

Research Report  
KTC -13-15/FRT190-11-1F

# **Tools for Applying Constructability Concepts to Project Development (Design)**

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Research Report  
KTC-13-15/FRT 190-11-1F

**TOOLS FOR APPLYING CONSTRUCTABILITY CONCEPTS TO PROJECT DEVELOPMENT  
(DESIGN)**

**Final Report**

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<b>16. Abstract</b>  The purpose of this report is to document the activities of Phases I and II of the research effort and present the findings of the work accomplished. Phase I developed the Constructability Review Database for the Kentucky Transportation Cabinet and Phase II conducted a benefit analysis of the constructability review process. The database provides the basis for entry and collection of constructability reviews and allows for the identification of trends leading to potential improvements of the process. The database can be used to summarize activities, generate reports for a project, and be capable of quantifying the benefits from the process. The analysis documents the benefits of the reviews and recommends continuation and expansion to all projects.			
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## EXECUTIVE SUMMARY

Significant benefits (e.g., cost savings, shortened schedules, and improved quality) are realized when construction expertise is integrated early and throughout the design phases of a project. For many years, the Kentucky Transportation Cabinet (KYTC) has attempted to consistently review design documents for constructability issues before they reach the construction stage. This has been accomplished mainly through independent constructability reviews and value engineering studies. The current process is more of an ad hoc approach that lacks a systematic means for collecting the required data and identifying potential benefits.

The study presented here developed tools with the capability to summarize activities and quantify the benefits from the process, and utilized a set of case studies to quantify the benefits (such as cost, time, schedule, magnitude, or others) materialized from these reviews.

The literature review indicated there are benefits from the constructability reviews and their timing is critical. A review of other state Departments of Transportation (DOT) was undertaken to identify commonly used comment categories. A list of categories was developed based on other DOT practices and the literature review. This list was utilized to develop a database in which existing reviews were entered to be analyzed for trends and tendencies. This provided a very basic and immediately needed tool for organizing and streamlining constructability reviews for KYTC.

The data entered in the constructability review database was analyzed for trends and issues aiming to develop recommendations for conducting these reviews. The analysis showed in general that Pavement, Maintenance of Traffic and Guardrail are the most frequent categories observed. These were characterized either as Errors or Omissions, where Errors indicated wrong quantities while Omissions noted absence of the item needed for construction. Plan Note Clarity was another type of comment that was frequently noted. The data did not reveal any particular trend regarding which of these three types is predominant and all seem to have an equal presence in the existing database.

The reviews are currently conducted by four reviewers and there were differences in the comment types that each reviewer identified. The data also indicated that each reviewer is likely to review areas within their expertise. Ideally, a reviewer should be familiar with all areas of expertise required for a particular review and be capable of conducting such a review. Given the reality as presented herein, reviewers can be influenced by their unique area of expertise. It is recommended that reviews be conducted either by reviewers competent in all areas of design or by a team to help achieve a comprehensive and well balanced review. The team reviews would not necessarily have to be conducted in person; they could be completed electronically.

The data for comment severity indicates that errors and omissions could result in significant cost issues and possible time delays. The same three categories identified above are also present as having a high severity for several comments, indicating their significant impact on project cost and time.

The review of the data in each district indicated that there are disproportionate numbers of reviews. This could not be further evaluated, since the total number of projects that should be considered for a review for each district is not known. Trends have been identified by district with respect to the comment type. An effort should be undertaken to examine these in more detail to determine whether they are random.

The case study analysis indicated that there is a benefit from the constructability reviews and that these benefits can be frequently quantified. The benefits accrued could be of low monetary amount (most comments resulted in less than \$2,000 benefit) but there are other intangible benefits such as project delays and scope changes that could not be estimated from the available data. The qualitative analysis of the comments showed that there were few comments with a high severity but those are comments that result in high benefits.

The statistical analysis performed attempted to develop prediction models for the benefits accrued based on the various attributes of the comments. The low number of case studies and comments reviewed did not allow for a meaningful and robust statistical analysis. However, there are indications that this could be feasible if additional case studies and more comments are included in a future analysis. This would not only allow for the development of the models based on comment type, category, severity and qualitative level, but would also permit the use of other variables, such as project type and cost that were not utilized here. The inclusion of these additional variables will also permit for a possible prioritization of constructability reviews among projects aiming to address first those projects that could have the greater benefit potential.

The findings of the study allowed for the development of a set of recommendations that could improve the current practices and allow for a more efficient constructability review process. The recommendations include the following:

- Constructability Review in Preliminary Design Phase: It is highly recommended that the reviewers should have the opportunity to review the plans early in the design phase, since this will allow for a better usage of the constructability knowledge of the reviewers.
- Constructability Review Teams: The use of a team of experts to review plans will continue to improve the constructability of the project. The team effort can address all areas and it will not necessitate that a person be familiar with all required areas of expertise. The recommendation for Central Office is to set up the team through the Quality Assurance Branch of KYTC.
- Training Workshops: Training workshops for districts that have a large number of comments for any category should be conducted to address constructability issues and help eliminate constructability concerns.
- Constructability Database Availability: The database should be available for all persons involved in project development, which include KYTC Districts and Central Office personnel and consultants.
- Constructability Reviews: It is highly recommended to continue and expand the reviews to as many projects as possible.



## INTRODUCTION

Roadway projects are developed through a phased team process that ensures delivery of the most appropriate solutions. Significant benefits (e.g., cost savings, shortened schedules, and improved quality) are realized when construction expertise is integrated early and throughout the design phases of a project. Studies have shown that the lack of integration between construction and design is the root cause for many of the cost, schedule, and quality issues faced in the construction industry (Gambatese et al. 2007).

For many years, the Kentucky Transportation Cabinet (KYTC) has attempted to consistently review design documents for constructability issues before they reach the construction stage. This has been accomplished through a variety of methods, including independent constructability reviews and value engineering studies. The integration of the construction perspective within the design phase of projects is improving statewide. The existing Constructability Review practices involve a group of four reviewers conducting individual Constructability Reviews. However, the current process is more of an ad hoc approach that lacks a systematic means for collecting the required data and identifying potential benefits. The Quality Assurance Branch at KYTC is placing significant effort into improving their Post Construction Review Process, Value Engineering Program and the Lessons Learned Database ("Quality Assurance" 2012). The Constructability Program is building a systematic method for cataloging the results of the process, analyzing their findings with rating and cost associations, and yielding direct tools for design engineers to use on future projects.

The study described is divided into two phases and the results from both phases are presented in this report. Phase I resulted in developing tools with the capability of summarizing activities and quantifying the benefits from the process. Phase II utilized a set of case studies to quantify the benefits (such as cost, time, schedule, magnitude, or others) materialized from these reviews or for tracking their success throughout the lifecycle of a project.

With the increasing need for road improvements and the diminishing availability of funds, it is important to critically examine the project development process. A variety of efforts and processes have been initiated by several states aiming to reduce projects costs. Some target specific phases of the project while others apply a more generic approach. For example, Value Engineering is typically applied in early design phases utilizing functional analysis to identify alternative designs that could reduce costs and increase value for a project. Similarly, Post Construction Reviews are conducted once the project is complete and attempt to consolidate the information gained from the project, providing helpful information on avoiding costly mistakes in the future. The Practical Solutions approach that Kentucky implemented attempts to maximize the rate of return for a project by identifying a solution that targets the project needs (Stamatiadis and Hartman 2011).

The purpose of constructability reviews is to evaluate design options and identify areas where benefits can materialize. The practice of addressing potential project oversights and minimizing problems during construction has been in place by several states' Departments of Transportation (DOTs) (Anderson and Fisher 1997). This practice allows for a systematic review of projects during various phases in their development aiming at minimizing future disputes and scope changes with construction issues. The process usually relies on the expertise of construction engineers and integrated knowledge of techniques, advancements, and experience while trying to avoid future project oversights. Efforts to produce a systematic Constructability Review process have been discussed in NCHRP Report 390 (Anderson and Fisher 1997) where preliminary benefits for the process were also identified.

A recent effort also demonstrated that the benefit/cost ratio of Constructability Reviews is greater than two (Dunston et al. 2002). The report noted that effective Constructability Reviews would not only decrease costs but could easily affect the project duration and improve the quality of the constructed facility. Despite the possible benefits of such reviews, NCHRP Report 390 found that only 23 percent of state DOTs use a formal Constructability Review process (Anderson and Fisher 1997). While it is likely that more state DOTs now utilize a form of Constructability Review process, the survey noted that the implementation of a formal process is typically limited due to designers' lack of construction experience, inadequate communication between construction and design personnel, and the absence of a record of past construction changes.

A final issue with these reviews is their timing in the project development process. Projects moving through the various development phases become less capable of changing as they approach the construction phase. It is important to conduct such reviews in the early stages of design in order to maximize flexibility in plans and avoid potential redesigns. It is apparent that a review prior to construction may identify possible oversights, but at the same time any changes at that point will require additional costs and time for the project to be completed. It is therefore imperative to properly time these reviews to allow for a sufficient amount of time to address the issues during the early stages of a project.

Another aspect of a systematic cataloguing of the reviews is the development of a lessons learned database that can identify common areas of potential problems and provide an opportunity for addressing them in a timely manner. Moreover, such a database could be used as a training tool for personnel involved in the various phases of the project development process, thus providing the required understanding of the critical areas where checks are essential.

The issues noted here indicate that there is a need to perform a systematic Constructability Review and identify the benefits from such practices. This is an area that this study will address by providing the required tools and quantifying the benefits from constructability reviews.

This study builds on preliminary research by KYTC personnel (Hancher et al. 2003). To develop the required tools and to quantify the benefits of Constructability Reviews, a two-phased approach was developed. The first phase involved a review of literature; cataloguing and organizing past reviews using Microsoft Access and GIS database; and identification of trends to improve practices. The second phase reviewed a set of case studies to quantify the Constructability Reviews conducted and establish possible benefits to KYTC. Specifically, the work completed through the following tasks:

- Task 1: Review of literature and research work relevant to identification of practices in conducting Constructability Reviews; identification of potential categories to be used in the database.
- Task 2: Cataloguing of past reviews using the categories defined in Task 1 and development of the GIS database.
- Task 3: Analysis of database and identification of trends aiming to improve the quality and systematic approach of the Constructability Reviews.
- Task 4: Development of an interim report summarizing the findings of Phase I.
- Task 5: Acquisition of the appropriate case study data and preliminary analysis of the data to estimate metrics and benefits for Constructability Reviews.
- Task 6: Identification of metrics to be used for estimating the benefits from Constructability Reviews.

- Task 7: Assignment of values that correlate with the case studies and the metrics for evaluating the estimated benefits from each Constructability Review.
- Task 8: Preparation of final report.

This report presents the findings of both phases of the work. A literature review is presented first that identified current national trends and developed a potential set of categories. Next, a database was developed and a formal tool for entering constructability reviews was developed. A data analysis was conducted to determine trends and issues of the reviews conducted in the past and to identify areas of improvement. A set of cases was analyzed to determine the potential benefits to KYTC and a set of guidelines for reviews was developed.

## LITERATURE REVIEW

A comprehensive literature review was conducted to investigate the current practices and existing research regarding lessons learned databases for constructability issues. Often, lessons learned from past construction and maintenance of roadway facilities were not properly documented, and therefore not effectively used for the development of future projects. One of the most important features of a database is organization. If Constructability Reviews can be properly categorized, efficient and accurate queries are possible.

In *Constructability Knowledge-Intensive Database System*, Kartam et al. (1999) discuss a new idea for databases related to construction issues. Figure 1 shows the feedback channels for lessons learned on the life cycle of a project.

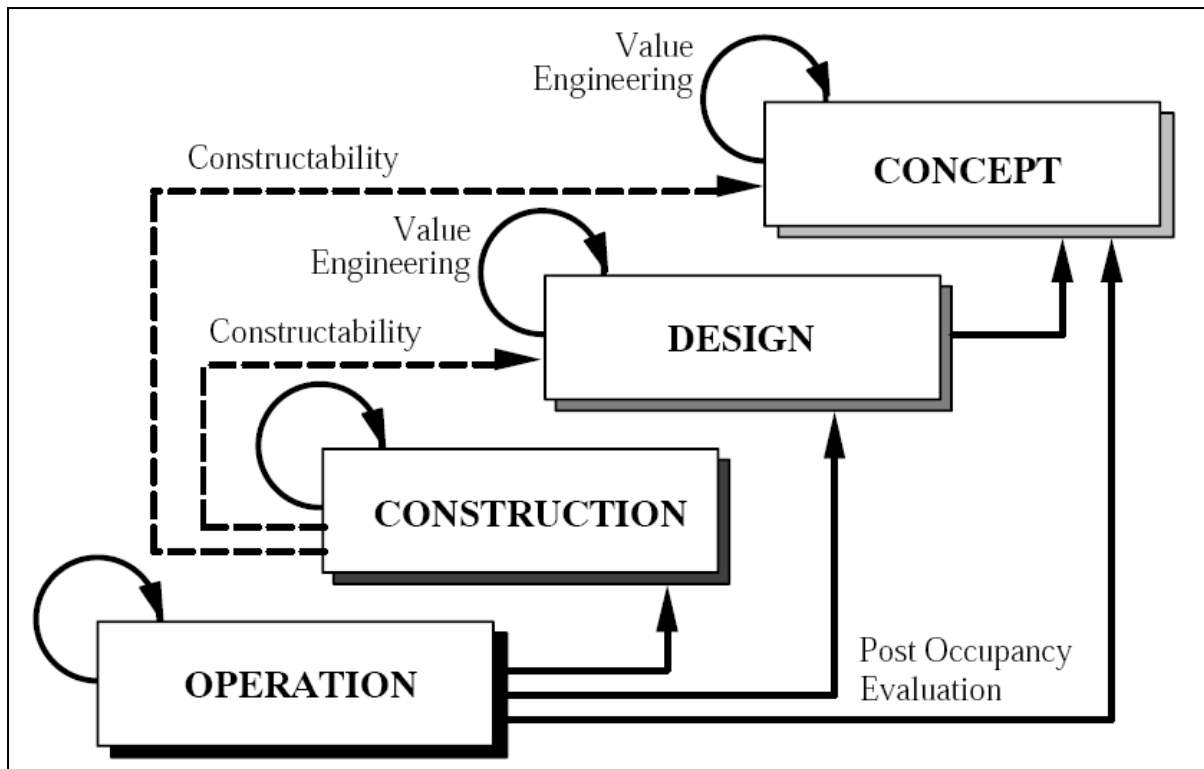


Figure 1 - Feedback Channels in the Project Life Cycle (Kartam et al. 1999)

Modeling the constructability knowledge is the next obstacle (Kartam et al. 1999). Each lesson learned needs a title, a description of the problem or situation, a description of the solution or method, additional comments and a sketch or reference to other documented information. Next, the information regarding the source of the lesson learned is necessary. Finally, the last component needed for a lesson learned is a classification system. The classification system will allow the user to quickly review selected and relevant lessons from the knowledge database. If categories are too broad, it will be easy to classify the lessons, but it will not be as user friendly. If the categories become too specific, they may become overwhelming to the user.

## **Terminology**

There are several terms used throughout the research that may seem similar but have very different meanings. The terms comment and category are not used interchangeably. Comments are a series of words or sentences describing one type of concern on a set of project plans. Comments on a set of plans may also label an issue or concern. The comments are describing ways to increase the constructability of project plans. The term “category” describes a certain group of terms used to help distinguish one comment from another comment. Therefore, similar types of comments are assigned to the same category. The use of categories is to assist in the querying of the database for later analysis. For example, the category of drainage can be queried and all drainage comments can be produced.

## **State Efforts**

A research of state agencies was undertaken with the goal of identifying categories that are consistently being used throughout the nation in the Constructability Reviews. Several State Transportation Agencies (STA) across the nation perform Constructability Reviews and use constructability checklists. The American Association of State Highway and Transportation Officials (AASHTO) published a report entitled Constructability Review Best Practices (2000). Within this report, AASHTO identifies states with Constructability Review Programs. A systematic review of the current practices for each state identified in the report was conducted as part of this literature review.

The state agencies that were reviewed for their current report format include:

- California Department of Transportation (CALTRANS)
- Connecticut Department of Transportation (CTDOT)
- Florida Department of Transportation (FDOT)
- Indiana Department of Transportation (INDOT)
- New Jersey Department of Transportation (NJDOT)
- New York Department of Transportation (NYSDOT)
- Pennsylvania Department of Transportation (PENNDOT)
- Washington State Department of Transportation (WSDOT)

Some checklists are comprised in a question format, where a “Yes” or “No” answer was necessary to complete the form. Other checklists were simply statements that were intended to stimulate the reviewer’s thinking process. Once the different types of checklists were established, a collaborated list was formed that encapsulated the individual categories and topics that varied throughout each STA (Table 1).

