	$ 6,868,670.00	Grading, paving, and guardrail	Freeway Modernization	Rural	Moderate	yes - E	no	3/15/2007
19	I-5	Louse Creek US 199 (Bundle 304(08018))	$ 24,158,000.00	n/a	Bridge replacement	Rural	n/a	yes - E	yes	1/11/2008
20	I-5	S. Wolf Creek (Bundle 303-Bridge 08333)	$ 11,723,000.00	Bridge	Bridge repair	Rural	n/a	yes - E	yes	2/15/2007
21	I-5	Seven Oaks Interchange (Bundle A06)	$ 30,257,000.00	Bridge replacement	Bridge Replacement	Rural	n/a	yes - E	no	12/15/2005
22	I-5	South Medford Interchange	$ 59,645,369.20	Grading, paving, structures, signals, illumination, landscaping	Freeway Modernization	Urban	Complex	yes - H	yes	3/27/2006
23	OR-42	Lookingglass Creek - Glenhart	$ 1,962,293.90	Grading, paving, drainage, structures, and signing	2 Lane highway Modernization	Rural	Moderate	yes -E	yes	2/10/2006
24	OR-62	Corridor Solutions - Medford	n/a	Grading, structures, paving, signing, illumination, and signals	2 Lane highway Modernization	Urban	Complex	yes - H	no	n/a
25	OR-58	US 97 Overcrossing (Bundle 221 (07984))	$ 4,366,000.00	Bridge replacement	Bridge Replacement	Rural	Simple	yes -E	no	n/a
26	US-126	MP 97 – Rimrock Way	$ 5,780,780.00	Grading, paving, bridge retrofit	2 Lane highway Modernization	Urban	Moderate	yes - H	no	5/8/2008
27	US-97	Re-route Phase 1, Unit 2	$ 24,559,555.55	New construction, roadway, bridge, traffic signals	Multi lane highway Modernizaton	Urban	Complex	yes - H	yes	11/30/2006

Project Number	Route Number	Project Name	Project Size ($)	Project Scope	Project Type	Setting	TCP Complexity (Designer Rating)	TCP Drawing s	TCS Pay Item	Date Awarded
28	US-97	Re-route Phase 1, Unit 3	$ 1,000,000.00	Grading, underground, paving	Multi lane highway Preservation	Urban	Complex	yes - E	no	6/4/2008
29	I-84	Burnt R. (Dixie Cr)-Lime Interchange (Bundle 203, 01786)	$ 12,487,827.25	Replace 3 bridges with 4 bridges; strengthening repairs 1 bridge	Bridge repair	Rural	Complex	yes -E	yes	10/6/2007
30	I-84	Cabbage Hill Chain-up – Meacham	$ 813,317.00	Grading, paving, and illumination	Freeway Preservation	Rural	Simple	yes - H	no	4/27/2007
31	I-84 connection	Grande Ronde R./UPRR U'Xing Upper Perry Arch	$ 2,834,301.00	I-84 "WB" Lane Closure @ MP 256 for Br. access on Frtg. Rd.	Bridge repair	Rural	Moderate	yes -E	no	1/7/2008
32	OR207	MP214 Mission and OR-207: MP26.5 Madison VMS	$ 324,955.50	Variable message sign signing	Bridge (walkway/VMS)	Rural	Simple	yes - H	no	5/31/2005
33	I-84	North Ontario Interchange	n/a	Bridge repair	Bridge repair	Urban	Complex	yes -E	no	1/25/2006
34	I-84	Pendleton - North Powder (Bundle 205, 07292)	$ 5,536,750.00	Replace br. rails - 16 bridges; rail retrofit 1 br.; 1 br. repair	Bridge repair	Rural	Complex	yes -E	yes	7/31/2007
35	I-84	Pleasant Valley - Durbin Creek	$ 33,830,955.00	Concrete paving, curve corrections, ITS/VMS signs	Freeway Modernization	Rural	Complex	yes -E	no	12/17/200 8
36	I-84	Pleasant Valley Interchange Bridges Section	$ 12,466,954.75	Grading, structures, and paving	Bridge replacement	Rural	Moderate	yes - H	no	3/27/2005
37	I-84	Stanton Blvd - Snake River (Bundle 202, 08107)	$ 8,083,000.00	n/a	Bridge repair	n/a	n/a	yes -E	no	n/a
38	OR-244	Irrigon Jct - Hilgard Interchange (Bundle 206, 08502)	$ 10,470,548.61	Replace Bridge	Bridge replacement	Rural	Complex	yes -E	yes	n/a
39	US-20	Riley Jct. - Warm Springs Rd/US 395 Chip seal	$ 4,568,615.02	Grading, paving, and guardrail. Realignment of intersection.	2 lane highway Preservation	Rural	Simple	yes -E	no	4/29/2008

PROJECT MAP SHOWING LOCATIONS OF PROJECTS INVESTIGATED



APPENDIX C:
CASE STUDY EMAIL AND SURVEY QUESTIONNAIRE

EMAIL TO CASE STUDY PARTICIPANTS

The following e-mail was used to transmit the questionnaire to the survey participants and ask for their participation in the survey:

Dear TCP Designer,

OSU Construction Engineering Management is conducting a research study for ODOT titled "Work Zone Design and Operation Enhancements". The research is focused on 39 individual project case studies. One project in the study shows that you were involved as the TCP Designer:

OR-58 US 97 Overcrossing (Bundle 221 (07984))

Could you please fill out an on line survey for the project listed above? Many of the questions have multiple choice answers and the format is intended to be user friendly. Just follow the link below, choose a project from the drop down list and complete the survey:

https://secure.engr.oregonstate.edu/survey/public/survey.php?name=TCP_DesignerUpdated

After submitting the survey, you can revisit the site and complete it again for other projects if necessary. All individual responses will be kept confidential and not be used for anything unrelated to this study. Summarized data will not identify individual participants or companies. If you have any questions or concerns about the survey, please feel free to contact me. Thank you very much for your help in this project case study.

Michael Johnson
OSU Construction Engineering Management
Graduate Research Assistant

SAMPLE CASE STUDY QUESTIONNAIRE-ODOT/OBDP PROJECT MANAGER

OSU/ODOT WORK ZONE STUDY

Questions marked with a * are required.

*1. Please select the project for which you are completing this survey.

[▾]

2. What project delivery method was used on this project?

- ○ Design-Build
- ○ Design-Bid-Build

3. How many years of experience do you have in each of the following areas? Please check all areas in which you have experience and indicate number of years in the blanks that follow.

- ☐ TCP Design ______
- ☐ Roadway or Bridge Design ______
- ☐ Construction Management ______
- ☐ Testing ______
- ☐ Roadway or Bridge Construction ______
- ☐ Inspection ______
- ☐ Other ______

4. Have you taken ODOT's Traffic Control Plans Design Class?

- ○ Yes
- ○ No

5. Have you had formal Traffic Control Supervisor training?

- Yes
- No

6. What was the quality of the final TCP design included in the bid documents for this project? (1=low quality, 10=high quality)

7. How well did the final TCP design that was included in the bid documents match field conditions for this project? (1=did not match, 10=matched exactly)

8. How does the quality of the TCP design in the bid documents on this project compare to the TCP design for other projects on which you have worked? (1=lower quality, 10=higher quality)

9. Did the contractor prepare a modified TCP design for use in implementation?

- Yes
- No

10. If you answered YES to QUESTION 9, why was the TCP design included in the bid documents modified?

11. If you answered YES to QUESTION 9, what method was used to communicate your approval of the TCP design modifications made by the contractor?

- ☐ Off-site verbal approval
- ☐ On-site verbal approval
- ☐ Off-site written approval
- ☐ Plan revisions signed by EOR
- ☐ I was not consulted for TCP design modification approval
- ☐ I don't know
- ☐ TCP design was not modifed
- ☐ Other: ______

12. If you answered YES to QUESTION 9, what was the quality of the modified TCP design? (1=low quality, 10=high quality)

[▾]

13. What was the quality of the actual TCP implementation for this project? (1=low quality, 10=high quality)

[▾]

14. To what extent were field changes necessary after the TCP was initally constructed to improve safety conditions on site? (1=insignificant, 10=significant)

[▾]

15. To what extent did your firm receive calls from motorists voicing concerns about the TCP for this project? (1=insignificant, 10=significant)

[▾]

16. How does the quality of the TCP implementation on this project compare to the TCP implementation for other projects on which you have worked? (1=lower quality, 10=higher quality)

17. What was the quality of the inspection of the TCP implementation for this project? (1=low quality, 10=high quality)

18. How does the quality of the TCP inspection on this project compare to the TCP inspection for other projects on which you have worked? (1=lower quality, 10=higher quality)

19. To what extent did you have sufficient resources available to effectively implement the TCP for this project? (1=not sufficient, 10=sufficient)

20. When during the design phase was your input on the TCP first requested?

- Scoping Team
- Intial Project Team Meeting
- Design Acceptance Package
- Preliminary Plans
- Advance Plans
- Plans in Hand Review
- Specification Writing

21. To what extent were there constructability reviews on the project? (1=insignificant review, 10=significant review)

22. Was there a crash in the work zone during the construction phase of this project?

- Yes
- No

23. Please rate the level of motorist safety provided by the TCP on this project.

24. Please rate the level of worker safety provided by the TCP on this project.

25. Please describe the culture surrounding the TCP on this project.

26. Please describe the culture surrounding SAFETY on this project.

27. What were the most challenging aspects regarding the TCP design for this project?

28. Please rate the importance placed on each of the following project objectives when designing the TCP for this project. (1=not important, 10=very important)

	1	2	3	4	5	6	7	8	9	10
Constructablilty	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Construction Productivity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Motorist Safety	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Schedule	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Traffic Flow	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Quality	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Worker Safety	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

29. Are there others who worked on this project whose input could be valuable and from whom we should request a survey response? If so, please enter their name, role and email in the space provided below.

30. Thank you very much for taking time to participate in the Work Zone Design and Operational Enhancement study. If you would like to receive a copy of the survey results upon completion of the project, please check the appropriate box below. Also, if we may contact you for future information regarding this study, please check the

appropriate box below. When you are finished, PLEASE SELECT THE 'SUBMIT' BUTTON ON THE LEFT BELOW.

☐ I would like to receive a copy of the survey results

☐ You may contact me for future information regarding the Work Zone study

APPENDIX D:
TRAFFIC CONTROL PLANS MATRIX

Take Off Quantities

Project Number	Route Number	Project Name	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures	Lane Closures 2-D	Traffic entering/leaving WZ (y/n)	Stages (#)	TCS	TCP Cost	Urban Setting (urban=y, rural=n)
1	I-205	Willamette River Bridge – Pacific Hwy. (Unit 3) Sec.	0	400	18	20	0	0	y	n	n	y	n	n	1	0	1	y	4	y	$ 3,861,958.50	y
2	I-5	Marquam Bridge – Capitol Hwy. Sec.	340	186	0	20	4	0	y	n	n	y	n	n	1	1	1	y	4	y	$ 4,613,710.00	y
3	OR-219	Hillsboro-Silverton Hwy. at Farmington Road	0	112	2	17	0	0	y	n	n	n	n	y	0	0	0	y	3	n	$ 238,842.00	n
4	US-26	Langensand Rd. – Cherryville Dr. Sec.	TM700, TM705, TM710, TM715, TM717, TM750, TM770, TM775																	n	$ 138,793.00	n
5	I-5	Sodom Ditch-Calapooia (Bundle 216 (08233 and 08235))	0	300	6	10	5	0	y	n	n	y	n	n	1	0	1	n	4	y	$ 749,202.75	n
6	OR-18	Fort Hill – Wallace Bridge	486	259	7	37	0	2	y	n	n	n	n	y	0	0	0	y	3	n	$ 508,295.24	n
7	OR-18	Oregon Coast HWY – Oldsville Road (megapave)	RD900, RD905, RD910, RD911, RD915, RD935, RD945, RD950																	y	$ 683,990.00	n
8	OR-213	Lone Pine Corner – Hwy. 214	0	0	0	4	0	1	n	n	n	n	n	y	0	1	1	y	1	y	$ 173,200.50	y
9	OR-219	Springbrook Road - Wynooski Road (Newberg)	0	154	0	12	0	0	n	n	y	n	n	y	0	0	0	y	2	y	$ 289,363.00	y
10	OR-22	Sublimity Interchange	228	110	4	51	0	0	y	n	n	y	n	y	1	0	1	y	3	y	$ 826,929.00	y