The Kentucky Transportation Center (KTC) has conducted reports in the past relevant to Constructability and Lessons Learned Databases (Hancher et al. 2003, Goodrum and Taylor 2009). Categories were established as a result of these research reports. Since the categories originated as a direct result from issues associated with KYTC, these categories were also used to establish the proposed list of frequent categories.

In the Division of Highway Design, the Quality Assurance Branch contains both the Constructability Review Program, as well as the Post Construction Review Program. Post Construction Review solicits input from various stakeholders following project completion to be used on future projects (KYTC 2012). The input from the stakeholders is then documented in a Lessons Learned GIS database, which utilizes a list of Categories and Sub-Topics. The main category headings will be mimicked for the Constructability Review categories.

Categories from the State Transportation Agencies listed above, along with KTC and KYTC, were consolidated into one list shown below. This list was then used to identify the most frequently used categories throughout all constructability programs.

- **Claims Prevention** – Issues to prevent claims on the project and increased costs due to litigation.
- **Construction** – Issues pertaining to the construction process and ways to improve constructability.
- **Cost Estimating** – Verifies that the cost estimations are accurate.
- **Design** – Issues concerning geometric features and roadway alignments are addressed.
- **District Office Engineer** – Reviews the project plans.
- **Drainage** – Issues pertaining to both temporary and permanent drainage are addressed.
- **Earthwork** – Issues pertaining to clearing (removing trees), grubbing (removing roots) and excavation (moving of cut and fill materials) are addressed.
- **Environmental** – Aspects of a project that affect the environment, such as disturbing endangered species.
- **General** – Addresses constructability issues that pertain to all aspects of the project.
- **Geotechnical** – Issues pertaining to geotechnical related design issues and notes throughout the project plans.
- **Hazardous Waste** – Issues concerning hazardous waste designs are aligned with the district's hazardous waste procedures.
- **Hydrology** – Issues for drainage basin designs are addressed to protect property and highways against flooding.
- **Landscape Architecture** – Issues concerning the design plans for landscape architecture are addressed.
- **Maintenance** – Issues pertaining to access for maintenance personnel, such as trash, landscape, electrical, structures and parking.
- **Maintenance of Traffic** – Issues concerning the Traffic Control Plan, i.e., traffic control signs and barricades.
- **Pavement** – Issues concerning the pavement that will be placed on the project (estimation of quantities).
- **Pay Items** – Issues pertaining to pay items, such as omissions or errors on quantities are addressed.
- **Pedestrians** – Issues concerning pedestrian mobility throughout the project.
- **Permit Requirements** – Issues concerning permit requirements for utility agreements or environmental permits are addressed.
- **Phasing** – Issues concerning the step by step process of construction are addressed and adjusted for optimizing production.
- **Plan Content** – Review the Plan Notes and Comments to ensure clarity throughout the design plans.
- **Railroad** – Issues concerning nearby railroad facilities or any future problems that may arise are addressed.
- **Removal Structures** – Issues pertaining to the demolition of structures that are currently on the job site are addressed.
- **Right of Way** – Issues that arise from obtaining the necessary land needed to construct the project are addressed.
- **Signalization and Electrical** – Issues with lighting plans, or intersection signals matters in the design plans are addressed.

- **Site Investigation** – Issues concerning the current site conditions and how they differ from those shown on the plans are addressed.
- **Structures** – Issues pertaining to any bridges or culverts that are to be erected on the project are addressed.
- **Surveying** – Issues concerning the site survey or control points are examined and addressed.
- **Utilities** – Issues with coordinating underground or overhead wiring on the project with other related activities are addressed.
- **Vertical Construction** – Issues concerning retaining walls or wall panels on the project are addressed.

Table 1 was used to identify the most frequently used categories within the existing practices. The categories were separated into three groups based upon their frequencies: 1) greater than 50 percent, 2) 50 percent to 30 percent, and 3) below 30 percent. These categories represent the majority (greater than 50 percent), the close majority (50 percent to 30 percent) and the minority (below 30 percent).

Table 1 - Category Frequency

Categories	NY	FL	NJ	CT	CA	IN	PA	WA	PCR	KY 1	KY 2	Totals	Frequency
Claims Prevention Checklist											1	1	9%
Construction					1				1			2	18%
Cost Estimating						1						1	9%
District Office Engineer					1							1	9%
Drainage		1	1	1	1	1	1	1	1		1	9	82%
Plan Content	1			1		1	1					4	36%
Earthwork		1	1				1	1		1	1	6	55%
Environmental		1			1	1		1	1		1	6	55%
General										1		1	9%
Geotechnical		1			1			1	1	1		5	45%
Hazardous Waste					1							1	9%
Hydrology					1							1	9%
Landscape Arch.					1			1				2	18%
Maintenance		1			1							2	18%
MOT	1	1	1	1	1	1	1	1	1	1	1	11	100%
Pavement			1					1	1	1		4	36%
Pay Items						1						1	9%
Pedestrians				1								1	9%
Permit Requirements								1				1	9%
Phasing	1	1	1			1	1	1			1	7	64%
Railroad				1		1						2	18%
Removal Structures		1									1	2	18%
Design	1				1	1	1	1	1		1	7	64%
ROW	1		1		1	1	1	1	1			7	64%
Signalization/Electrical		1	1	1			1				1	5	45%
Site Investigation	1		1					1				3	27%
Structures		1	1	1			1	1	1	1	1	8	73%
Surveying		1		1	1						1	4	36%
Utilities		1	1	1		1	1	1	1	1	1	9	82%
Vertical Construction				1								1	9%
<b>TOTALS</b>	<b>6</b>	<b>12</b>	<b>10</b>	<b>10</b>	<b>13</b>	<b>11</b>	<b>10</b>	<b>14</b>	<b>10</b>	<b>7</b>	<b>12</b>	<b>109</b>	

Notes: KY 1 – Hancher et al. 2003 and Goodrum and Taylor 2009; KY 2 – KYTC 2012; PCR – Post Construction Reviews

The data in Table 1 indicates that categories with a frequency of 50 percent or greater include:

- Drainage
- Earthwork
- Environmental
- Maintenance of Traffic (MOT)
- Phasing
- Design
- Right of Way
- Structures
- Utilities

Categories with the frequency of 30 percent to 50 percent include:

- Geotechnical
- Pavement
- Plan content
- Signalization/Electrical
- Surveying

The categories with a frequency of over 30 percent have been identified as categories to be used in this research.

The Kentucky Transportation Center also conducted a study over the frequency of Change Orders (Goodrum and Taylor 2009). This study documented a high number of Change Orders for guardrail and barriers, and this category has been added to the proposed categories. All other items that were examined in this study that caused an increase in change orders could be classified into one of the other categories established above. The list of categories, with the addition of guardrail and barriers, is to be further analyzed to ensure that each category will enhance the database.

### **Category Definition**

Each category is presented below (in alphabetical order) and is examined to determine the most frequent problems or situations that need to be identified.

#### *Design (Frequency 64 percent)*

The category of design is a category including Structures Design, Roadway Design and Preliminary Design. The main concern with design was receiving each department's inputs early to avoid redesign later. Designers should have some indication of what permits will be required for the contract. Right of way and drainage should be considered early to help the design choose a proper alignment to address potential issues. Horizontal and vertical alignments need to be addressed early, e.g., curve data, sight distance and vertical datum. Preliminary studies should be conducted for the structures along with preliminary investigation for materials to be used. All of the work shown on the plans needs to be adequately described in the Standard Specifications. The plans should also show embankment foundations and settlement estimations, slope design and subsurface/groundwater control.

The KTC Constructability Review Checklist Report notes that appropriate lessons learned from previous projects be reviewed (Hancher et al. 2003). There should be cross-referencing between various contract documents for consistency. The roadway design plans and structure



design plans should also be examined to confirm that they match up. The Post Construction Reviews of KYTC showed that the largest concerns result from plan omissions, which could be reduced with a proper and intensive review of plan documents. Other issues noted were incorrect quantities reported, incorrect guardrail type, and borrow and waste estimates.

#### *Drainage (Frequency 82 percent)*

Drainage is used in the Post Construction Review by KYTC and has sub-categories, which include pipes, omissions, ponding, existing pipes, drop box inlets, ditches and culverts.

Other typical areas with comments in this category address temporary construction drainage. If an overlay of an intersection, gutter or curb is to be placed, then the effect on drainage must be considered. This may be a problem because raising the elevation of existing surfaces can decrease flood capacity. Proposed methods of connecting new and old drainage facilities must be addressed. Sheeting or shoring should also be considered if the roadway needs to be protected during phased construction.

CTDOT has drainage comments directed toward drainage specifications. For example, culverts should not be set level, but at a minimum one percent grade, and any pipe with a diameter 36 inches or greater will need an oversized catch basin (CTDOT 2012). These specifications were frequent issues and the DOT wanted to make sure that this is resolved before construction. CALTRANS has different items that are addressed at the 30 percent, 60 percent and 95 percent milestones of the Design Process (CALTRANS 2006). The drainage plans are reviewed for consistency with the roadway and structures plans. Other concerns include the accuracy of quantities and acquiring all required documents and permits.

The phasing during construction of drainage facilities is extremely important. Many comments point out that drainage must be constructed from low to high elevations without interference. The installation of drainage structures also needs to be coordinated with the entire Project Phasing and Maintenance of Traffic.

The KTC Constructability Review Checklist Report indicates that drainage easements and elevations be shown on the plans (Hancher et al. 2003). The outfall locations of temporary and permanent drainage facilities should be shown, if there are any.

#### *Earthwork (Frequency 55 percent)*

Many of the items addressed the placement of stockpiling, storage or dump sites. Contractors use stockpiling and storage sites to keep excess equipment or materials. Dump sites are used by the excavation crew to store excess soil. The shrink and swell factors for soil are not currently represented in the KYTC plans. Designers however are required to consider these effects when establishing bid items.

The type of equipment to be used must meet project requirements, i.e., crane limits and height limits. Rock cuts need to be wide enough to accommodate construction equipment. The size of the construction equipment to be used needs to be considered when determining grading and fill widths. If the grading is too steep, the efficiency of the construction equipment will be impeded. The earthwork phasing needs to be compatible with construction requirements. The length of the phases needs to be reviewed to confirm that the earthwork to be done within that phase is feasible.

Other frequent issues to be considered include displaying the delineation of grubbing, clearing and landscaping on the plans. Any known subsurface obstructions, such as underground storage and sinkholes, must be indicated on the plans. PENNDOT requires that the classification and quantities of all earthwork items be clearly shown on the plans (PENNDOT 2012). If excavation is to occur below the water table, it is to be identified because operating earthwork equipment and performing earthwork operations below the water table can be dangerous. If the contractor is unaware of the water table, issues on the project could occur.

The KTC Constructability Review Checklist includes many of the issues noted above as well as provisions to minimize borrow and use of excavated material for fills (Hancher et al. 2003). Minimizing borrow could be accomplished by phasing adjustment to balance the project. All underground utilities need to be indicated on plans to prevent any difficulty. KYTC also specifies that soil lay-down areas be on the same side of the road as fill areas.

#### *Environmental (Frequency 55 percent)*

The most frequently occurring Environmental items needing to be addressed were the required permits needed for the project. INDOT only introduces environmental issues in the Preliminary Field Check Phase (INDOT 2010). They are concerned mainly with identifying environmental restrictions and anticipating their impact on the schedule. Other examples of concerns entail that the designer apply for all necessary permits. Local agencies may have different permit requirements that should be indicated on the plans. The prevention of groundwater contamination needs to be addressed. Sufficient space is needed (25-30 feet) for power mowers in areas where trees are to be planted.

KYTC Post Construction Reviews have encountered environmental problems such as asbestos, underground tanks, contaminated material, stream mitigation, and landscaping issues (Hancher et al. 2003). If environmental issues are encountered on site, it can cause a major delay on the schedule of the project.

#### *Geotechnical (Frequency 36 percent)*

CALTRANS recommends that a Material Report be completed for the following: structural section design, slope design, embankment foundations, settlement estimates, subsurface control, ground water control, earthwork and seismic design criteria (CALTRANS 2006). They also specify that all testing methods comply with California test methods, ASTM or an AASHTO alternative. Other issues in the Post Construction Reviews of KYTC are slides, subsurface issues, top of rock elevations and unsuitable material (Hancher et al. 2003).

#### *Guardrail and Barriers<sup>1</sup>*

Guardrail and barriers were identified as an issue that occurred frequently with significant change order costs in the Change Orders and Lessons Learned Report (Goodrum et al. 2009). The main problems with guardrail and barriers involve contract omissions, contract item overrun and owner induced enhancements. Reviewing and identifying the correct type and quantity of guardrail and barriers throughout the design will lead to a decrease in change orders related to these items.

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<sup>1</sup> The category does not have a frequency because it was added based on the SAC input.

### *Maintenance of Traffic (Frequency 100 percent)*

The review of the maintenance of traffic plans should be of utmost importance to the reviewers, since this was the single item consistent in all checklists and reviews. Many of the recurring concerns iterate that the traffic operation requirements be met, such as signing, pavement markings and signals. If detours are to be used, they should fit traffic needs.

Maintenance of traffic plans are typically reviewed to confirm the compatibility with the current site conditions. The lane closures should be compatible with expected traffic volumes. Adequate access for local residents and businesses in the area should be considered to prevent future problems. Accommodations for intersecting and crossing traffic should be taken into account when developing the plans. Alternatives should be created and considered to optimize any maintenance of traffic features. The exits and entrances to the work zones should be adequate and safe. Accommodations for bicyclist and pedestrians should be also considered.

The Post Construction Reviews of KYTC have a Maintenance of Traffic category with the most frequent sub-categories being omissions, safety, phasing, quantities, shoulders and striping (Hancher et al. 2003). The Constructability Review Checklists of KYTC suggest that the maintenance of traffic restrictions be printed on the plans, e.g., lane closures, general construction procedures and peak hour restrictions in urban areas. Sufficient clearance within the work zone should also be examined.

### *Pavement (Frequency 36 percent)*

They suggest minimizing low production and hand work areas. In regards to constructability, the roadway needs to be designed wide enough to accommodate all standard equipment, such as concrete and asphalt paving equipment (NJDOT 2010). The haul distance for special materials needs to be available and within a reasonable haul distance.

The Post Construction Reviews of KYTC have several issues concerning pavement problems (Hancher et al. 2003). The main issues are the design of the pavement, striping plans, shoulder design and errors in the estimated quantities. The lessons learned from these reviews separate pavement into two different categories, Portland Cement Concrete Pavement and Asphalt Pavement, but to simplify the database these have been combined.

### *Phasing (Frequency 64 percent)*

The main issues that arose involved verifying the compatibility of construction phasing and scheduling. Constructability Reviews typically consider the design and construction phasing in detail to evaluate whether it could be constructed. The expected duration and productivity rates need to be reasonable.

The Constructability Reviews of KYTC require that maintenance be allowed access to all occupied spaces during the construction of the project (Hancher et al. 2003). The easements on adjacent properties need to be considered for storage and construction through the project's duration.

### *Right of Way (Frequency 64 percent)*

Right of way was not included as a category in the KTC Constructability Review Checklist Report, even though it is a common category for several STA's (Hancher et al. 2003). The

majority of all other documents bring up a single concern regarding whether sufficient Right of Way has been acquired. Though this may seem to be an obvious issue, it can lead to major setbacks once construction has begun. Therefore, acquisition of right of way needs to be considered early in the design process.

Right of way for equipment, materials and hazardous waste storage needs to be taken into account. CALTRANS suggests that all construction and footing easements are identified (CALTRANS 2006). They also recommend that all utilities have Joint Use or Common Use agreements. WSDOT suggests that at the design report stage, a right of way estimate and purchasing cost be established. This could have the potential to affect which alternative is chosen.

#### *Signalization and Electrical (Frequency 45 percent)*

Signalization and electrical was combined into one category, since the two are closely related. There are several issues that need to be covered concerning signalization and electrical issues. If temporary signals or highway lighting is needed during staging or construction, they should be considered beforehand. Existing loop detectors should be identified. Pole locations should be identified, as well as whether there will be any conflicts with utilities or drainage structures. All signs that should be attached to overhead traffic signals should also be identified.

#### *Structures (Frequency 73 percent)*

Many agencies discuss the importance that the Traffic Control Plan be coordinated with construction roadwork phasing. Other frequent concerns include whether the water depth was sufficient to float barges if needed, and if the barges will block boat traffic. The site should be checked to verify if dewatering is necessary. Overhead utilities should be checked to see if there are conflicts with construction or if aerial utilities will limit crane usage. The KTC Constructability Review Checklist Report suggests that other structure characteristics be considered, such as mix design, strength, concrete and steel requirements. The Post Construction Review of KYTC main issues deals with the amount and size of reinforcement steel, omissions in the plan and guardrail for the structures (Hancher et al. 2003).