Project Number	Route Number	Project Name	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures	Lane Closures 2-D	Traffic entering/leaving WZ (y/n)	Stages (#)	TCS	TCP Cost	Urban Setting (urban=y, rural=n)
11	US-101	Jetty Creek Fish Passage	20	23	14	0	0	0	y	n	y	y	n	y	1	0	1	n	2	n	$ 172,300.00	n
12	US-101	Latimer Road	24	112	0	0	0	0	y	n	n	y	n	n	0	0	0	y	3	n	$ 146,881.37	y
13	US-101	Meda Loop Road - Redburg Road	TM700, TM705, TM710, TM750, TM775																	n	$ 71,446.58	y
14	US-101	New Youngs Bay Bridge	TM700, TM705, TM710, TM745, TM750, TM775, TM780, TM100, TM105																	n	$ 301,580.00	y
15	US-101	Newport Signal Upgrades	RD900, RD905, RD907, RD908, RD911, RD950, TM100, TM105, TM207																	n	$ 112,831.00	y
16	US-101	Otis Junction – Boiler Bay Sec.	RD900, RD905, RD906, RD907, RD910, RD915, RD945, RD950, TM100, TM105, TM207, TM239																	y	$ 361,172.50	n
17	US-30	John Day River Bridge	TM700, TM705, TM710, TM735, TM750, TM775																	n	$ 174,305.04	n
18	I-5	Azalea – Glendale Reconstruction	32	20	2	8	0	0	y	n	n	y	n	y	1	0	1	n	4	n	$ 1,074,930.93	n
19	I-5	Louse Creek US 199 (Bundle 304(08018))	0	96	5	0	16	1	y	n	y	y	n	y	1	0	1	y	3	y	$ 3,540,495.01	n
20	I-5	S. Wolf Creek (Bundle 303-Bridge 08333)	0	135	2	3	2	0	y	n	y	n	n	n	1	0	1	y	5	y	$ 535,930.00	n
21	I-5	Seven Oaks Interchange (Bundle A06)	0	315	16	45	5	0	y	n	n	y	n	y	0	0	0	y	5	n	$ 1,182,997.32	n

Project Number	Route Number	Project Name	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures	Lane Closures 2-D	Traffic entering/leaving WZ (y/n)	Stages (#)	TCS	TCP Cost	Urban Setting (urban=y, rural=n)
22	I-5	South Medford Interchange	50	120	5	18	0	0	y	n	n	y	n	y	1	0	1	y	5	y	$ 4,088,238.00	y
23	OR-42	Lookingglass Creek - Glenhart	205	17	0	0	0	0	n	n	y	n	n	n	1	0	1	y	2	y	$ 315,369.00	n
24	OR-62	Corridor Solutions - Medford	123	7	4	7	0	0	y	n	n	n	n	y	1	0	1	y	4			y
25	OR-58	US 97 Overcrossing (Bundle 221 (07984))	52	129	2	0	0	0	y	n	y	y	n	n	1	0	1	y	3	n	$ 291,239.96	n
26	US-126	MP 97 – Rimrock Way	97	119	6	5	0	2	y	n	y	n	n	n	1	0	1	n	3	n	$ 236,755.51	y
27	US-97	Re-route Phase 1, Unit 2	n/a	n/a	n/a	n/a	n/a	0	n	n	n	y	n	n	1	1	1	y	3	y	$ 588,189.00	y
28	US-97	Re-route Phase 1, Unit 3	0	n/a	2	n/a	0	0	y	n	n	n	n	n	1	0	1	y	3	n	$ 130,401.70	y
29	I-84	Burnt R. (Dixie Cr)-Lime Interchange (Bundle 203, 01786)	0	200	0	5	0	0	n	n	n	n	n	y	1	0	1	n	2	y	$ 316,464.00	n
30	I-84	Cabbage Hill Chain-up – Meacham	0	40	0	6	0	2	n	n	y	n	n	n	1	0	1	y	2	n	$ 49,055.00	n
31	I-84	Grande Ronde R./UPRR U'Xing Upper Perry Arch	52	60	1	4	1	0	y	n	n	y	y	y	1	0	1	y	1	n	$ 183,428.00	n
32	I-84	MP214 Mission and OR-207: MP26.5 Madison VMS	RD900, RD910, RD920, RD950, TM100, TM105, TM607-612																	n	$ 10,723.00	n

Project Number	Route Number	Project Name	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures	Lane Closures 2-D	Traffic entering/leaving WZ (y/n)	Stages (#)	TCS	TCP Cost	Urban Setting (urban=y, rural=n)
33	I-84	North Ontario Interchange	270	50	6	12	0	0	y	n	n	y	n	y	1	1	1	y	4	-	n/a	y
34	I-84	Pendleton - North Powder (Bundle 205, 07292)	0	76	2	2	2	0	y	n	n	y	n	n	1	0	1	y	3	y	$ 116,791.50	n
35	I-84	Pleasant Valley - Durbin Creek	981	66	8	14	2	0	y	n	n	y	n	n	1	0	1	y	3	n	$ 4,093,759.00	n
36	I-84	Pleasant Valley Interchange Bridges Section	94	388	2	14	5	4	y	n	n	Y	n	n	1	0	1	y	2	n	$ 681,900.50	n
37	I-84	Stanton Blvd - Snake River (Bundle 202, 08397)	43	227	4	23	4	0	y	y	n	y	n	n	1	0	1	n	2	n	$ 1,032,371.60	
38	OR-244	Irrigon Jct - Hilgard Interchange (Bundle 206, 08502)	0	100	4	4	4	2	y	n	y	n	n	y	1	0	1	y	3	y	$ 1,177,461.00	n
39	US-20	Riley Jct. - Warm Springs Rd/US 395 Chip seal	TM700, TM710, TM750, TM775, TM780																	n	$ 262,735.96	n

Presence Factor

Project Number	Route Number	Project Name	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures 1-D	Multiple Lane Closures 2-D	Traffic entering/leaving WZ from other roadway (y/n)	Stages (#)	TCS	Cost	Setting	Duration
1	I-205	Willamette River Bridge – Pacific Hwy. (Unit 3) Sec.	1	3	3	3	1	1	3	0	0	3	0	0	3	0	3	3	3	2	3	3	3
2	I-5	Marquam Bridge – Capitol Hwy. Sec.	3	2	1	3	3	1	3	0	0	3	0	0	3	3	3	3	3	2	3	3	3
3	OR-219	Hillsboro-Silverton Hwy. at Farmington Road	1	2	2	2	1	1	3	0	0	0	0	3	1	0	1	3	2	0	2	0	2
4	US-26	Langensand Rd. – Cherryville Dr. Sec.	3	1	1	1	1	1	n/a	n/a	n/a	n/a	n/a	n/a	1	0	1	n/a	1	0	1	0	1
5	I-5	Sodom Ditch-Calapooia (Bundle 216 (08233 and 08235))	1	3	2	2	3	1	3	0	0	3	0	0	3	0	3	0	3	2	2	0	2
6	OR-18	Fort Hill – Wallace Bridge	3	3	3	3	1	3	3	0	0	0	0	3	1	0	1	3	2	0	2	0	1
7	OR-18	Oregon Coast HWY – Oldsville Road (megapave)	3	1	1	1	1	1	n/a	n/a	n/a	n/a	n/a	n/a	1	0	1	n/a	1	2	2	0	1
8	OR-213	Lone Pine Corner – Hwy. 214	1	1	1	2	1	3	0	0	0	0	0	3	1	3	3	3	1	2	3	3	1
9	OR-219	Springbrook Road - Wynooski Road (Newberg)	1	2	1	2	1	1	0	0	3	0	0	3	1	0	1	3	3	2	2	3	1
10	OR-22	Sublimity Interchange	3	2	2	3	1	1	3	0	0	3	0	3	3	0	3	3	2	2	3	3	3

Project Number	Route Number	Project Name	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures 1-D	Multiple Lane Closures 2-D	Traffic entering/leaving WZ from other roadway (y/n)	Stages (#)	TCS	Cost	Setting	Duration
11	US-101	Jetty Creek Fish Passage	2	1	3	1	1	1	3	0	3	3	0	3	3	0	3	0	3	0	1	0	2
12	US-101	Latimer Road	2	2	1	1	1	1	3	0	0	3	0	0	1	0	1	3	2	0	1	3	2
13	US-101	Meda Loop Road - Redburg Road	3	1	1	1	1	1	n/a	n/a	n/a	n/a	n/a	n/a	1	0	1	n/a	1	0	1	3	2
14	US-101	New Youngs Bay Bridge	3	1	1	1	1	1	n/a	n/a	n/a	n/a	n/a	n/a	1	0	1	n/a	1	0	2	3	2
15	US-101	Newport Signal Upgrades	3	1	1	1	1	1	n/a	n/a	n/a	n/a	n/a	n/a	1	0	1	n/a	1	0	1	3	2
16	US-101	Otis Junction – Boiler Bay Sec.	3	1	1	1	1	1	n/a	n/a	n/a	n/a	n/a	n/a	1	0	1	n/a	1	2	2	0	3
17	US-30	John Day River Bridge	3	1	1	1	1	1	n/a	n/a	n/a	n/a	n/a	n/a	1	0	1	n/a	1	0	2	0	1
18	I-5	Azalea – Glendale Reconstruction	2	1	2	2	1	1	3	0	0	3	0	3	3	0	3	0	3	0	3	0	2
19	I-5	Louse Creek US 199 (Bundle 304(08018))	1	2	2	1	3	3	3	0	3	3	0	3	3	0	3	3	2	2	3	0	1
20	I-5	S. Wolf Creek (Bundle 303-Bridge 08333)	1	2	2	1	2	1	3	0	3	0	0	0	3	0	3	3	3	2	2	0	2
21	I-5	Seven Oaks Interchange (Bundle A06)	1	3	3	3	3	1	3	0	0	3	0	3	1	0	1	3	3	0	3	0	3

Project Number	Route Number	Project Name	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures 1-D	Multiple Lane Closures 2-D	Traffic entering/leaving WZ from other roadway (y/n)	Stages (#)	TCS	Cost	Setting	Duration
22	I-5	South Medford Interchange	2	2	2	3	1	1	3	0	0	3	0	3	3	0	3	3	3	2	3	3	3
23	OR-42	Lookingglass Creek - Glenhart	3	1	1	1	1	1	0	0	3	0	0	0	3	0	3	3	3	2	2	0	2
24	OR-62	Corridor Solutions - Medford	3	1	2	2	1	1	3	0	0	0	0	3	3	0	3	3	3	n/a	1	3	1
25	OR-58	US 97 Overcrossing (Bundle 221 (07984))	2	2	2	1	1	1	3	0	3	3	0	0	3	0	3	3	2	0	2	0	2
26	US-126	MP 97 – Rimrock Way	2	2	2	2	1	3	3	0	3	0	0	0	3	0	3	0	2	0	2	3	2
27	US-97	Re-route Phase 1, Unit 2	3	3	3	3	3	1	0	0	0	3	0	0	3	3	3	3	2	2	2	3	3
28	US-97	Re-route Phase 1, Unit 3	1	3	2	3	1	1	3	0	0	0	0	0	3	0	3	3	2	0	1	3	2
29	I-84	Burnt R. (Dixie Cr)-Lime Interchange (Bundle 203, 01786)	1	3	1	2	1	1	0	0	0	0	0	3	3	0	3	0	3	2	2	0	1
30	I-84	Cabbage Hill Chain-up – Meacham	1	1	1	2	1	3	0	0	3	0	0	0	3	0	3	3	3	0	1	0	2
31	I-84	Grande Ronde R./UPRR U'Xing Upper Perry Arch	2	2	1	2	2	1	3	0	0	3	3	3	3	0	3	3	1	0	2	0	1
32	I-84	MP214 Mission and OR-207: MP26.5 Madison VMS	3	1	1	1	1	1	n/a	n/a	n/a	n/a	n/a	n/a	1	0	1	n/a	1	0	1	0	2