CTDOT is the only agency that has an extremely detailed structures checklist (CTDOT 2012). It begins with a general section and continues with a box culvert, prestressed, substructure and superstructure section. Each section is detailed with specific topics pertaining to that item. For example, the sub-category of superstructures has an issue: "Review the ratio of the flanges to webs on seismic retrofits. American Institute of Steel Construction (AISC) mandates a minimum 3/8" thickness. Even this is too thin, as with rolled sections the web will kink during process" (CTDOT 2012).

#### *Surveying (Frequency 36 percent)*

The main issue throughout the documents is that the control points are noted from project limit to project limit. Control points should also be on both sides of a structure to ensure accuracy. Retaining walls need bottom of footing and top of wall elevations. Right of way and property lines should be delineated on the plans. The existing topography should be accurate and up-to-date. The profile should fit the terrain, and the plans should be clear and legible.

The KTC Constructability Review Checklist Report has a Site Survey category that is used in collaboration with the Plan and Profile Checklist (Hancher et al. 2003). The checklist suggests

that benchmark data, elevations and curve data be shown on the plans. Water table elevations and requirements for dewatering should be addressed prior to construction.

*Utilities (Frequency 83 percent)*

This category includes existing and proposed utility problems. The main issue to be identified is that all existing utilities be properly marked on the plans. A list of all utility owners and contact numbers needs to be readily available as well. If utility conflicts with the proposed construction are to occur, they need to be indicated on the plans and relocations need to be identified. Underground utilities need to be considered and relocated if necessary. If utilities can be relocated before construction, it should be considered to help move construction along faster. Connection points between new and existing utilities need to be identified. If utilities crossing are a problem, it can be resolved by a temporary structure or scheduling restrictions, such as weekends or after hours. There needs to be verification that overhead utilities will not cause potential problems with operations and access of large equipment. If utilities have the possibility to conflict with drainage, the issue should be reviewed.

The Post Construction Reviews of KYTC have a Utilities Category with 12 different sub-categories. The most recurring issues are problems with existing utilities, relocation and omissions. The KTC Constructability Review Checklist Report indicates that sewer lines are placed below all water lines and gas lines are placed far above all other utilities (Hancher et al. 2003). Adequate space also needs to be provided for Right of Way and drainage structures to allow proper drainage.

## **DATABASE DESIGN**

The main goal of the database is to allow the constructability reviewer to complete and easily assign categories to reviewers' comments for the Constructability Review document. A second goal is to develop a consistency in the reporting in order to address current differences in reporting content and style. Another important goal is the ability to query the database in order to develop reports and statistics regarding the completed reviews. The reviewer will be required to enter project-related information, such as Item Number, Route Number and Designer. The database relationships have been established to relate each single project, identified through its Item Number, to multiple comments. The database was developed using 2010 Microsoft Access.

The details to be entered in the Access database are grouped into two categories: project and review comments. To allow for consistency and ease of analysis, every comment is classified into specific categories that could concisely describe the comment. The reviewer can select as many categories that apply to that comment. Every comment is also classified with respect to its potential for budgetary or time implications in the event that the comment was not identified prior to construction using a severity index. Some additional project parameters that could be of use include the Date, Review Type, Design Phase, the Designer of the plans, and the Reviewer conducting the review. The following presents the parameters included in the database and the rationale for their inclusion.

### **Category Development**

The categories for the review comments were developed in a two-step process. The findings from the literature review along with the review of the STA practices were used to develop the first list of categories. The Study Advisory Committee (SAC) met and reviewed the proposed list of categories in order to determine the final list of categories.

The list developed based on the literature review identified those categories that were common and most frequently used by the various DOTs and have been utilized in the KYTC Post Construction Review Database. These categories include the following:

- Design
- Drainage
- Earthwork
- Environmental
- Geotechnical
- Guardrail and Barriers
- Maintenance of Traffic
- Pavement
- Phasing
- Plan Note Clarity
- Right of Way
- Signalization/Electrical
- Structures
- Surveying
- Utilities

From the 2010 and 2011 periods, KYTC conducted 80 Constructability Reviews. These 80 reviews contained 1,053 comments and all the comments were grouped utilizing the categories

shown above. Figure 2 shows the distribution of the comments into the selected categories. It should be noted that the category “Plan Content” has been changed to “Plan Note Clarity” to be more reflective of KYTC terminology.

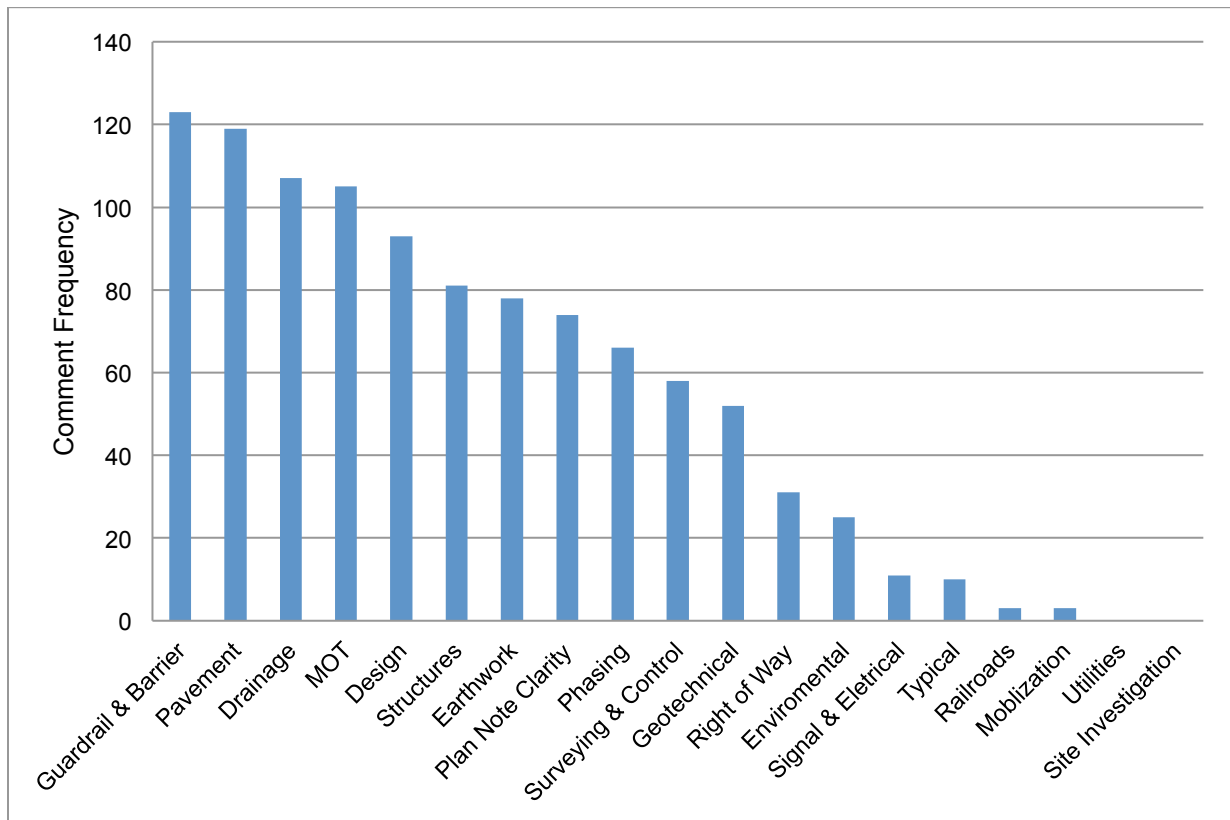


Figure 2 – Review Comment Frequency for Literature Review Categories

The categories of Plan Note Clarity, Typical Sections, Railroads and Mobilization were added to the list as it was developed because of the repeated frequencies of each category. Plan Note Clarity occurred in 74 of the comments, suggesting it to be a significant issue.

The categories that accounted for more than 50 percent of the comments were Guardrail and Barrier, Pavement, Drainage, Maintenance of Traffic, Design, and Structures. Comments comprised 12 percent of the total identified Guardrail and Barrier with the main issue identified as the wrong type of end treatments prescribed in the plans. Pavement issues were the second most frequent comment (11 percent) that included most of the comments pertaining to the over or under estimation of quantity calculations. Drainage occurred in ten percent of the comments and most pertained to pipe size alternatives. Maintenance of Traffic also occurred ten percent of the time and the majority of the comments were suggestions for alternative traffic routes. Design was included in nine percent of the comments and the main issues were with horizontal alignment, vertical alignment and superelevation transition. Structures issues occurred in eight percent of the comments and the main issues were adding the “Remove Structure” bid item to the project. Florida DOT has a checklist devoted to removals and demolitions on the project. Since the “Remove Structure” bid item is so often forgotten, it should be reiterated to designers that it must not be omitted.

These data were presented at the SAC meeting where the list was reviewed and adjusted to reflect specific needs and concerns relevant to KYTC. The two categories that received zero comments were Utilities and Site Investigation. Utilities plans are not reviewed because each District reviews these plans. However, the category of Utilities will remain in the database, to address potential regulation changes in the future. Site Investigation was not an issue and therefore it will be removed from the data.

Recommendations were made to expand the Design category into more detailed sub-sections. The new categories were based upon the categories established by the Post Construction Review Database and are as follows:

- Horizontal Alignment
- Vertical Alignment
- Coordination
- Cross-Section
- Superelevation

The category of Striping was added as an extension of the Pavement category. The Drainage category was broken down into three different types of drainage applications: Existing Drainage, Proposed Drainage and Temporary Drainage. More categories were added upon request of the SAC, including Easements, Seeding and Part-Width Construction. It was also determined to group the categories based on the type of the comment. The comment types to be used are Error, Omission and Plan Note Clarity. Many of the comments will either be correcting an error, adding an omitted section or bid item to the project plans or improving the clarity of the plan notes. The development of comment types will be a great advantage for any future lessons-learned database, since it will allow for systematically identifying the reasons for comment.

The final list of categories to be used for the Access Database is shown below:

- Coordination
- Cross-Section
- Design
- Earthwork
- Easements
- Environmental
- Existing Drainage
- Geotechnical
- Guardrail
- Horizontal Alignment
- Maintenance of Traffic
- Part-Width Construction
- Pavement
- Phasing
- Proposed Drainage
- Right of Way
- Seeding
- Signalization/Electrical
- Structures
- Superelevation



- Surveying
- Temporary Drainage
- Utilities
- Vertical Alignment

### **Comment Severity**

Constructability reviews have the potential to reduce project costs and construction time, since they can identify issues that could result in change orders and time delays, if they made it to construction. It is therefore important to establish the severity of impact that each comment could have on the project if it was undetected. This should be captured in the database to allow for estimating the potential time and money effects. Each comment encapsulates different aspects of a project, and as such, each comment could have a different order of magnitude on the design process. Therefore, each comment is examined to estimate the cost and schedule impacts that it could impose on a project, and assigned a severity index.

Classifying the different levels of severity based on quantitative data is important to ensure consistency for the database. In order to gain a statistical basis for analyzing the data, the Change Orders and Lessons Learned database were reviewed (Goodrum and Taylor 2009). The data for the 1000-series projects from that report were used to develop the average cost of change orders as a percentage of the original contract amount. The projects used here are those that follow a standardized process through the KYTC project development process and are not influenced by extraneous factors, such as political decisions. The average change order amounts on new construction projects for KYTC are about 3.5 percent of the original contract amount. The same data showed that the average standard deviation is seven percent. These figures were used to establish the cost severity categories.

Project delays were included in the severity index as a binary variable. If not corrected before construction begins, the constructability issue would likely result in a project delay, then a value of one will be assigned to that comment. If no delay would occur, even if the constructability issue was not caught, then a value of zero will be assigned.

A two-step process is proposed for establishing the severity of the comment in order to address both cost and schedule impacts. First, the comment is classified based on the cost impacts using a three-level scale: low, medium and high. The guidelines for this classification are provided below. The second step involves the determination of the schedule impacts utilizing the binary choice noted above. This number will then be added to the cost severity so that if delay is anticipated, then the severity index will be increased by a level. For example, for a comment with medium severity, if a delay had occurred, the severity index would be upgraded to high. If no delay would occur, then the level would remain as assigned at medium.

#### *Low Severity*

Low severity comments should have both low cost and low schedule impacts. Low severity was usually associated with striping quantities estimated incorrectly and seal aggregate quantities. Low severity would be a comment that does not require a large change order and will not cause delay on the project. If the constructability issue was not corrected before construction begins, the error would likely result in a construction cost change order less than 3.5 percent of the proposed construction budget to correct once construction begins.

### *Medium Severity*

Medium severity contains constructability issues that if not resolved before construction would require a change order, which could impact the construction cost. An example of medium severity would be when structure quantities are estimated incorrectly. Fabricated structural items, such as a beam can have a high impact on schedule. However, steel quantities that are incorrect are usually caught early enough that they are not a detrimental issue, other than additional cost. A contract item omitted can also have a large effect on schedule because a change order must be submitted to establish the bid item and continue work. Utility relocation plan issues can have an impact when the relocation is to be done by the roadway contractor.

The average cost of a change order is 3.5 percent, and one standard deviation is seven percent; the boundaries could be established as the average and one standard deviation (i.e., 10.5 percent). If a medium severity constructability issue is not corrected before construction begins, the error would likely result in a construction cost change order between 3.5 percent and 10.5 percent.

### *High Severity*

High severity is associated with any structure redesign, misfabrication of materials, and alignment errors. Any comments that would alter the terms that the contractor agreed to by bidding on the project would have a large effect on the schedule. Other examples include imposing working hour restrictions or boundaries to work around streams. Impacts can also be felt with any type of insufficient right of way to tie slopes according to design. Most constructability issues concerning maintenance of traffic should be considered severe because they impact the driving public through delays and can create multiple traffic changes that may confuse some drivers. Most high severity items significantly remove control of the pace and sequence of the work from the contractor. If the schedule is changed, then the contractors plan is altered and construction becomes more difficult.

If a high severity constructability issue is not corrected before construction begins, the error would likely result in a construction cost change order in excess of 10.5 percent of the proposed construction budget to correct.

### **Review Timing**

Constructability Reviews are completed during many different phases of the design process. Currently, KYTC conducts them at the Preliminary Line and Grade, Final Joint Inspection and Check Print phases of the project development. The Highway Design Manual of KYTC describes the delivery process for every design project (KYTC 2012). The diagram for the entire process is shown in Figure 3.

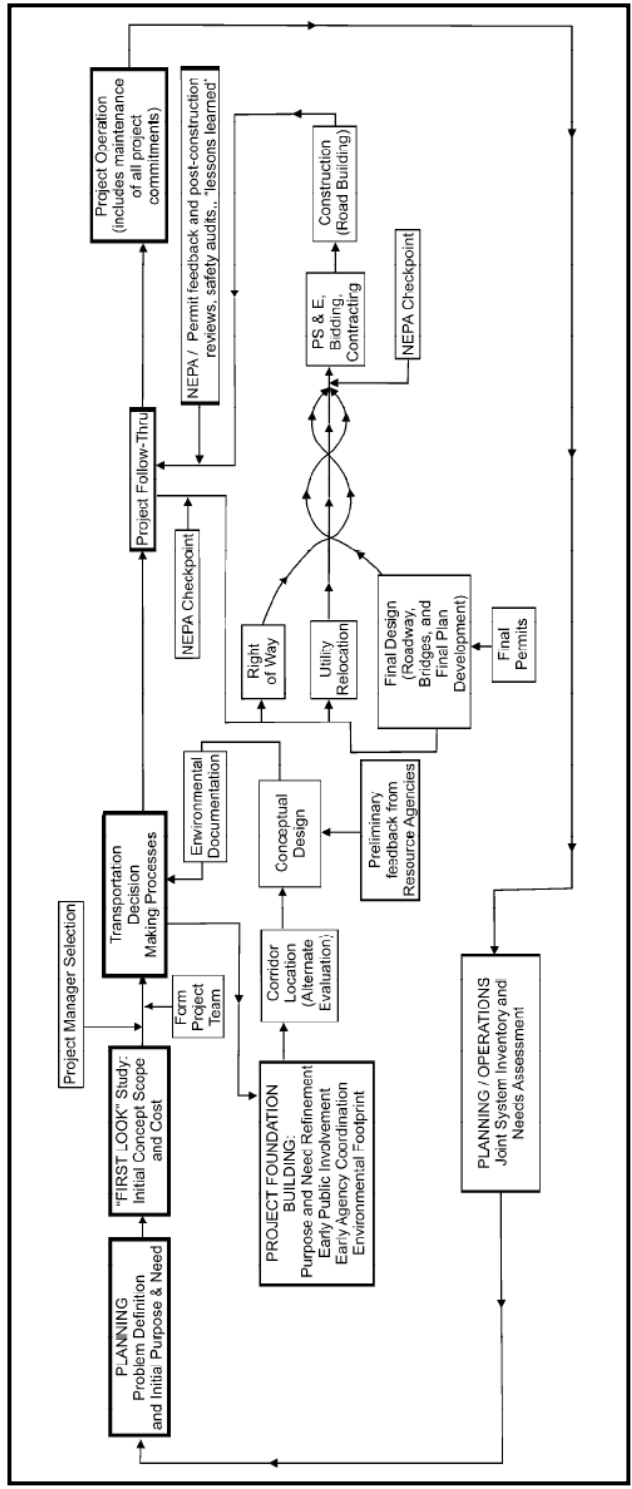


Figure 3 - Project Delivery Core Processes (KYTC)

## Preliminary Line and Grade

The Preliminary Line and Grade is approximately when 30 to 40 percent of the design is complete. The meeting usually indicates the completion of the conceptual design phase. Therefore, alternative alignments are selected at this time and preliminary plans show a general layout for the proposed alignments. Potential Right of Way is identified and will need to be acquired. Environmental documents have also been approved for the project at this point.