Project Number	Route Number	Project Name	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures 1-D	Multiple Lane Closures 2-D	Traffic entering/leaving WZ from other roadway (y/n)	Stages (#)	TCS	Cost	Setting	Duration
33	I-84	North Ontario Interchange	3	1	2	2	1	1	3	0	0	3	0	3	3	3	3	3	3	n/a	3	3	3
34	I-84	Pendleton - North Powder (Bundle 205, 07292)	1	2	2	1	2	1	3	0	0	3	0	0	3	0	3	3	2	2	1	0	2
35	I-84	Pleasant Valley - Durbin Creek	3	2	3	2	2	1	3	0	0	3	0	0	3	0	3	3	2	0	3	0	3
36	I-84	Pleasant Valley Interchange Bridges Section	2	3	2	2	3	3	3	0	0	3	0	0	3	0	3	3	3	0	2	0	3
37	I-84	Stanton Blvd - Snake River (Bundle 202, 08397)	2	3	2	3	3	1	3	3	0	3	0	0	3	0	3	0	3	0	3	0	2
38	OR-244	Irrigon Jct - Hilgard Interchange (Bundle 206, 08502)	1	2	2	2	3	3	3	0	3	0	0	3	3	0	3	3	2	2	3	0	2
39	US-20	Riley Jct. - Warm Springs Rd/US 395 Chip seal	3	1	1	1	1	1	n/a	n/a	n/a	n/a	n/a	n/a	1	0	1	n/a	1	0	2	0	2

Device Complexity Rating

Project Number	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures 1-D	Multiple Lane Closures 2-D	Traffic entering/leaving WZ from other roadway (y/n)	Stages (#)	TCS	Cost	Setting	Duration	Length
1	n/a	n/a	14.8	n/a	5.5	5.8	18.5	0.0	0.0	19.4	0.0	0.0	15.8	0.0	21.3	19.5	24.9	13.1	17.3	17.1	14.8	15.0
2	n/a	n/a	4.9	n/a	16.5	5.8	18.5	0.0	0.0	19.4	0.0	0.0	15.8	21.0	21.3	19.5	24.9	13.1	17.3	17.1	14.8	10.0
3	n/a	n/a	9.8	n/a	5.5	5.8	18.5	0.0	0.0	0.0	0.0	20.1	5.3	0.0	7.1	19.5	16.6	0.0	11.5	0.0	9.8	10.0
4	n/a	n/a	4.9	n/a	5.5	5.8	n/a	n/a	n/a	n/a	n/a	n/a	5.3	0.0	7.1	n/a	8.3	0.0	5.8	0.0	4.9	15.0
5	n/a	n/a	9.8	n/a	16.5	5.8	18.5	0.0	0.0	19.4	0.0	0.0	15.8	0.0	21.3	0.0	24.9	13.1	11.5	0.0	9.8	10.0
6	n/a	n/a	14.8	n/a	5.5	17.5	18.5	0.0	0.0	0.0	0.0	20.1	5.3	0.0	7.1	19.5	16.6	0.0	11.5	0.0	4.9	10.0
7	n/a	n/a	4.9	n/a	5.5	5.8	n/a	n/a	n/a	n/a	n/a	n/a	5.3	0.0	7.1	n/a	8.3	13.1	11.5	0.0	4.9	15.0
8	n/a	n/a	4.9	n/a	5.5	17.5	0.0	0.0	0.0	0.0	0.0	20.1	5.3	21.0	21.3	19.5	8.3	13.1	17.3	17.1	4.9	10.0
9	n/a	n/a	4.9	n/a	5.5	5.8	0.0	0.0	15.3	0.0	0.0	20.1	5.3	0.0	7.1	19.5	24.9	13.1	11.5	17.1	4.9	10.0
10	n/a	n/a	9.8	n/a	5.5	5.8	18.5	0.0	0.0	19.4	0.0	20.1	15.8	0.0	21.3	19.5	16.6	13.1	17.3	17.1	14.8	10.0

Project Number	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures 1-D	Multiple Lane Closures 2-D	Traffic entering/leaving WZ from other roadway (y/n)	Stages (#)	TCS	Cost	Setting	Duration	Length
11	n/a	n/a	14.8	n/a	5.5	5.8	18.5	0.0	15.3	19.4	0.0	20.1	15.8	0.0	21.3	0.0	24.9	0.0	5.8	0.0	9.8	5.0
12	n/a	n/a	4.9	n/a	5.5	5.8	18.5	0.0	0.0	19.4	0.0	0.0	5.3	0.0	7.1	19.5	16.6	0.0	5.8	17.1	9.8	5.0
13	n/a	n/a	4.9	n/a	5.5	5.8	n/a	n/a	n/a	n/a	n/a	n/a	5.3	0.0	7.1	n/a	8.3	0.0	5.8	17.1	9.8	10.0
14	n/a	n/a	4.9	n/a	5.5	5.8	n/a	n/a	n/a	n/a	n/a	n/a	5.3	0.0	7.1	n/a	8.3	0.0	11.5	17.1	9.8	5.0
15	n/a	n/a	4.9	n/a	5.5	5.8	n/a	n/a	n/a	n/a	n/a	n/a	5.3	0.0	7.1	n/a	8.3	0.0	5.8	17.1	9.8	10.0
16	n/a	n/a	4.9	n/a	5.5	5.8	n/a	n/a	n/a	n/a	n/a	n/a	5.3	0.0	7.1	n/a	8.3	13.1	11.5	0.0	14.8	15.0
17	n/a	n/a	4.9	n/a	5.5	5.8	n/a	n/a	n/a	n/a	n/a	n/a	5.3	0.0	7.1	n/a	8.3	0.0	11.5	0.0	4.9	10.0
18	n/a	n/a	9.8	n/a	5.5	5.8	18.5	0.0	0.0	19.4	0.0	20.1	15.8	0.0	21.3	0.0	24.9	0.0	17.3	0.0	9.8	10.0
19	n/a	n/a	9.8	n/a	16.5	17.5	18.5	0.0	15.3	19.4	0.0	20.1	15.8	0.0	21.3	19.5	16.6	13.1	17.3	0.0	4.9	15.0
20	n/a	n/a	9.8	n/a	11.0	5.8	18.5	0.0	15.3	0.0	0.0	0.0	15.8	0.0	21.3	19.5	24.9	13.1	11.5	0.0	9.8	15.0