### *Final Joint Inspection*

The Final Joint Inspection meeting is generally held when between 75 to 90 percent of the design is complete. The vertical and horizontal alignments are commonly set at this point. This meeting is an opportunity for many different project team members to come together and discuss any project concerns. The team members include representatives from the Drainage, Environmental, Utilities, Right of Way, Construction and Design Divisions. This gives each Division a chance to discuss problems that will affect more than one Division. Major alignment changes are usually not appropriate this late in the design process, but constructability input at this phase is extremely important. Contract time is also discussed and determined at this point in the process.

### *Check Prints*

The Check Prints phase should occur around 95 percent of the design completion. This phase involves a last review of the plans by the Plan Processing Section of the Division of Highway Design approximately three months before the scheduled letting date. The Plan Processing Section will review that all Computer-Aided Drafting and Design (CADD) Standards have been met, the proper bid items have been used, and the right standard drawings have been referenced. This process strives to achieve a level of consistency. The contract time is also finalized. Plan Processing will then return the project plans with corrections and comments to the original designer.

## **Database Relationships**

The Constructability Database uses the coded project information categories and comment information to set up working relationships within the database. The project information and comment information is entered through the user interface (Figure 4), which has multiple dropdown boxes and text boxes for ease of entering the data.

**Project Information Input**

ItemNO: 00-0000.00      ReviewType: [Dropdown]

ReviewDate: [Text Box]      RouteName: [Text Box]

Reviewer: [Dropdown]      RouteNO: [Text Box]

District: [Dropdown]      DesignPhase: [Dropdown]

County: [Dropdown]      Designer: [Text Box]

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**Comment Input**

Comment: [Large Text Area]

Select Category(ies): [Dropdown]      Select Severity: [Dropdown]

Record: 1 of 1      No Filter      Search

Figure 4 - User Interface

The content of each entry is described below:

- **Item Number** is the project number and has an eight-digit mask within the ItemNO cell. This makes the Reviewer only enter an eight-digit number. This mask will allow all Item Numbers to be consistent, and will decrease user input errors.
- **Review Date** is to document a time stamp for when the Constructability Review took place. By holding the cursor to the right of the Review Date cell, a calendar will appear to select the correct date.
- **Reviewer** is the KYTC Constructability Reviewer, and has a drop down menu with a list of the past and current KYTC Constructability Reviewers.
- **District and County** sections have a drop down box for the twelve districts in Kentucky and all of the Kentucky counties.
- **Review Type** identifies the plans reviewed and provides for a choice of Roadway, Structures or “Other” in case plans such as lighting and signal are reviewed separate from the roadway plans. Typically, these plans are part of the Roadway plans and they should be reviewed with them.
- **Route Name and Route Number** are text boxes for the reviewers to enter the information based on the subject project.

- **Design Phase** identifies the phase during which the review is completed and has a drop down box with the Design Phases identified above, including an “Unknown” option. The reviews conducted in the past did not capture the Design Phase and therefore, past reviews entered in the database will have an “Unknown” Design Phase. However, every review in the future will identify the Design Phase at which it was conducted.
- **Designer** is the person responsible for the designs reviewed section and is a text box for the reviewer to indicate whether the plans were completed by the District, Central Office or contracted out to a Design Consultant. Many of the reviews previously conducted did not capture who the designer was; therefore many of the projects will have the Designer to be recorded as “Unknown”. However, in the future the Reviewer will have to record the Project Plan Designer.

The parameters are connected through strategic relationships. Figure 5 shows the database relationships for all of the parameters.

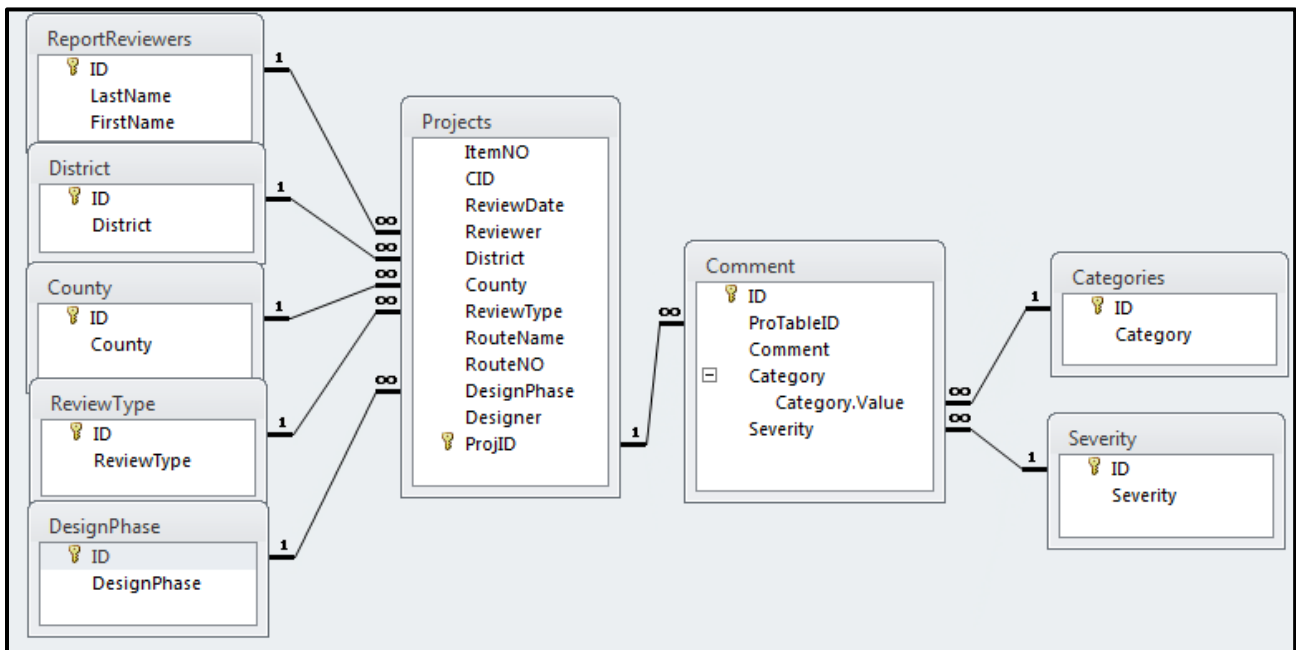


Figure 5 – Database Relationship

The database allows each design parameter on the left to be assigned to infinite projects. However, the comments have a unique relationship with the project table. The relationship is set up as one to infinity. This means that an infinite number of comments can be associated with one specific project ID. This will allow the Reviewer to input as many comments as are necessary to conduct a complete Constructability Review. This will also keep the Reviewer from having to continually repeat the Project Information for each comment. The Project Information will automatically be assigned to every comment pertaining to that review.

The Comment table has a direct relationship with the categories and the severities. The Reviewer can associate multiple categories with each comment.

## **DATABASE ANALYSIS**

The completion of the Constructability Database Design led to the input of Constructability Reviews, which were previously conducted in 2010 through 2012. A total of 118 Constructability Reviews containing 1,110 comments were examined. The 24 categories established and stated earlier were used to classify the comments along with the comment types and other variables of interest.

A basic data description is presented in this section aiming to identify any potential trends that could be helpful in improving the quality of the data and providing the basis for training for future reviews.

### **Comment Type**

The first variable examined was the comment type for each review conducted. Among the 1,110 comments, 372 dealt with Plan Note Clarity, 367 were Errors, 356 were Omissions, and eight dealt with Drawing Clarity. There were also seven comments with no type specified. The data indicates that the majority of issues dealt with the notations in the plans requiring additional clarification in order to improve the constructability of the project. Each of the three main types represent approximately one third of the total comments and it seems that there is no significant difference (practical or statistical) among these types. It should be noted that the Drawing Clarity type has very few cases (less than one percent) and therefore, it was not considered in the statistical analysis. This is because the Drawing Clarity comment type was added later in the process and it was not addressed in 2010 and 2011 reviews.

### **Comment Category**

The comment category is examined, since it identifies the most frequent sources of issues on a project. The data shows that the most frequent categories are those of Pavement, Maintenance of Traffic, Guardrail, Existing Drainage, and Structure (Table 2). These five categories account for approximately 57 percent of the comment categories and hence could be considered as the most significant categories that are identified through a review process.

Table 2 also shows the frequency of categories by comment type to determine whether there is any particular pattern within each type. The total is greater than 1,110, since several comments were classified in more than one category. The data reveals that the same five categories are the most frequent within each comment type. Those five categories account again for over 57 percent of the overall categories. A small percentage of comments did not have any corresponding category or comment type and is indicated as blank. No particular trends were identified for Drawing Errors, since the number of observations was small (less than one percent of the total categories).

Table 2 – Frequency of Comments by Category and Type

Category	Comment Type					Total
	Drawing Clarity	Error	Plan Note Clarity	Omission	Blank	
Coordination	0	17	13	8	0	38
Cross Section	2	25	12	10	0	49
Earthwork	0	27	27	16	0	70
Easement	1	3	9	4	0	17
Environmental	0	5	2	10	0	17
<b>Existing Drainage</b>	<b>0</b>	<b>23</b>	<b>51</b>	<b>34</b>	<b>1</b>	<b>109</b>
Geotechnical	0	25	23	23	0	71
<b>Guardrail</b>	<b>3</b>	<b>71</b>	<b>36</b>	<b>81</b>	<b>1</b>	<b>192</b>
Horizontal Alignment	0	13	18	22	0	53
<b>Maintenance of Traffic</b>	<b>0</b>	<b>59</b>	<b>94</b>	<b>87</b>	<b>0</b>	<b>240</b>
Part-Width	0	3	19	4	0	26
<b>Pavement</b>	<b>4</b>	<b>117</b>	<b>80</b>	<b>64</b>	<b>1</b>	<b>266</b>
Permanent Drainage	1	20	9	18	0	48
Phasing	0	26	29	6	0	61
ROW	0	10	4	18	0	32
Seeding	0	10	7	20	0	37
Signalization	0	6	3	11	0	20
Striping	0	11	8	10	1	30
<b>Structure</b>	<b>2</b>	<b>36</b>	<b>35</b>	<b>26</b>	<b>1</b>	<b>100</b>
Superelevation	0	12	3	9	0	24
Survey/Control	0	19	19	15	0	53
Temporary Drainage	0	4	3	5	0	12
Vertical Alignment	0	9	12	4	0	25
Blank	1	3	9	0	2	15
<b>Total</b>	<b>14</b>	<b>554</b>	<b>525</b>	<b>505</b>	<b>7</b>	<b>1605</b>

A chi-square analysis was conducted to determine whether there are any differences in the frequency of the categories examined among the comment types. This test determines if specific categories have a greater presence in certain comment types. The results indicate that there are statistically significant differences, i.e., there are categories that are more likely to be more prevalent in certain comment types. These categories include Pavement, with greater frequency of occurrence in Errors, Guardrail, with greater frequency in Errors and Omissions, and Existing Drainage, with greater frequency in Plan Note Clarity.

### Review Year

The frequency with which reviews are conducted is also of interest, since it can identify the potential personnel needs. The current data can be used to determine the desired level and amount of reviews to be conducted in the future and establish the workload of the reviewers. The data indicates that there were approximately equal numbers within each year. Of the 118 reviews, 45 were conducted in 2010, 47 in 2011, and 26 in 2012. It should be noted that the 2012 data is only up through June, representing a partial number of reviews.



The frequency of the comments within each year was also examined to determine whether there is any trend that could indicate improvements (Table 3). The data indicates that the number of comments has reduced over time (statistically significant). Even though KYTC could not provide any reasoning as to why this trend may exist, it could be indicative of an improvement in the process and efforts to address potential constructability issues earlier in the project development. The greatest reduction over time is observed for Errors (almost 50 percent) while the other two types show smaller improvements (20 percent for Plan Note Clarity and 15 percent for Omissions). This trend is encouraging and could indicate improvement; however, additional years of data will be needed to determine whether this is sustainable and indicative of improved practices.

Table 3 – Frequency of Comment Type by Year

Review Year	Comment Type					Total
	Drawing Clarity	Error	Plan Note Clarity	Omission	Blank	
2010	0	215	179	159	5	558
2011	0	110	142	135	0	387
2012	8	42	51	62	2	165
Total	8	367	372	356	7	1110

The average number of comments per review has also been reduced over time. In 2010, the average review had 12.4 comments, while in 2011 this was reduced to 8.2 and in 2012 to 6.4. Of interest is also the relative distribution of categories within each year (Figure 6). The data is presented in percentages to normalize for the different number of reviews.

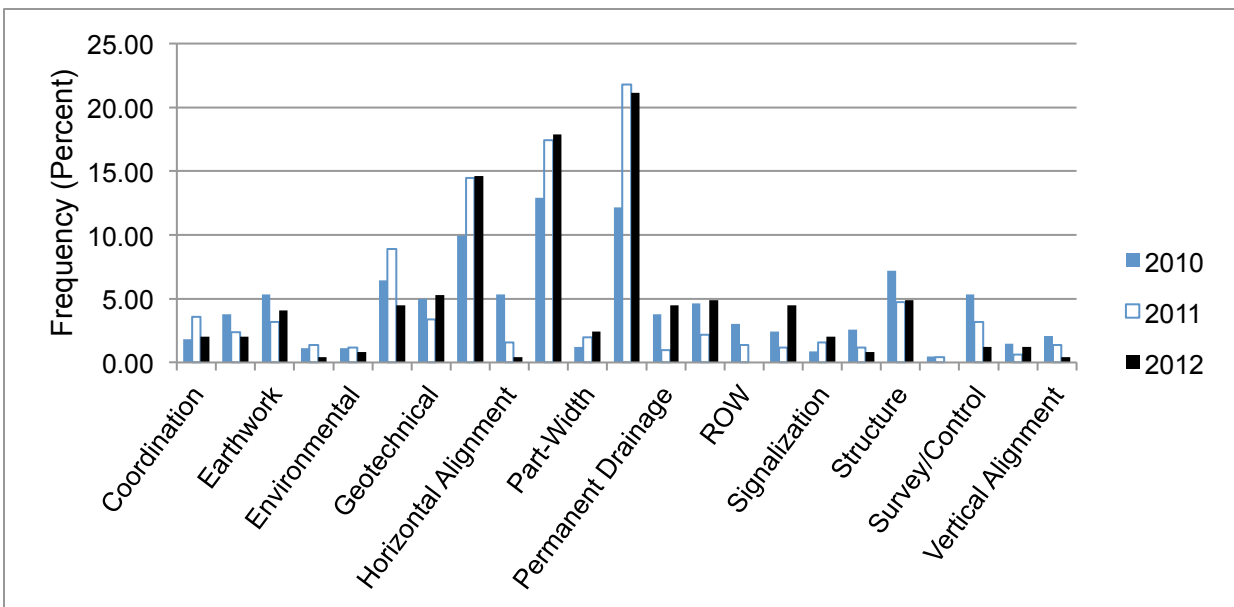


Figure 6 - Category Frequency by Year

These data indicate that there is variability in the frequency of the categories over time. However, a closer evaluation of the data reveals that there is a consistency in the top categories for all years. Table 4 presents the categories that comprise at least 50 percent of the total. A greater number of categories was used in 2010, which is reflective of the larger number of comments completed for each review, thus reducing the corresponding percentages. The most frequent categories are the same in these three years, indicating a consistency of the issues that reviews can identify. This may also indicate an emphasis area for designers to avoid constructability issues and address them in a proactive manner.

Table 4 – Frequent Categories by Year

2010		2011		2012	
Category	Percent	Category	Percent	Category	Percent
<b>MOT</b>	12.90	<b>Pavement</b>	21.78	<b>Pavement</b>	21.14
<b>Pavement</b>	12.17	<b>MOT</b>	17.43	<b>MOT</b>	17.89
<b>Guardrail</b>	9.98	<b>Guardrail</b>	14.46	<b>Guardrail</b>	14.63
Structure	7.18				
Existing Drainage	6.45				
Earthwork	5.35				

Notice that similar categories were noted in 2011 and 2012 as those observed in 2010 following the top three noted above.

An analysis of the category types by year and comment type did not reveal any different trends than those observed and discussed in Table 4. For example, there was no consistent pattern as to whether the issues relative to Maintenance of Traffic were Plan Note Clarity or Omission related in any of the three years.

### Reviewers

The reviewer who performed the Constructability Reviews for the project has been documented in the database. There were four Reviewers who worked during the 2010-2012 period and each has conducted a different number of Constructability Reviews (Table 5). The large discrepancy in numbers could be attributed to work schedules and availability. However, this may be indicative of personnel needs and the need for a more equitable workload regarding these reviews.

Table 5 – Number of Constructability Reviews by Reviewer

Reviewer	Year			Total
	2010	2011	2012	
1	3	4	--	7
2	--	5	7	12
3	27	8	--	35
4	15	30	19	64

Each reviewer also produced a different number of comments for each review. There are also differences in the comment types as well as the categories identified by each reviewer. Table 6 presents the number of comments by type and provides an indication of the variability of the number of comments by reviewer. It should be noted that these figures do not reflect lack of effort by the reviewer but rather could be viewed as an indication of the lack of consistent templates for conducting the reviews. The large discrepancy in numbers could be attributed to

work schedules and availability. However, this may be indicative of personnel needs and the need for a more equitable workload regarding these reviews. The data also indicates that each reviewer has a different perspective for comment types, which could reflect their specific expertise and background. For example, reviewer 1 has an almost even distribution among the three predominant comment types, while reviewer 3 coded most (43 percent) of the reviews as Errors.

Table 6 – Comment Type by Reviewer

Reviewer	Comment Type				Total
	Drawing Clarity	Error	Plan Note Clarity	Omissions	
1	0	8	7	9	24
2	0	13	18	16	47
3	0	209	140	138	491
4	8	137	207	193	548

An analysis of the comment categories provides additional information that supports the assumption that each reviewer could have their own expertise on subjects and will naturally be more inclined to correct issues in areas where they are comfortable (Figure 7).

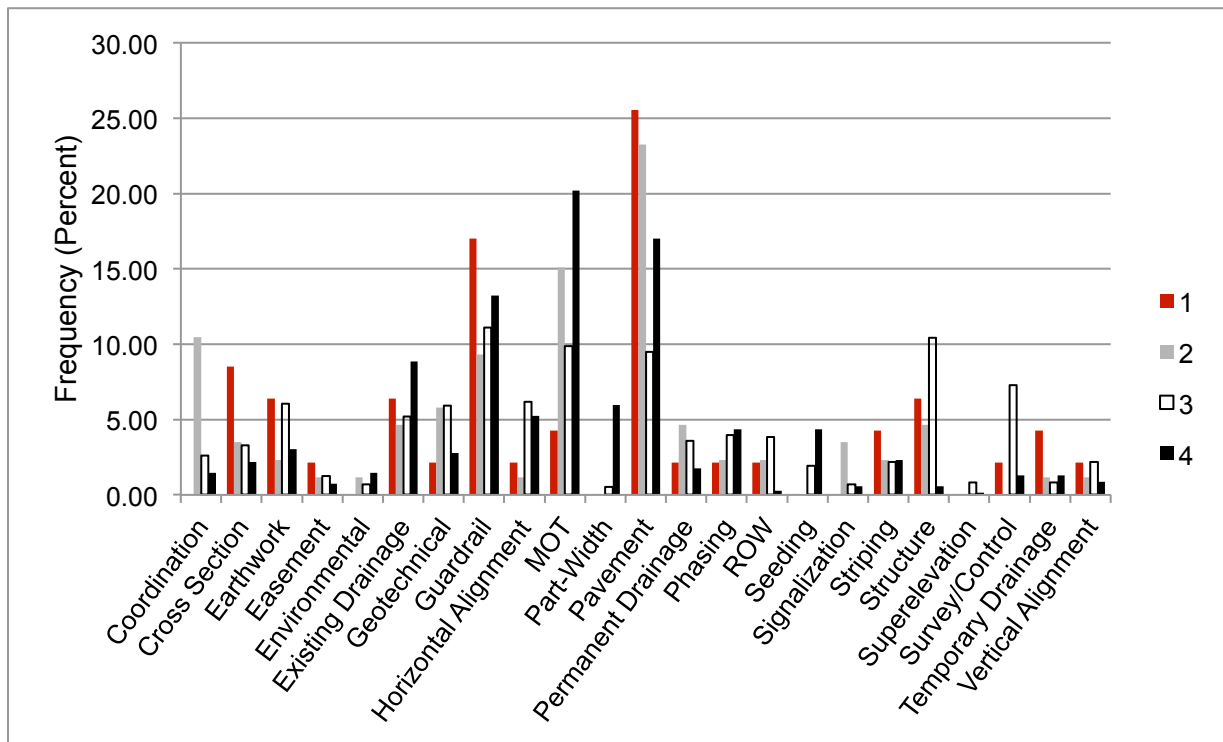


Figure 7 - Categories by Reviewers

A closer evaluation of the data reveals that there is a difference in categories among the reviewers. Table 7 presents the categories that comprise at least 50 percent of the total. A greater number of categories is used by some reviewers, which is reflective of the differences in their number of reviews and comments by review. There are two categories that are present for all reviewers: Pavement and Guardrail. The Maintenance of Traffic is the next category that is

common to three reviewers and is also the next most frequent category for reviewer 1. The data points to a consistency in the top three categories. At the same time, there is variability in the remaining categories that could reflect the reviewer’s expertise. For example, Structures is a frequent comment for reviewer 3 while for reviewer 2, Coordination is one of the top categories. The data supports the general assumption that reviewers may have a tendency to inspect areas within their expertise with more emphasis and thus identify a greater number of issues, resulting in more comments in the corresponding category.

Table 7 – Frequent Categories by Year

Reviewer 1		Reviewer 2		Reviewer 3		Reviewer 4	
Category	Percent	Category	Percent	Category	Percent	Category	Percent
Pavement	25.53	Pavement	23.26	Guardrail	11.13	MOT	20.20
Guardrail	17.02	MOT	15.12	Structure	10.44	Pavement	17.01
Cross section	8.51	Coordination	10.47	MOT	9.89	Guardrail	13.23
		Guardrail	9.30	Pavement	9.48		
				Survey/Control	7.28		
				Horiz. Align.	6.18		

The data in Table 7 shows that the structure category appears only for one reviewer as a frequent category, possibly indicating that reviewer 3 has a more extensive expertise in the area of Structural Design. It is apparent that a reviewer should be knowledgeable in all areas and the analysis shows that currently reviewers focus more in their relative area of expertise. It is imperative that reviewers should be trained to review all areas of project plans and they should avoid focusing on what they are more familiar with. Reviewers should be able and know how to review the entire set of plans.

**Severity**

Each comment was evaluated based on its potential impact on the time and cost of the project if it went undetected. This was accomplished as a subjective evaluation based on the scale and instructions provided in the previous section. The severity levels considered here address only the cost implications, since the time severity was added at a later time, and it was decided to not review the comments again and reclassify them. There were 197 comments that were classified as having a high severity, 655 as medium, and 251 as low. The data indicates that 77 percent of the comments could result in an increase to the project budget, if they were not identified during the review process.

The severity of the comments as a function of the comment type was also examined to determine whether there were any trends that could associate severity with type (Table 8). The data indicates that errors and omissions account for more than 50 percent for each of the severity levels. For high severity comments, these two comment types account for approximately 80 percent of the comments. It is therefore critical to identify these issues during the review process in order to avoid significant change order amounts, which would most likely result in time delays as well.

Table 8 – Frequency of Comment Type by Severity

Severity	Comment Type					Total
	Drawing Clarity	Error	Plan Note Clarity	Omission	Blank	
High	0	50	38	109	0	197
Medium	1	250	233	171	3	658
Low	7	67	101	76	2	253
Total	8	367	372	356	5	1110

Of interest is also the relative distribution of categories within each level of severity (Figure 8). The data is presented in percentages to normalize it for the different number of comments in each category.

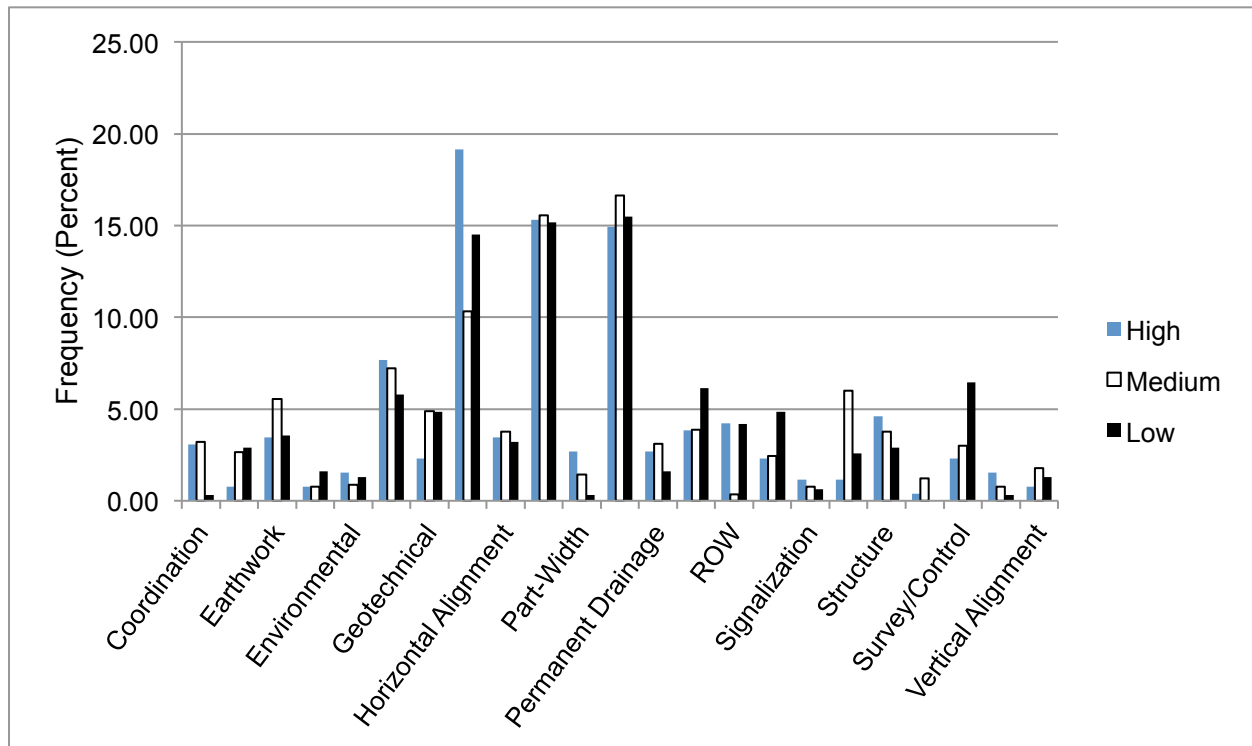


Figure 8 - Category Frequency by Severity Level

The data indicates that, in general, there is variability in the frequency of the categories over the severity level. However, consistency in the top categories for all severity levels is observed. Table 9 presents the categories that comprise at least 50 percent of the total. The most frequent categories are the same in each level, indicating the pervasive issues noted in all variables examined, as well as indicating a consistency of the issues that the reviews can identify. This data also supports the concept that these topics should be emphasized during the design process to avoid constructability issues and address them in a proactive manner.

Table 9 – Frequent Categories by Severity Level

High		Medium		Low	
Category	Percent	Category	Percent	Category	Percent
Guardrail	19.16	Pavement	16.66	Pavement	15.48
MOT	15.33	MOT	15.54	MOT	15.16
Pavement	14.94	Guardrail	10.32	Guardrail	14.52
Existing Drainage	7.66	Existing Drainage	7.21	Survey/Control	6.45
		Striping	5.99		

An analysis of the category types by severity level and comment type did not reveal any different trends than those observed and discussed in Table 2. For example, most of the Pavement issues for medium severity were identified as Errors. On the other hand, there was no consistent pattern as to whether the issues relative to Maintenance of Traffic were related to Plan Note Clarity or Omission for any of the three severity levels.

**District**

The district in which the review was conducted was also identified in order to determine possible trends in the number of reviews and workload. Figure 9 shows the breakdown for each district and its total number of reviews.

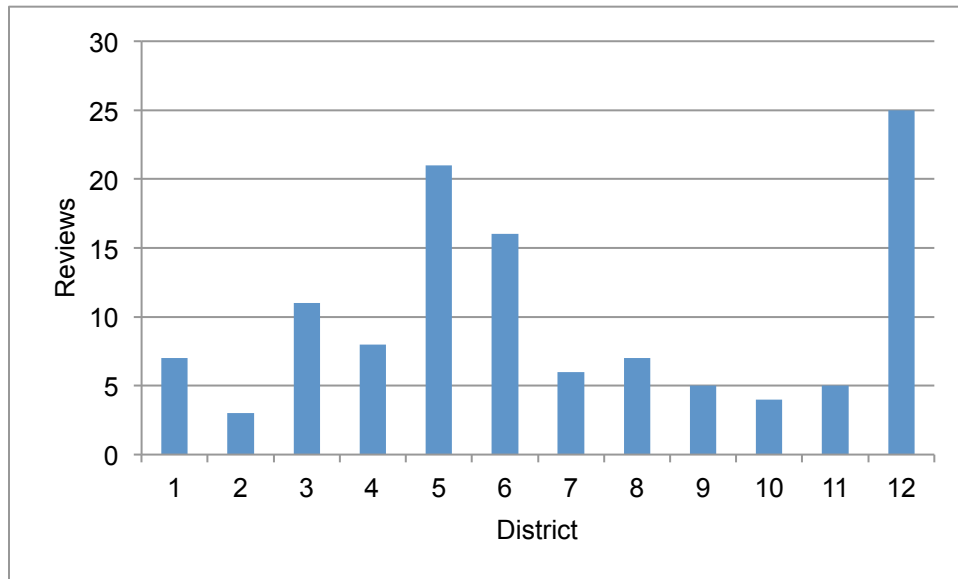


Figure 9 - Number of Reviews by District

The data indicates a large variability in the number of reviews conducted for each district. However, the number of projects within each district is not available in order to provide an understanding of the percentage of projects reviewed or frequency of reviews by district. In this case, it cannot be convincingly concluded that the greater number of reviews conducted in District 12 is reflective of other issues, such as improper designs that could lead to Errors, Omissions or Plan Note Clarity relative to constructability.

A review of the comment type by district was also undertaken to determine specific trends within a district (Table 10). The data indicates that some districts have a greater number of a specific

comment type, which could indicate the need to improve that aspect of the design. For example, District 6 has 50 percent (56 of 111) of the comments noted as Omissions, while District 8 has the same percentage (62 of 124) for Errors.

Table 10 – Frequency of Comment Types by District

District	Comment Type				Total
	Drawing Clarity	Error	Plan Note Clarity	Omission	
1	0	6	10	13	29
2	0	5	8	4	17
3	2	17	29	27	75
4	3	35	58	29	127
5	0	37	66	45	148
6	0	27	28	56	111
7	0	20	27	20	67
8	0	62	22	40	124
9	0	14	9	14	37
10	0	41	20	22	83
11	3	8	9	28	50
12	0	95	86	58	242
Total	8	367	372	356	1110

The analysis of the comment categories did not provide any specific trends, and for most districts the comments received for each category were similar in proportions (i.e., no statistical differences per the chi-square analysis for each category by district).

## **ANALYSIS OF CASE STUDIES**

The main goal in any review process is the documentation of potential benefits for conducting these reviews and validation of their usefulness. The use of case studies with constructability reviews was deemed appropriate in order to determine and demonstrate the potential gains from constructability reviews.