Project Number	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures 1-D	Multiple Lane Closures 2-D	Traffic entering/leaving WZ from other roadway (y/n)	Stages (#)	TCS	Cost	Setting	Duration	Length
21	n/a	n/a	14.8	n/a	16.5	5.8	18.5	0.0	0.0	19.4	0.0	20.1	5.3	0.0	7.1	19.5	24.9	0.0	17.3	0.0	14.8	10.0
22	n/a	n/a	9.8	n/a	5.5	5.8	18.5	0.0	0.0	19.4	0.0	20.1	15.8	0.0	21.3	19.5	24.9	13.1	17.3	17.1	14.8	10.0
23	n/a	n/a	4.9	n/a	5.5	5.8	0.0	0.0	15.3	0.0	0.0	0.0	15.8	0.0	21.3	19.5	24.9	13.1	11.5	0.0	9.8	10.0
24	n/a	n/a	9.8	n/a	5.5	5.8	18.5	0.0	0.0	0.0	0.0	20.1	15.8	0.0	21.3	19.5	24.9	#######	5.8	17.1	4.9	10.0
25	n/a	n/a	9.8	n/a	5.5	5.8	18.5	0.0	15.3	19.4	0.0	0.0	15.8	0.0	21.3	19.5	16.6	0.0	11.5	0.0	9.8	5.0
26	n/a	n/a	9.8	n/a	5.5	17.5	18.5	0.0	15.3	0.0	0.0	0.0	15.8	0.0	21.3	0.0	16.6	0.0	11.5	17.1	9.8	15.0
27	n/a	n/a	14.8	n/a	16.5	5.8	0.0	0.0	0.0	19.4	0.0	0.0	15.8	21.0	21.3	19.5	16.6	13.1	11.5	17.1	14.8	10.0
28	n/a	n/a	9.8	n/a	5.5	5.8	18.5	0.0	0.0	0.0	0.0	0.0	15.8	0.0	21.3	19.5	16.6	0.0	5.8	17.1	9.8	5.0
29	n/a	n/a	4.9	n/a	5.5	5.8	0.0	0.0	0.0	0.0	0.0	20.1	15.8	0.0	21.3	0.0	24.9	13.1	11.5	0.0	4.9	5.0
30	n/a	n/a	4.9	n/a	5.5	17.5	0.0	0.0	15.3	0.0	0.0	0.0	15.8	0.0	21.3	19.5	24.9	0.0	5.8	0.0	9.8	15.0

Project Number	Tubular Markers (#)	Plastic Drums (#)	Impact Attenuators (#)	Barricades (#)	Sequential Arrow Signs (#)	PCMS (#)	Concrete Barriers (y/n)	Pilot Car (y/n)	Flaggers (y/n)	Temporary Striping (y/n)	Dense Temporary Signage (y/n)	Road Closure (y/n)	Single Lane Closures	Multiple Lane Closures 1-D	Multiple Lane Closures 2-D	Traffic entering/leaving WZ from other roadway (y/n)	Stages (#)	TCS	Cost	Setting	Duration	Length
31	n/a	n/a	4.9	n/a	11.0	5.8	18.5	0.0	0.0	19.4	20.5	20.1	15.8	0.0	21.3	19.5	8.3	0.0	11.5	0.0	4.9	10.0
32	n/a	n/a	4.9	n/a	5.5	5.8	n/a	n/a	n/a	n/a	n/a	n/a	5.3	0.0	7.1	n/a	8.3	0.0	5.8	0.0	9.8	5.0
33	n/a	n/a	9.8	n/a	5.5	5.8	18.5	0.0	0.0	19.4	0.0	20.1	15.8	21.0	21.3	19.5	24.9	n/a	17.3	17.1	14.8	5.0
34	n/a	n/a	9.8	n/a	11.0	5.8	18.5	0.0	0.0	19.4	0.0	0.0	15.8	0.0	21.3	19.5	16.6	13.1	5.8	0.0	9.8	5.0
35	n/a	n/a	14.8	n/a	11.0	5.8	18.5	0.0	0.0	19.4	0.0	0.0	15.8	0.0	21.3	19.5	16.6	0.0	17.3	0.0	14.8	10.0
36	n/a	n/a	9.8	n/a	16.5	17.5	18.5	0.0	0.0	19.4	0.0	0.0	15.8	0.0	21.3	19.5	24.9	0.0	11.5	0.0	14.8	10.0
37	n/a	n/a	9.8	n/a	16.5	5.8	18.5	19.0	0.0	19.4	0.0	0.0	15.8	0.0	21.3	0.0	24.9	0.0	17.3	0.0	9.8	15.0
38	n/a	n/a	9.8	n/a	16.5	17.5	18.5	0.0	15.3	0.0	0.0	20.1	15.8	0.0	21.3	19.5	16.6	13.1	17.3	0.0	9.8	5.0
39	n/a	n/a	4.9	n/a	5.5	5.8	n/a	n/a	n/a	n/a	n/a	n/a	5.3	0.0	7.1	n/a	8.3	0.0	11.5	0.0	9.8	15.0

APPENDIX E:
SAMPLE CRASH DATA

OREGON DEPARTMENT OF TRANSPORTATION - TRANSPORTATION DEVELOPMENT DIVISION
TRANSPORTATION DATA SECTION - CRASH ANALYSIS AND REPORTING UNIT
CRASH SUMMARIES BY YEAR BY COLLISION TYPE
Highway 035 MP 71.82 to 73.71, Both Add and Non-Add mileage 03/17/2006 to 10/16/2006

COLLISION TYPE	FATAL CRASHES	NON-FATAL CRASHES	PROP. DAMAGE ONLY	TOTAL CRASHES	PEOPLE KILLED	PEOPLE INJURED	TRUCKS	DRY SURF	WET SURF	DAY	DARK	INTER-SECTION	INTER-SECTION RELATED	OFF-ROAD
FIXED / OTHER OBJECT	0	0	1	1	0	0	0	1	0	1	0	0	0	1
REAR-END	0	1	0	1	0	3	0	1	0	1	0	1	0	0
TURNING MOVEMENTS	0	2	2	4	0	2	0	4	0	3	1	2	0	0
YEAR 2006 TOTAL	0	3	3	6	0	5	0	6	0	5	1	3	0	1
FINAL TOTAL	0	3	3	6	0	5	0	6	0	5	1	3	0	1

The infomation contained in this report is compiled from individual driver and police crash reports submitted to the Oregon Department of Transportation as required in ORS 811.720. The Crash Analysis and Reporting Unit is committed to providing the highest quality crash data to customers. However, because submittal of crash report foms is the responsibility of the individual driver, the Crash Analysis and Reporting Unit can not guarantee that all qualifying crashes are represented nor can assurances be made that all details pertaining to a single crash are accurate.