### **Case Study Selection**

The work plan called for developing a detailed and comprehensive set of example projects for which analysis of reviews conducted would be feasible. It was agreed that a maximum of ten cases be reviewed to allow for adequate variety of projects and timely completion of the work. The cases were identified in cooperation with the Study Advisory Committee, since this was deemed critical to the success of this work and their knowledge of the projects. Projects were selected to include a variety of types of construction and design as well scope and budget. A list of criteria was developed to select the appropriate cases, including:

- **Project Characteristics:** Typical issues to be considered were project type, density of surrounding development, estimated construction cost, project designer, highway district, project manager, and project origination. It was decided that the low number of case studies to be considered would not provide results of any significance in connection with the effects of several of these criteria on the value of the constructability reviews. However, an assumption was made to consider an even distribution of projects with higher estimated construction costs and lower estimated construction costs. Ten million dollars was selected as the threshold for estimated construction cost based on that value being the average estimated construction cost for all projects reviewed.
- **Reviewer:** This variable was considered in order to allow for adequate distribution across the different reviewers completing the reviews. However, the small number of cases would not allow for any significant evaluation and therefore, this was not considered in the case selection process.
- **Project stage:** The case studies should be selected among projects that have undergone a Constructability Review and have been completed in the past few years. The selection of completed projects was considered appropriate, since all change orders and cost items would have been submitted and recorded. This allowed for an accurate estimation of the impact that each review comment had on the cost of the project, and identify any potential shortcomings of the reviews completed.
- **Number of comments:** The number of comments per case study plays an important role, in order to determine their impact on the project and thus estimate the value of the constructability review. The assumption is few comments resulting from a constructability review are likely a product of a design with high quality and little room for value added from the review. The threshold of ten comments was used for case study selection, since the analysis of the database indicated an average number of nine comments (118 reviews with a total of 1,110 comments).
- **Geographic distribution:** Adequate coverage of cases throughout the state is sought in order to avoid any concentration in a specific district. This criterion was relaxed, since all districts were not going to be represented due to the low number of cases.



A structured approach was undertaken in selecting the case studies. First, cases with ten or more comments were identified. This criterion was utilized to establish a large enough pool of comments for analysis given the small number of cases to be selected. Second, the timing of the review of each case was considered to determine the stage of inspection. Cases selected should have reviews conducted at final joint inspection or check print indicating that the plans were advanced to near completion. This was deemed appropriate, since plans in preliminary design are of limited detail and would not have provided an opportunity to estimate a value for the constructability review comments with any accuracy. Next, the project budget was examined and half of the cases selected had a budget over \$10 million and the remainder less than that amount. This threshold was determined as being the cutoff between what would be considered a “large” project. The average estimated construction cost for all projects reviewed is \$10 million and this value was set as the threshold to be used here with the approval of the SAC.

As an additional selection criterion, the database is comprised of information from two main periods, data collected and entered by researchers during this project prior to the presentation of the database to the reviewers and data entered by the reviewers themselves. An even distribution of cases between self-entered and researcher entered reviews would allow an evaluation of risk assignment by the researchers versus the risk assignment by the constructability reviewers.

The final criterion used was the level of design process utilized in the process. There are projects, such as those associated with maintenance issues, that do not completely pass through the review process and therefore the constructability reviews conducted in such projects may not be reflective of the overall conditions. It was determined that it will be more appropriate to select projects that have been through the entire process. This was achieved by selecting projects with item numbers in the 1000’s or lower series or the greater than 8000 series.

The process and criteria discussed here were utilized to select the cases shown in Table 11.

Table 11 - Selected Cases for Analysis

Case No.	Phase of Review	Review Type	No. of Comments	Project Type	Construction Est.
1	Final Joint Inspection	Roadway	18	Major Widening	\$19,510,000.00
2	Check Print	Roadway	36	Major Widening	\$41,250,000.00
3	Final Joint Inspection	Roadway	11	Safety	\$675,000.00
4	Final Joint Inspection	Structure	3	New Route	\$12,120,000.00
5	Check Print	Roadway	13	New Route	\$12,120,000.00
6	Final Joint Inspection	Roadway	15	Bridge Replacement	\$850,000.00
7	Final Joint Inspection	Roadway	13	Bridge Replacement	\$400,000.00
8	Preliminary Line and Grade	Roadway	12	Relocation	\$45,450,000.00
9	Final Joint Inspection	Roadway	20	Bridge Replacement	\$900,000.00

### Identification of Benefit Metrics

Following the selection of the cases for review, benefit metrics were established to evaluate the cases and assign values to the corresponding comments. Preliminary evidence and analysis suggested that valuation of the constructability review program could occur both at the project and comment level.

At the project level, projects that were reviewed through the constructability review program were compared to projects that were not formally reviewed by said program. Data for projects

from 2007 to the present were compared to projects that were reviewed through the constructability program from 2010 through 2012. The comparison was made by investigating the percentage of cost increase (or decrease) from the as-bid project cost to the final cost inclusive of change order adjustments. Any trending difference between these two categories of projects (reviewed versus not reviewed) would demonstrate a relationship between the constructability review program and any savings that could be noted.

At the comment level, there were two broad areas of benefit metrics used in evaluation of the comments with this study: quantitative valuation and qualitative valuation. Quantitative valuation was based on identifying the issues and costs associated with the comment if it was not addressed until the project was already under construction. In other words, if the problem, concern, or question were to occur during construction how would it have been addressed. From this analysis, the value of the comment could be determined by calculating the algebraic difference between the costs of addressing the comment during design versus addressing it during construction.

The qualitative valuations of the comments were categorized into three distinct groups (Table 12). These groups are defined by the level of corrective actions required during construction for not addressing the comments in design. The corrective actions might entail additional project communication, additional project documentation, additional project costs, change orders, additional project time, and project disputes or claims.

Table 12 - Qualitative Value Level Description

Qualitative Level	Description of Corrective Actions
Low	Corrective action may require additional project communication or clarification, but can be completed without a change order. Project management staff efforts would be minimal to rectify the situation.
Medium	Corrective action may incur minor project cost or time increases by change order but the overall effects are considered average. Recall the average change order results in a 3.5 percent increase to the project. Project management staff would incur additional documentation and time to rectify the situation.
High	Corrective action will result in large additions to the project in cost and/or time, and would have potential for leading to project disputes or claims. Project management staff would incur excessive amounts of added documentation and time to rectify the situation. May result in additional tension between the contractor and project management staff.

All comments were evaluated qualitatively and only a subset was evaluated quantitatively due to lack of appropriate quantitative data. This allowed for a basic comparison between similar qualitative values and the ability to infer an estimate of what their quantitative value might be.

### Project Level Evaluation

One method of determining the value provided by a constructability review program is a comparison between projects that were reviewed and those that were not. Ideally, this comparison would occur while projects were ongoing. Such analysis and documentation would be cumbersome and time consuming. A perceived method of estimating this comparison is to compare change orders of projects reviewed and not reviewed. While change orders may not

capture all changes or problems occurring on a project, the majority of those impacting the project cost would be represented.

To complete this analysis, data regarding projects from 2007 through 2012 was collected. This data included as-bid project cost and cost modifications by change orders. There was also information available to determine if the project was complete or not, and what design item series (an indication of project type and development process) was related to the project. The available constructability review database allowed comparing these datasets in multiple ways and across multiple variables such as reviewer, district, completion status, or item number series. The amount of change orders as a percentage of the as-bid project cost was calculated and reported in Table 13 in various categories of concern.

Table 13 – Change Orders as Percent of Project Budget for Project Level Evaluation

All Projects				
Reviewed	Project Series			
	All Projects	Item#<3000	Item#>7000	Item#<3000, >7000
Yes	3.383	3.794	1.902	No Reviews
No	4.403	4.490	5.932	5.309
Completed Projects				
Reviewed	Project Series			
	All Projects	Item#<3000	Item#>7000	Item#<3000, >7000
Yes	3.012	3.546	0.074	No Reviews
No	4.427	4.781	6.647	4.181
Reviewed Projects				
Reviewer	Project Series			
	All Projects	Item#<3000	Item#>7000	Item#<3000, >7000
1	2.370	3.060	0.682	No Reviews
2	4.611	5.001	2.884	No Reviews
3	2.863	2.589	3.958	0.000
4	0.882	0.882	No Reviews	No Reviews

The data here indicates that projects reviewed through the constructability review program incur at a lower amount of change orders (on average 1.25 percent) than projects that were not reviewed. This percentage cannot directly be referred to as savings because for projects that were reviewed, it is likely that changes were made based on the constructability review comments adding work or items during design that would have otherwise been added during construction by change order. The KYTC change order procedures indicate that change order items are acceptable at 110 percent of the average unit bid prices. An estimate of the value of the constructability review program for 2010-2012 can be derived utilizing the assumption that the reviews saved this 10 percent premium on the 1.25 percent in change order additions (Table 14). This estimation is extremely conservative as it is likely the reviews saved beyond the 10 percent change order premium. In addition, much of the value in constructability review is not accounted for here that could include construction management time savings, designer lessons learned, and schedule delays.

Table 14 - Estimated Savings of the Constructability Review Program by Letting Year

Letting Year	Bid Amount for Projects Reviewed	1.25% Estimated Price Reduction	Savings (10% Premium)
2010	\$112,060,060.98	\$1,400,750.76	\$140,075.08
2011	\$232,134,684.84	\$2,901,683.56	\$290,168.36
2012	\$88,625,270.91	\$,107,815.89	\$110,781.59

### Case Study Level Evaluation

As previously mentioned, a second measure by which to estimate the value of a constructability review program is by evaluating the constructability reviews at the comment level. Even though this approach requires several assumptions, it provides a much more discrete analysis of the reviews based on each comment. The assumptions and procedures for evaluating the constructability review comments are discussed in the next sections. A probability analysis is also presented aimed in developing a multivariate regression formula for estimating comment value.

#### Case Study Comments

There is great variability across the comments reviewed. Some variability is explained by using multiple reviewers who each will have their own comment style and level of detail. The constructability review database will assist in developing a more consistent approach in categorizing comments but variability in level of detail will still be prevalent. Another source of variability is in the type of comments themselves. Comments may be simply notes of the reviewer to themselves or could be complex enough that they have rippling effects throughout the project. In both of these cases, and cases in between, valuation of these comments can be difficult. As such, careful documentation was kept during the comment valuation for validation purposes.

A total of 141 comments were analyzed from the nine cases reviewed. Some comments were associated with multiple comment types and two were not associated with a comment type at all. When multiple comment types were associated, the comment was counted for each type with which it was associated to establish a distribution (**Error! Reference source not found.**).

The cases studied included a varied selection of the comment categories available ( Figure 11). These comments were often associated with multiple category types. Each comment was associated with its appropriate categories and comments with multiple categories are counted for all associated categories.

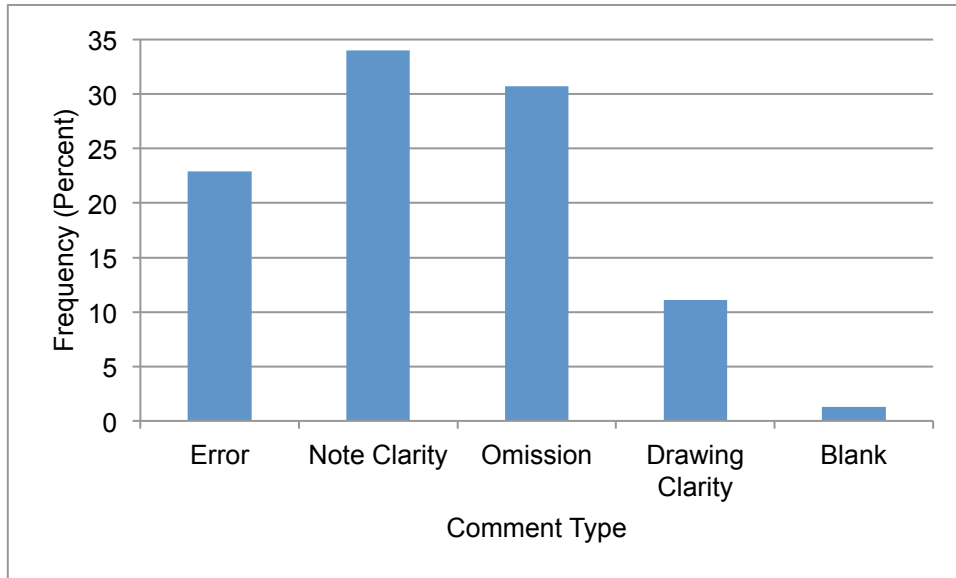


Figure 10 - Comment Type Frequency for Case Studies

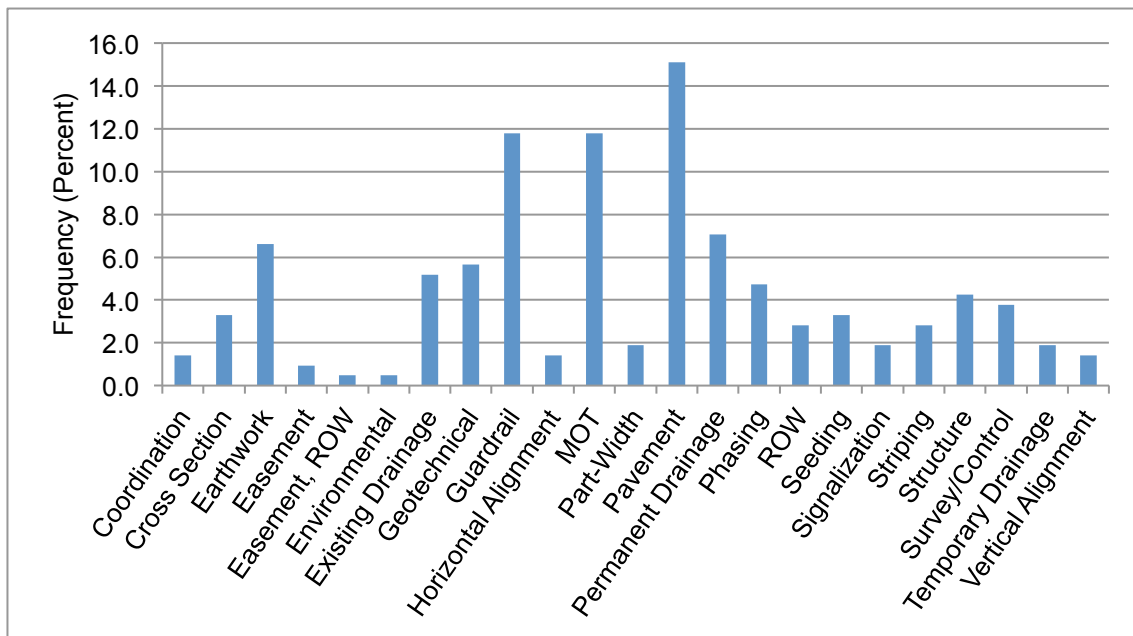


Figure 11 - Category Frequency for Case Studies

There were some associations that could be made between comment type and the type of analysis to determine comment value. Often comments of the drawing or note clarity type would entail a simple clarification or comment as a resolution. These comments were often not quantifiable in terms of value. However, these comments were characterized utilizing the qualitative scale shown above (Table 12) and were often considered medium to high impact. This would occur because inconsistencies or ambiguities in contract documents can lead to expensive delays or disputes when encountered during construction. Even though the quantitative value of these comments could not be captured, their value cannot be underscored.

Omission type comments were usually related to a missing bid item or item of work. These comments were most often quantifiable and in many occurrences they would necessitate a change order for correction. These comments were regularly considered low on the qualitative scale because commonly omissions are quickly resolved by in-field agreement that the omission exists and is rectified by change order.

Error type comments range in their ability to quantitatively evaluate them and they were spread across the three qualitative categories.

One final aspect of the case studies reviewed is the distribution of the comment severity, as it was defined above. Most comments were of low (54 percent) to medium (37 percent) severity. Further, if severity levels were converted to a numerical scale with 1 corresponding to “low” and 3 corresponding to “high,” the average is 1.54 with a standard deviation of 0.65. The same estimates for the entire constructability review database are 1.86 for the average and 0.66 for the standard deviation. This comparison indicates that the comments reviewed may have been less severe than the overall population. Therefore, the valuation of the comments, as described in the next section, could be viewed as conservative.

#### *Case Study Quantitative Comment Evaluation*

The case study comment evaluation was performed by a research team member with over ten years of experience in construction management with six of those years directly related to the KYTC change order process. This knowledge allowed for a review of each comment utilizing a scenario based analysis where comments were related to similar past project experiences. Appendix B documents the evaluation of each case and comment.

Each comment was first evaluated to determine the possibility for a quantitative evaluation. From the 141 comments analyzed, 73 were evaluated quantitatively. Various approaches were utilized to determine the value of each comment with an underlying objective to determine the impact the problem, issue, or ambiguity would have during construction. The approaches utilized for the evaluation are discussed below and the valuation method of each of the 73 comments is documented in Appendix B.

Two approaches were utilized for estimating the value of comments related to omitted work or bid items. The most straightforward approach was when the bid item was not included. In this case, the KYTC average unit bid prices (AUBP) were used to estimate what costs would have been added to the project at a 10 percent premium, i.e. using a 110 percent of the AUBP. The benefit accrued from the comment was only the 10 percent premium savings that would occur due to correction prior to construction. The second approach involved comments for which omitted work simply meant additional quantity for a bid item already included in the project. Unless the omission affected the current bid quantity by more than 25 percent, by specification, no price adjustment is warranted during construction. In these cases where existing quantities were not changed by more than 25 percent no benefit was accrued for the comment. It can easily be inferred that economies of scale would apply to a quantity increase and therefore the comment does entail a direct benefit to the project; however, it is not quantifiable in this case.

There were several comments where there was a need to replace one set of bid items for another. The comment might require this based on the wrong items being used or simply a switch to a satisfactory, yet more cost effective option. In order to quantify these comments the value of the existing bid items was determined using the quantities and AUBP, then the new items needed were subtracted from this amount at the corresponding quantity and AUBP. The

110 percent premium was not used in these cases as subtracting at normal rate is the true benefit of the comment were it considered at the design stage in these cases.

The final approach taken to determine the value of a comment was for those that involved the simple elimination of bid items. The benefit in these cases simply entailed the quantities eliminated multiplied by the corresponding AUBP rates. If any items also had to be added after the comment eliminations were made, these were added at the normal AUBP rate according to the same reasoning above.

The quantities and values of these 73 comments were computed using the appropriate approach among those noted above. The data indicates that most of the comments resulted in a benefit of less than \$2,000 (52 comments of the 73 or 71.2 percent) with only eight comments with benefits over \$10,000 (11 percent). However, these 52 comments below \$2,000 only account for 4.2 percent of the quantified savings while the eight comments over \$10,000 account for 85.3 percent of the calculated savings. Having a majority of the dataset account for the smallest portion of the value determined makes the values over \$10,000 appear as outliers to the data. However, this is most likely due to the small number of cases and comments analyzed. This data variability affects also the regression analysis discussed below,

As previously mentioned all comments reviewed were assigned a qualitative value according to Table 12. A cross-examination of the qualitative scores by the estimated value indicates that most comments with low values are also those with a low qualitative level (Table 15). There are few comments with high qualitative level and large benefit value (4 percent). Additional comparison and cross-examinations of the value with the comment types and comment categories did not produce any significant trends.

Table 15 - Correlation of Qualitative to Quantitative Analysis of Comments

Value	Qualitative Level (Percent)		
	Low	Medium	High
<\$1,000	60	8	0
\$1,001-\$2,000	5	1	0
\$2,001-\$5,000	5	9	0
\$5,001-\$10,000	2	1	0
>\$10,000	0	5	4

#### *Probabilistic and Regression Analysis*

One of the goals of the case analysis was to determine if any trends were evident with regard to comment types, categories, benefits and comment severity. The analysis at the programmatic level discussed above provided an overall estimate for the value and benefits of the constructability reviews. The statistical analysis conducted here aimed at developing prediction models of the benefits of the review utilizing comment attributes. The analysis presented here is based on the 73 quantified comments.

The values obtained for the 73 comments range from \$12 to \$166,000. The majority of these values are below \$2,000 (71.2 percent) as noted above. Such a large concentration of data

within a small range could negatively influence efforts to develop any regression. Scatter plots of the data also indicate lack of any real trends.

Several attempts were made to develop a regression model in order to predict the possible benefits utilizing the available variables. Most of the models had a very low explanatory value, i.e.,  $R^2$ , and therefore there is no reasonable trend detected. The only reasonable model was the one that associated value with the qualitative level with an  $R^2$  of 0.32. The prediction model is as follows:

$$\text{Value} = -24510.9 + 24073.75 \text{ Quality level}$$

The comment type and category are categorical variables, i.e. there is no real numerical value associated with each value. For example, assigning the value of 1 to Errors does not make them more or less important than Omissions if they were assigned the value of 2. Therefore, a different data coding approach is required to model this. In this case, each case is coded in a binary mode, where the comment type and category are either present (1) or not (0). This allows for modeling each categorical variable to determine their potential impact on the model. The 22 comment categories are regrouped to a smaller number in order to limit the complexity of the model. The same approach was taken for the comment types where Note Clarity and Drawing Clarity were combined to make one type.

Table 16 – New Comment Category Groups

New	Original
Design	Coordination, Cross Section, Earthwork, Guardrail, Horizontal Alignment, Superelevation, Vertical Alignment,
Drainage	Existing Drainage, Permanent Drainage, Temporary Drainage
Construction	Easement, MOT, Part Width, Phasing, Seeding, Striping,
Pavement	Pavement
Other	Environment, Geotechnical, ROW, Survey, Structure, Signalization

The model developed from this approach includes as statistically significant predictors the qualitative level and the Errors. The model has an  $R^2$  of 0.37 and the prediction equation is

$$\text{Value} = -27603.01 + 24058.81 \text{ Quality level} + 11114.16 \text{ Error}$$

As noted above, the value for Error is 1 (yes) or 0 (no) indicating the presence of the comment category.

The statistical analysis conducted here provides some indication that there is the potential for developing prediction models for estimating the benefit of the reviewed comment based on various attributes of the comment. However, the limited data does not allow for strong models and predictions based on the two models developed here and should be used cautiously and only as very general predictors. The use of the qualitative level in both models indicates that this is a variable with a strong relationship to the estimated value. However, this value was estimated in a subjective manner and it was determined in conjunction to the quantitative value for the comments. These two evaluations, value and qualitative level, are somewhat correlated and the ability of the qualitative level to predict the value is anticipated and could bias the prediction models. The determination of the qualitative level requires an additional review of the



comments either by the reviewer or an independent party and this could be problematic and time consuming. It is therefore recommended that these models be used solely as indicators of potential relationships between value and comment attributes. At this point, additional work may be needed to ensure the accuracy of the assessment in the future and develop robust models that could be based on the other comment attributes such as the comment type and category.

## CONCLUSIONS

When construction expertise is integrated early and throughout the design phases of a project, there is the potential for increased benefits. KYTC has attempted to take advantage of this knowledge by establishing a Quality Assurance Branch which includes the Constructability Review Program. However, in the current state, this effort lacks a systematic method for cataloging the results of the process, analyzing their findings, and yielding direct tools for design engineers to use on future projects. A list of categories has been developed based on review of other state DOT practices, along with a literature review. This list was utilized to develop a database in which existing reviews were entered to be analyzed for trends and tendencies.

The findings from the data reveal several trends and issues. The analysis showed in general that Pavement, Maintenance of Traffic and Guardrail are the most frequent categories observed. These were characterized either as Errors or Omissions, where Errors indicated wrong quantities while Omissions noted absence of the item needed for construction. Plan Note Clarity was also another type of comment that was frequently noted. The data did not reveal any particular trend regarding which of these three types is predominant and all seem to have an equal presence in the existing database.

There were differences in the comment types that each reviewer identified. The data also indicated that each reviewer is likely to review areas within their expertise. Ideally, a reviewer should be familiar with all areas of expertise required for a particular review and be capable of conducting such a review. Given the reality as presented herein, reviewers can be influenced by their unique area of expertise. It is recommended that reviews be conducted either by reviewers competent in all areas of the design or by a team to help achieve a comprehensive and well balanced review. The team reviews would not necessarily have to be conducted in person; they could be completed electronically.

The data for the comment severity indicate that errors and omissions could result in significant cost issues and possible time delays. The same three categories identified above are also present as having a high severity for several comments indicating their significant impact on project cost and time.

The review of the data in each district indicated that there are disproportionate numbers of reviews. This could not be further evaluated, since the total number of projects that should be considered for a review for each district is not known. Trends have been identified by district with respect to the comment type. An effort should be undertaken to examine these in more detail to determine whether they are random.

The case study analysis indicated that there is a benefit from the constructability reviews and that these benefits can be frequently quantified. The benefits accrued could be of low monetary amount (most comments resulted in less than \$2,000 benefit) but there are other intangible benefits such as project delays and scope changes that could not be estimated from the available data. The qualitative analysis of the comments showed that there were few comments with a high severity but those are comments that result in high benefits.

The statistical analysis performed attempted to develop prediction models for the benefits accrued based on the various attributes of the comments. The low number of case studies and comments reviewed did not allow for a meaningful and robust statistical analysis. However, there are indications that this could be feasible if additional case studies and more comments are included in a future analysis. This would not only allow for the development of the models

based on comment type, category, severity and qualitative level but would also permit the use of other variables, such project type and cost that were not utilized here. The inclusion of these additional variables will also permit for a possible prioritization of constructability reviews among projects aiming to address first those projects that could have the greater benefit potential.

## **Recommendations**

### *Constructability Review in Preliminary Design Phase*

The comment type Plan Note Clarity was the most frequently observed. Although Plan Note Clarity correction improves constructability of the project plans, the reviewers have the tendency to do more Plan Note Clarity correction than examining the entire project for larger constructability issues. If the plans are reviewed earlier in the design process, the reviewers would have an opportunity to make these types of corrections. According to KYTC's Highway Design Memorandum No. 6-05, Constructability Reviews should be conducted in two stages. The first should be conducted before right of way plans are finalized, while the second is conducted at the end of the final design. The objectives and details for the first review can be found in Appendix A.

It is highly recommended that the reviewers should have the opportunity to review the plans early in the design phase, since this will allow for a better usage of the constructability knowledge of the reviewers.

### *Constructability Review Teams*

The analysis shows that the reviewers tend to review their areas of expertise in more detail. In order to assure that all project plans receive a thorough Constructability Review, a project team should be established. KYTC's Highway Design Memorandum No. 6-05, lays out guidelines for team compositions. As noted above, the first Constructability Review should be conducted before the Right of Way plans are finalized. This review has an option for two different team compositions based upon the budget of the project. The second Constructability Review should be conducted at the end of final design. The teams generally include a facilitator, project manager and two experts in construction. If the project is over \$2,000,000 a traffic operations and Right of Way engineer is involved in the review.

These guidelines should be examined and followed more closely. The current system has a single reviewer conducting each Constructability Review. The use of a team of experts to review plans will continue to improve the constructability of the project. The team effort can address all areas and it will not necessitate that a person be familiar with all required areas of expertise. The recommendation for the Central Office is to set up the team through the Quality Assurance Branch of KYTC.

### *Training Workshops*

Districts across the state that have a large number of comments for any category should be closely monitored for future trends and possible improvement. Training workshops for such districts targeting the areas with the higher frequency of comments could address constructability issues and help eliminate constructability concerns. The problems can be eliminated from the early stages of the project development once designers become aware of frequent errors they are making in project plans. The Quality Assurance Branch can recommend new topics for these workshops by querying the database and finding which categories have the potential to result in constructability issues.

### *Constructability Database Availability*

The database developed here provides useful knowledge for all designers, either new to the design world or those who have been designing for years. The database should be available for all persons involved in project development, which include KYTC Districts and Central Office personnel and consultants. Querying topics can help designers minimize construction issues while they are designing the project.

### *Constructability Reviews*

The analysis conducted here indicates that there is value in continuing and expanding the reviews to as many projects as possible. The database allows for a systematic and uniform data entry and this would enhance and streamline the process. The analysis showed that at a minimum 1.25 percent of project costs can be saved through the reviews and therefore expanding reviews in all projects could increase this benefit.

### *Future Work*

The work accomplished here is a major step toward the establishment and expansion of the constructability review process and a documentation of its value to KYTC. The analysis conducted shows a small but significant benefit of 1.25 percent of savings for projects that were reviewed. Such efforts of documentation should be continued in the future and KYTC should continue monitoring the accrual of these benefits. However, additional work is needed to develop the models that would allow for the prediction of benefits and possibly permit a prioritization of projects to be reviewed if such an approach is required.

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**APPENDIX A**

**KYTC HIGHWAY DESIGN MEMORANDUM NO. 6-05**

### Outline for Constructability Review Process

**Purpose:** The Constructability Review Process is being implemented as a means of minimizing change orders and identifying design errors and omissions before projects are let. The review is intended to contribute to the project development decision making process at all stages of the project. Constructability Reviews are NOT intended to replace the Project Development Team Process. Participation by Construction, Traffic Operations, Geotechnical and other disciplines are ESSENTIAL.

- I. Constructability Reviews Will Be Done on All Projects with Plans
  - A. Division of Highway Design will oversee the program and provide logistical support.

Options available for administering the program are the following:

    1. Branch Manager for Roadway Engineering
      - (a) Value Engineering Section
      - (b) Plan Processing Section
      - (c) Location Engineers
    2. Statewide Value Engineering Contract
      - (a) Facilitator for Constructability Review Team Meetings if necessary
      - (b) Provide "Specialized" expertise for Constructability Review Teams if necessary.
    3. Focus for the review are on the following areas:
      - (a) Feasibility of alternatives
      - (b) Implement lessons learned from previewing projects
      - (c) Identify preliminary ROW, Utilities, Railroad and other issues on the project
      - (d) Include and evaluate environmental issues
      - (e) Evaluate potential waste or borrow sites
      - (f) Evaluate traffic and highway capacity issues
      - (g) Evaluate need for auxiliary lanes and geometrics involved
- II. Constructability Reviews (CR) will be conducted in Two Stages. There will be two separate Constructability Reviews
  - A. Constructability Review No. 1 (CR-1): CR-1 will be conducted before Right of Way Plans are finalized.
    - a) Objectives of CR-1
      1. Consider findings of a formal VE study if conducted.



2. Provide detailed evaluation of the project design from the perspective of constructability, ROW issues (especially easement and entrances), utilities, railroad issues, maintenance of traffic and opportunities for innovative bidding techniques. Use “lessons learned” database from post-construction review and review of the database for design errors and omissions, to identify common constructability issues.

b) Team Composition for CR-1 (For Projects greater than \$2,000,000)

1. Facilitator—Location Engineer
2. Project Manager
3. Two Construction Subject Matter Experts (SME)-Resident expected to oversee Project and Resident from different District with experience on similar type project
4. Traffic Operation (SME)
5. Right of Way (SME)
6. Others as needed dependant upon complexity and characteristics of project

c) Team Composition for CR-1 (For Projects less than \$2,000,000)

1. Facilitator—Location Engineer
2. Project Manager
3. Two Construction Subject Matter Experts (SME)-Resident expected to oversee Project and Resident from different District with experience on similar type project or Central Office Construction Liaison for the District.
4. Others as needed dependant upon complexity and characteristics of project

d) Location engineer will prepare a “Constructability Review” report for distribution to the Project Manager

B. Constructability Review No. 2 (CR-2): CR-2 will be conducted at the end of final design and coincide with the submission of “check prints”.

a) Objectives of CR-2

1. Ensure that project plans, specifications and details are adequate for bidding.
2. Address final issues of “Constructability and Maintenance of traffic”.
3. Review contract time recommendations and any recommendations for innovative contracting.
4. Perform “Quality Assurance” check of at least one major bid item for the project. This essentially involves thoroughly checking a randomly selected major bid item for accuracy.

b) CR-2 Team Composition

1. Facilitation—Value Engineering Section or Location Engineer
2. Project Manager
3. Two Construction Subject Matter Experts (SME)-Resident expected to oversee Project and Resident from different District with experience on similar type project or Central Office Construction Liaison for the District.
4. Traffic Management SME
5. Plan Processing Selection Reviewer

c) The Branch Manager for Roadway Engineering will designate the appropriate individual to prepare a “Constructability Review” report for distribution to the Project Manager.

**APPENDIX B**

**COMMENT VALUATION PROCEDURES AND DOCUMENTATION**

## Process Assumptions

There were several assumptions made during the constructability review comment valuation process. These assumptions allowed for a conservative and founded approach to the analysis. These assumptions include the following:

- All comments provide some level of value. A qualitative measure is used when methods are not available to quantify the comment.
- This analysis does not address time costs associated with development and implementation of change orders.
- Average unit bid prices (AUBP) would be used at the 110 percent standard justification for added items.
- In the scenarios derived from the comments, it is assumed KYTC will be found at fault and be fiscally responsible for all resolutions.
- As AUBP's may vary year-to-year, multiple years may be consulted for the most appropriate priced determined by a larger frequency of use in the year chosen.
- There is no attempt at determining value associated with ripple effects, such as designers learning from comments, etc.
- There is also no attempt to quantify the potential impacts or savings that occur if contractors use known errors to their favor. Including costs for potential change order items in other bid items on the chance a change order may not be executed. If executed, in essence the contractor is paid twice for the same work.
- Not all comments were classified by the reviewers, some were by the researcher, they were assumed equivalent for this analysis.

## Case 1 Analysis

### *Comment 1:*

The value of this comment cannot be overshadowed as it brings to light a fundamental issue that this project could have had with drainage issues related to trapped water resulting from the use of a drain system pavement without a draining system in place to eliminate water that was going to be trapped. The results of this comment could come in a number of ways:

First, to address the comment by adding the necessary drain holes and edge drains would have added approximately,

94 cores in drop boxes (\$179.47/EACH), approximately 18000 LF of edge drain (\$4.50/LF), and 120 edge drain headwalls (\$441.79/EACH).

If savings is considered to be 10 percent of this (savings between adding at contract and approved change order pricing) that would make this part of the comment worth \$15,089.

This comment might also entail the elimination of drainage blanket in the median.

Elimination of estimated drainage blanket

14,000 SY of 4in at 110 lbs/SY-in is 3080 tons at \$41.14/ton = \$126,700

Also, eliminates curing seal (2lbs/SY @\$606.07/TON) and sand (5lbs/SY @\$28.84/TON)

$\$8485 + \$1010 = \$9,495$

Adds 3220 tons of DGA Base @\$19.15/TON = \$61,663

The pavement change would save the project \$74, 532.