SAMPLE COMPREHENSIVE CRASH DATA REPORT (OTMS)

09/29/2009

OREGON DEPARTMENT OF TRANSPORTATION - TRANSPORTATION DEVELOPMENT DIVISION
TRANSPORTATION DATA SECTION - CRASH ANALYSIS AND REPORTING UNIT
CONTINOUS SYSTEM CRASH LISTING
Highway 035 MP 71.82 to 73.71, Both Add and Non-Add mileage 03/17/2006 to 11/15/2006
1 - 7 of 7 rows shown.

SER# INVEST	SPEED	ALC	DRUGS	SCHL	WORK	DATE DAY TIME	COUNTY CITY URBAN AREA	RD# FC COMPNT MLG TYP MILEPNT	CONN# FIRST STREET SECOND STREET	RD CHAR DIRECT LOCTN	INT-TYP (MEDIAN) LEGS (#LANES)	INT-REL TRAF- CONTL	OFFRD RNDBT DRVWY	WTHR SURF LIGHT	CRASH COLL SVRTY	V#	SPCL USE TRLR QTY OWNER TYPE	MOVE FROM TO	P#	PRTC TYPE	INJ SVRTY	AGE	SEX	LICNS RES	PED LOC	ERROR	ACT	EVENT	CAUSE
01007 CITY	N	N	N			08/31/2006 TH 6P	Douglas Winston	1 02 MN 0 73.37	COOS BAY-ROSEBURG H SOUTH MAIN ST	INTER NE 06	3-LEG () 0 ()	N TRF SIGNAL	N N N	CLR DRY DAY	S-1STOP REAR INJ	01	NONE PRVTE PSNGR CAR	STRGHT NE-SW	01	DRVR	INJB	50	F	OR-Y OR<25		043	000 000	013	07 00 07
																02	NONE PRVTE PSNGR CAR	STOP NE-SW	01	DRVR	INJC	25	M	OR-Y OR<25		000	011 000	013	00 00
																03	NONE PRVTE PSNGR CAR	STOP NE-SW	01	DRVR	NONE	28	F	OR-Y OR<25		000	011 000		00 00
																			02	PSNG	NO<5	04	M			000			
																			03	PSNG	NO<5	01	M			000			
																			04	PSNG	INJB	08	F			000			
01306 NO RPT	N	N	N			10/10/2006 TU 5A	Douglas Winston	1 02 MN 0 73.37	COOS BAY-ROSEBURG H MAIN ST	INTER CN 03	3-LEG () 0 ()	N TRF SIGNAL	N N N	CLR DRY DARK	ANGL-OTH TURN PDO	01	NONE 0 PRVTE PSNGR CAR	TURN-L W -NE	01	DRVR	NONE	25	F	OR-Y OR>25		020	000 000		04 00 04
																02	NONE 0 PRVTE PSNGR CAR	STRGHT NE-SW	01	DRVR	NONE	45	M	OR-Y OR<25		000	000 000		00 00
01339 NO RPT	N	N	N			10/17/2006 TU 10A	Douglas Winston	1 02 MN 0 73.37	COOS BAY-ROSEBURG H SOUTH MAIN ST	INTER CN 03	3-LEG () 0 ()	N TRF SIGNAL	N N N	CLR DRY DAY	ANGL-OTH TURN INJ	01	NONE 0 PRVTE PSNGR CAR	STRGHT NE-SW	01	DRVR	NONE	66	F	OR-Y OR<25		020	000 000		04 00 04
																			02	PSNG	INJC	38	F			000			
																02	NONE 1 PRVTE SEMI TOW	TURN-L W -NE	01	DRVR	NONE	62	M	OTH-Y N-RES		000	000 000		00 00
																03	NONE 0 PRVTE PSNGR CAR	TURN-L W -NE	01	DRVR	NONE	55	F	OR-Y OR<25		000	022 000		00 00
01066 CITY	N	N	N			08/13/2006 SU 9A	Douglas Winston	1 02 MN 0 73.46	COOS BAY-ROSEBURG H BAKER ST	ALLEY SW 03	(NONE)	N UNKNOWN	N N N	CLR DRY DAY	ANGL-OTH TURN PDO	01	NONE 0 PRVTE PSNGR CAR	STRGHT SW-NE	01	DRVR	NONE	20	M	OR-Y OR<25		000	000 000		02 00 00

								(4)																	
													02	NONE 0 PRVTE PSNGR CAR	TURN-L W -NE	01	DRVR	NONE	33	M	OR-Y OR<25	028	018 000		00 02
00794 CITY	N N N	06/29/2006 TH 4P	Douglas Winston	1 MN 0	02 73.46	COOS BAY-ROSEBURG H BAKER ST	ALLEY SW 04	(RSDMD) (4)	N NONE	N N N	CLR DRY DAY	ANGL-OTH TURN INJ	01	NONE PRVTE PSNGR CAR	TURN-L NW-NE	01	DRVR	INJB	20	F	OR-Y OR<25	028	018 000	040,010 040,010	02 00 02
													02	NONE PRVTE PSNGR CAR	STRGHT SW-NE	01	DRVR	NONE	31	M	OR-Y OR<25	000	000 000		00 00
00903 CITY	N N N	07/28/2006 FR 5P	Douglas Winston	1 MN 0	02 73.53	COOS BAY-ROSEBURG H JORGEN ST	ALLEY N 08	(NONE) (4)	N UNKNOWN	Y N N	CLR DRY DAY	FIX OBJ FIX PDO	01	NONE PRVTE PSNGR CAR	STRGHT N -S	01	DRVR	NONE	77	F	OR-Y OR<25	081,052	088 025	040,088,079 040,079,088	16,32 00 16,32
													02	NONE PRVTE PSNGR CAR	PRKD-P E -W								008		00
													03	NONE PRVTE PSNGR CAR	PRKD-P E -W								008		00
01183 NO RPT	N N N	09/08/2006 FR 5P	Douglas Winston	1 MN 0	02 73.58	COOS BAY-ROSEBURG H SHERRY ST	INTER CN 03	3-LEG () 0 ()	N UNKNOWN	N N N	CLR DRY DAY	ANGL-OTH TURN INJ	01	NONE 0 PRVTE PSNGR CAR	STRGHT NE-SW	01	DRVR	INJC	59	M	OR-Y OR>25	000	000 000		02 00 00
													02	NONE 0 PRVTE PSNGR CAR	TURN-R W -SW	01	DRVR	NONE	18	M	OR-Y OR<25	028	000 000		00 02

First

The information contained in this report is compiled from individual driver and police crash reports submitted to the Oregon Department of Transportation as required in ORS 811.720. The Crash Analysis and Reporting Unit is committed to providing the highest quality crash data to customers. However, because submittal of crash report forms is the responsibility of the individual driver, the Crash Analysis and Reporting Unit can not guarantee that all qualifying crashes are represented nor can assurances be made that all details pertaining to a single crash are accurate.

SAMPLE CRASH DATA SUMMARY (TRIP CHECK)

Oregon
Theodore R. Kulongoski, Governor

Department of Transportation
Office of Maintenance and Operations
Intelligent Transportation Systems
800 Airport Road SE
Salem, Oregon 97301-4798
Telephone (503) 986-6568
Fax (503) 986-3055
Email TripCheck.Support@ODOT.state.or.us

#Name?

To whom it may concern:

As per your request, the following information is the record of Highway Incidents as entered into the system on route US26 from mile point 24.6 to mile point 32.97 on dates from 6/15/2007 to 10/04/2007.

We hope this information is helpful. Let us know if you have any other questions that I or any of the TripCheck staff may be able to assist you with.

Thank you, Kelle Forbes ITS Operations Coordinator

Archived Incident Report

Incident Number	Create Date/Time	Last Update Date/Time	End Date/Time	Route	Start Mile Point	End Mile Point	Category Description	Severity	Lanes Affected
43919	4/16/2007 8:44:30 AM	7/11/2007 2:50:13 PM	7/11/2007 2:50:12 PM	US26	15	39	Herbicide Application	Informational only	S/S
	TEXT DESCRIPTION Spot applications of Aqua Master will be applied.								
45133	5/15/2007 7:03:56 AM	7/11/2007 2:50:15 PM	7/11/2007 2:50:12 PM	US26	25	31	Herbicide Application	Informational only	SM/
	TEXT DESCRIPTION								
45286	5/17/2007 8:51:32 AM	7/11/2007 2:50:15 PM	7/11/2007 2:50:12 PM	US26	38	25	Herbicide Application	Informational only	S/
	TEXT DESCRIPTION								

Report Produced Monday, February 09, 2009 Page 1 of 20

Archived Incident Report

Incident Number	Create Date/Time	Last Update Date/Time	End Date/Time	Route	Start Mile Point	End Mile Point	Category Description	Severity	Lanes Affected
46874	6/26/2007 9:19:13 AM	6/26/2007 3:22:57 PM		US26	31.41	32.68	Construction Work	Informational only	BA/
	TEXT DESCRIPTION Roadwork has the left lane closed from Baty Rd to Sylvan Drive. Work to be completed by 3 pm.								
46874	6/26/2007 9:19:13 AM	6/26/2007 4:21:22 PM	6/26/2007 4:21:00 PM	US26	31.41	32.68	Construction Work	Informational only	BA/
	TEXT DESCRIPTION Roadwork has the left lane closed from Baty Rd to Sylvan Drive. Work to be completed by 3 pm.								
47053	7/1/2007 5:15:56 PM	7/1/2007 5:15:56 PM		US26	26	26	Crash/Hazard	Estimated delay of 20 minutes - 2 hours	SEDCBAM/
	TEXT DESCRIPTION Crash has the wb lanes closed. Traffic is being flagged thru the eb lanes. Expect delays in this area.								
47053	7/1/2007 5:15:56 PM	7/1/2007 5:38:41 PM		US26	26	26	Crash/Hazard	Closure	SEDCBAM/MABCDES
	TEXT DESCRIPTION Crash has all lanes closed with an estimated time to reopen at 6 p m. Expect delays in this area.								
47053	7/1/2007 5:15:56 PM	7/1/2007 5:53:37 PM		US26	26	26	Crash/Hazard	Closure	SEDCBAM/MABCDES
	TEXT DESCRIPTION Crash has cleared but a large backup remains. Expect delays in this area.								
47053	7/1/2007 5:15:56 PM	7/1/2007 6:18:34 PM	7/1/2007 6:18:00 PM	US26	26	26	Crash/Hazard	Closure	SEDCBAM/MABCDES
	TEXT DESCRIPTION Crash has cleared but a large backup remains. Expect delays in this area.								

APPENDIX F:
SAMPLE TRAFFIC CONTROL SUPERVISOR REPORTS

TP & DT DAILY REPORT

PROJECT NAME (SECTION)	DATE 7-7-08	CONTRACT NO.
TECHNICIAN	DAY ☐ S ☐ M ☐ T ☐ W ☐ T ☐ F ☐ S	TEMPERATURE HIGH 80 LOW 75	TCS
WEATHER ☒ CLEAR ☐ PT. CLOUDY ☐ CLOUDY ☐ RAIN ☐ SNOW	WIND CONDITIONS ☒ CALM ☐ LIGHT ☐ STRONG	ARRIVAL TIME 6:15 / DEPARTURE TIME 5:15

TODAY'S OPERATIONS

Shoulder Rock
Sidewalks

TRAFFIC CONTROL PLAN USED

One Lane Closure

NUMBER TM 705	LOCATION @
NUMBER TM 705	LOCATION @ 9th to 2nd
NUMBER	LOCATION

	NUMBER USED	ALL CORRECT	MISSING/DAMAGED
PILOT VEHICLE			
FLAGGERS	3		
CONSTRUCTION SIGNING	19 Hard Posted + 18 roll-ups		
BARRICADES	28		
DRUMS	90		
VERTICAL PANELS			
TUBULAR TRAFFIC MARKERS			
ARROW BOARD			
VARIABLE MESSAGE BOARD	4		
MESSAGE	(2) R.W.A., 2	[illegible] to 2nd	closed,
TEMPORARY CONCRETE BARRIER			
OTHER		June 18 to July 18	

LOCATION (STATION #) OF MISSING OR DAMAGED DEVICES

MAINTENANCE CORRECTIONS OR REPLACEMENT

DATE LAST CLEANED	LIGHTS NUMBER	ALL CORRECT ☐ YES ☐ NO	MISSING OR DAMAGED

LOCATION (STATION #) OF MISSING OR DAMAGED

MAINTENANCE CORRECTIONS OR REPLACEMENT

SIGNATURE OF TCS [signature]

DATE

734-2474(8-00)

SUBMIT ORIGINAL TO PROJECT MANAGER

PCA