94 cores in drop boxes (\$179.47/EACH), approximately 18000 LF of edge drain (\$4.50/LF), and 120 edge drain headwalls (\$441.79/EACH).

\$150,885.

This comment could have saved KYTC an estimated \$89,000. This comment is estimated to have high qualitative value.

*Comment 2:*

It appears the earthwork quantity for the median has been left out of the project quantity. The missing quantity of 146 CY is not 25 percent of the of the existing bid item (31,311 CY) so the work would have been added at the existing bid price but would have necessitated a change order. This comment is estimated to have low qualitative value.

*Comment 3:*

Specifying the saw cut depth will help the contractor prepare an accurate bid as depth and time are related in this operation. It appears the quantity for the inside curb saw cutting is not included in the bid item. The added quantity is estimated at 14,000 LF. At more than 25 percent of the existing bid item a price adjustment would have been allowed potentially at the 10 percent premium. This comment is therefore valued at:

$10\% \times 32,500 \text{ LF} \times \$1.42/\text{LF} = \underline{\$4,615}$ . This comment is estimated to have medium qualitative value.

*Comment 4:*

This comment would likely result in the elimination of a very thin base course and DGA would be used to compensate for the elevation difference. The following savings is likely:

Elimination of thin base course:

14,000 SY of 2in at 110 lbs/SY-in is 1540 tons at \$75.35/ton = \$116,040

Adds 1610 tons of DGA Base @\$19.15/TON = \$30,830

The pavement change would save the project \$85,200. This comment is estimated to have high qualitative value.

*Comment 5:*

This comment was already addressed in comment 1. This comment is estimated to have medium qualitative value.

*Comment 6:*

A detail for the overlay only section would be helpful for clarity. There is no quantitative value that could be calculated for this comment. This comment is estimated to have low qualitative value.

*Comment 7:*

If this guardrail section were changed by this comment saved:

\$612.60 (Eliminate Type 2A) - \$43.81 (Add Terminal Section Type 1) = \$568.79. This comment is estimated to have low qualitative value.

*Comment 8:*

If this guardrail section were changed by this comment saved:

\$612.60 (Eliminate Type 2A) - \$43.81 (Add Terminal Section Type 1) = \$568.79. This comment is estimated to have low qualitative value.

*Comment 9:*

This comment illustrates a confusing issue on the plans. The plans should note the concrete shoulder as existing and not work to be completed by the contract. This comment cannot be valued quantitatively and has a low qualitative value.

*Comment 10:*

Given this route and usage the liquidated damages should be much more clear. This comment is valuable in that regard but is not able to be evaluated quantitatively. This comment is estimated to have low qualitative value.

*Comment 11:*

If this note were not changed, the contractor could legitimately request a change order bid item for CSB. In that instance this comment saved:

10% x 150 TON x \$19.19/TON = \$288. This comment is estimated to have low qualitative value.

*Comment 12:*

Adding omitted bid item would result in a 10% premium.

10% x \$102.37 x 48 LF (estimated quantity) = \$490. This comment is estimated to have medium qualitative value.

*Comment 13:*

Given this route and usage the liquidated damages should be clearer. This comment is valuable in that regard but is not evaluable quantitatively. This comment is estimated to have low qualitative value.

*Comment 14:*

Given this route and usage the lane limitations should be much clearer. This comment is valuable in that regard but is not evaluable quantitatively. This comment is estimated to have low qualitative value.

*Comment 15:*

Given this route and usage the closures should be much clearer. This comment is valuable in that regard but is not evaluable quantitatively. This comment is estimated to have low qualitative value.

*Comment 16:*

Given this route and usage weekend restrictions should be much clearer. This comment is valuable in that regard but is not evaluable quantitatively. This comment is estimated to have low qualitative value.

*Comment 17:*

This comment would clear up having conflicting notes. It would also clarify how this work is to be paid; either work is incidental or by bid unit prices. Due to the conflicting items this comment cannot be given a quantifiable value. This comment is estimated to have medium qualitative value.

*Comment 18:*

The geotechnical notes should indicate the locations of any sinkholes to be cleaned and how those are to be filled. This comment cannot be given a quantifiable value. This comment is estimated to have low qualitative value.

**Case 2 Analysis**

*Comment 1:*

Note addition to make sawcutting of existing pavement incidental. Without adding this language this issue could have been contested by the contractor. The result would have been paying for the work by change order, the contractor agreeing to do it as incidental, or it being contested to a claim.

In these scenarios, it seems conservative to say the savings was at the change order price.

Estimate of sawcutting required, 46,000 LF @ \$2.10/LF add 10% for a change order = \$106,260

This comment is estimated to have high qualitative value.

*Comment 2:*

Changing to the proper bid item based on 2011 AUBP, would have saved:

\$94 (incorrect item) - \$86 (correct item) x 20,755LF = \$166,000 It is possible field correction would have occurred without this savings.

This comment is estimated to have medium qualitative value.

*Comment 3:*

Based on geotechnical notes, required bid items for some materials adding by change order would have resulted in a 10% premium or the following saving to the project by this comment:

Geotextile TY III 10% x 1350 SQYD x \$1.45/SQYD = \$195

Geotextile TY IV 10% x 6000 SQYD x \$1.56/SQYD = \$935

Total \$1,130

This comment is estimated to have low qualitative value.

*Comment 4:*

Striping Correction, needed 6 inch temporary stripe added.

Cost in the field would have been:

110% x \$0.17 x 209,628 LF - \$0.18 x 209,628 = \$1,475

This comment is estimated to have low qualitative value.

*Comment 5:*

Permanent stripe added for approaches. Calculated savings:

10% x \$0.18/LF x 5200LF = \$95

Temporary Stripe Added for Approach:

10% x \$1.51 LF x 1128LF = \$170

Total: \$265

This comment is estimated to have low qualitative value.

*Comment 6:*

While this comment may have save confusion, it was likely to be field corrected at no cost. It involves the installation of the same device which averages the same cost only with a different lens color configuration. This comment is estimated to have low qualitative value.

*Comment 7:*

Estimated 3 additional signs needed.

9 SQFT\*12.01/SF = 108.09

60 LF of post \$7.40/LF =444

Total \$552.09

This comment is estimated to have low qualitative value.



*Comment 8:*

With 7ft post \$16.58/LF of a quantity of 27,387.5 LF

Regular \$15.49/LF

If change made by change order would be a savings of 10% over, for a savings of \$45,400.

This comment is estimated to have medium qualitative value.

*Comment 9:*

Add items for pipe inspection:

7950 LF for Pipeline video inspection at \$4.70/LF = \$37,365 given that a change order would have cost 10% more = savings of \$3,737

Adding inspection of edge drain system, Lump Sum at \$7,142.86 or at 10% more by change order = savings of \$714.29

Total Estimated Comment Savings \$4,450.

This comment is estimated to have medium qualitative value.

*Comment 10:*

Eliminates 49,942 SQYD @ \$0.20/SQYD of Crown Vetch, approximate savings of:

\$9,988.

This comment is estimated to have medium qualitative value.

*Comment 11:*

No bid item for material around headwalls,

A change order to add 118 TON of material:

No. 2 Stone: \$17.64/TON = \$2,080 (10% would be \$208).

This comment is estimated to have low qualitative value.

*Comment 12:*

CL3 ASPHALT SURFACE 0.50D PG64-22 is 71.99

CL3 ASPHALT SURFACE 0.38D PG64-22 is 69.96

CL4 ASPHALT SURFACE 0.50A PG76-22 is 81.70

CL4 ASPHALT SURFACE 0.38A PG76-22 is 82.75

For the class 3, there are 51,779 tons and for class 4, 267,288 tons.

If this necessary change would have resulted in a change order, it likely would have added \$175,500 conservatively. This comment's resulting savings at 10% would be \$17, 550.

This comment is estimated to have medium qualitative value.

*Comment 13:*

Add quantity for permanent signs:

111 SQFT of Signs @ \$12.82/SQFT

300 LF of post @ \$7.40/LF

= \$3,643.02 this work would be done by change order so actual savings would likely result at \$364.30

It is likely that recommending having a review of signing plans would add signs to the project and therefore save more money so that they would not be added later at the 110% premium.

This comment is estimated to have low qualitative value.

*Comment 14:*

Elimination of unneeded signs and posts:

36 SQFT of Signs @ \$12.82/SQFT

80 LF of post @ \$7.40/LF

Savings of \$1,050.

This comment is estimated to have low qualitative value.

*Comment 15:*

This clarification would eliminate confusion and possible questions but unable to value.

This comment is estimated to have low qualitative value.

*Comment 16:*

Several Areas call for the removal pipe, headwalls, or drop box inlets. Adding this recommended note would eliminate this work as it would be accounted for in clearing operations.

Estimates of these quantities include:

Pipe for removal: 210 LF @ \$12.77/LF

Drainage Boxes to Remove: 33 EACH @ \$475/EACH

Headwalls to Remove: 13 EACH @\$501/EACH

Perforated Pipe to Remove: 68,000 LF , not included in value

Perforated Headwalls to Remove: 110 EACH @ \$84/EACH

Elimination of a possible \$34,109.70.

This comment is estimated to have medium qualitative value.

*Comment 17:*

Being that guardrail weighs about 7 lbs per LF and there is 27,785 LF to remove, that would be 97 tons of guardrail to move an additional 100 miles, conservative estimate of the additional cost added during the project would have been (using a flatbed \$2/mi rate) \$2000. This would value the comment at 10% of that amount or \$200.

This comment is estimated to have low qualitative value.

*Comment 18:*

There was no bid item for granular embankment nor quantity for quarry stone.

A change order to add 800 TON of material:

Granular Embankment: \$25.64/TON = \$20,512 (10% would be \$2,050)

No. 2 Stone: \$17.64/TON = \$14,112 (10% would be \$1,410)

The estimated savings is \$2,000.

This comment is estimated to have low qualitative value.

*Comment 19:*

This comment could eliminate some frustration in constructing the guardrail and median wall transition but likely would not have a monetary value that can be estimated. This comment is estimated to have low qualitative value.

*Comment 20:*

Adding the note would clearly identify the work involved. Also needed is the bid item. This comment would result in the following savings.

$10\% \times 1 \times \$470 = \underline{\$47}$

This comment is estimated to have low qualitative value.

*Comment 21:*

Change to the correct bid item resulted in a savings if the change was made by change order of:

$110\% \times \$2300.55 - \$1296.15 \times 8 = \underline{\$9875}$

This comment is estimated to have low qualitative value.

*Comment 22:*

The change to the correct bid item resulted in a savings of:

$$\text{\$25.45/LF} - \text{\$19.20/LF} \times 159 \text{ LF} = \text{\$995}$$

This comment is estimated to have low qualitative value.

*Comment 23:*

Change to the correct bid item resulted in a savings if the change was made by change order of:

$$110\% \times \text{\$2300.55} - \text{\$1296.15} \times 8 = \text{\$9875}$$

This comment is estimated to have low qualitative value.

*Comment 24:*

Eliminates confusion but there likely would not have been resulting monetary savings.

This comment is estimated to have low qualitative value.

*Comments 25-26:*

While these comments offer very good advice, as survey accuracy can result in severe project issues, there is no way to quantify the value of this comment.

These comments are estimated to have low qualitative value.

*Comment 27:*

While the addition of the suggested notes will add clarity there is no real monetary contribution that can be estimated.

This comment is estimated to have low qualitative value.

*Comment 28:*

This comment would clarify that striping removal was incidental. No accurate estimate of removal quantity can be known without knowing the phasing and of construction. A conservative estimate would be would be 1200 LF (100 LF x 3 stripes at both ends of the project) at \$0.38/LF, this comment resulted in a possible savings of \$456.

This comment is estimated to have low qualitative value.

*Comment 29:*

The Contractor would have to furnish this wall at \$5/LF instead of \$3/LF over approximately 39,000 LF. The resulting saving here would likely have been \$78,000.

This comment is estimated to have medium qualitative value.

*Comment 30:*

Symbol correction is valuable for clarity buy not monetarily quantifiable.

This comment is estimated to have low qualitative value.

*Comments 31-33:*

These comments address the maintenance of traffic and therefore construction sequence phasing of the project. These are routinely adjusted but the project contractor as the sequence presented in the plans are most usually suggested and may not account for many constructability issues. These corrections are valuable to the process and to design understanding but are not monetarily quantifiable.

These comments are estimated to have low qualitative value.

*Comment 34:*

This comment would have assisted with maintenance issues. Had this item been field added it would have contributed the following in extra cost:

Geotextile Fabric TY I \$2.04/SQYD x 800 SQYD (approx.) = \$1650

This comment is estimated to have low qualitative value.

*Comment 36:*

The bridge lengths are approximated at 150 ft each, if this item was added by change order, this comment saved:

10% x 600 LF x \$87.57/LF = \$5,250

This comment is estimated to have low qualitative value.

**Case 3 Analysis**

*Comment 1:*

If the designers were able to incorporate existing storm sewer into the new system, this would automatically eliminate work from the contract. While perhaps the existing system may not be able to be used in its entirety, any piece of it would provide savings.

The maximum savings that could occur for this comment is estimated at:

Storm Sewer 15": 40' x \$42.08/LF = \$1,685

Storm Sewer 24": 30' x \$54.58/LF = \$1,640

Storm Sewer 30": 40' x \$70.48/LF = \$2,820

Total: \$6,145

This comment is estimated to have medium qualitative value.

*Comment 2:*

Issues related to residential mowing have ended up costing the Cabinet in the past in relation to rework to ease slopes for mowing. This comment does not have a quantifiable value to savings from avoiding rework and possible complaints and negative publicity certainly provides value. This comment is estimated to have low qualitative value.

*Comment 3:*

This note will provide clarification that potentially resulting in a savings to the Cabinet. The worst case scenario would have been that the Contractor has anticipated using the stone themselves. The valuation of this comment is difficult but in the worst case scenario the savings to the Cabinet would have been the entire cost of the stone estimated at:

$$350 \text{ CY} \times 1.1 \times \$6.26/\text{CY} = \underline{\$2,400}$$

This comment is estimated to have low qualitative value.

*Comment 4:*

This is often an area where field staff has difficulty getting the contractor to adequately construct entrances when quantities are initially set too low.

If the project needed 1000 TONS and only 250 TONS were originally included the anticipated savings of this comment was:

$$10\% \times 750 \times \$17.77 = \underline{\$1,334}$$

This comment is estimated to have low qualitative value.

*Comment 5:*

These omissions would have cost KYTC an estimated additional:

Remove Pavement Markers

$$10\% \times 63 \text{ each} \times \$10.60 = \$66.78$$

$$10\% \times 2510 \text{ LF} \times \$0.38 = \$95.38$$

Or approximately \$160.00

This comment is estimated to have low qualitative value.

*Comment 6:*

This omission would have cost KYTC an estimated additional  $10\% \times 2,478 \text{ TONS} \times \$17.64/\text{TON}$  or \$4,370. For Crushed Aggregate No.2

This comment is estimated to have medium qualitative value.

*Comment 7:*

The comment does provide clarity but it is likely it would have been rectified by project management staff without consequence to KYTC.

This comment is estimated to have low qualitative value.

*Comment 8:*

The pavement was likely noted as 0.38D. Due to the ESAL's the aggregate needed to be Type B for at least the mainline. The unit price for 0.38D is \$72.37/TON for 0.38B it is \$79.59/TON.

There is a quantity of 239 tons for mainline surface. If done by change order this would have incurred an estimated additional cost to KYTC if 10% of the AUBP or (10% x \$79.59 x 239) \$1,900.

This comment is estimated to have medium qualitative value.

*Comment 9:*

Comment clarifies a note. Not able to value but would have assisted in avoidance of claims.

This comment is estimated to have low qualitative value.

*Comment 10:*

Provides general guidance but not able to value.

This comment is estimated to have low qualitative value.

*Comment 11:*

General comments not value added.

This comment is estimated to have low qualitative value.

#### **Case 4 Analysis**

*Comment 1:*

It is not possible to quantify this comment but it would provide valuable to the Contractor and thereby value to the Cabinet. This comment is estimated to have low qualitative value.

*Comment 2:*

This comment is difficult to quantify but brings to light a concern that if alleviated could result in substantial savings to the Cabinet. The phasing of the project is showing excavation is excess of that needed for final design configuration. While this cannot be shown as a quantifiable savings, qualitatively it stands to reduce project schedule and cost significantly.

This comment is estimated to have medium qualitative value.

*Comment 3:*

This comment is also difficult to qualify and is vague in nature leading the researcher to a concern that reviewers should be cautioned to be specific so designers understand the corrective action needed if any. It is anticipated this comment referred to slurry used for pipe protection during phased construction. In that since a note may have been useful to let the contractor understand if this material was designed to stay in place or to be removed. Pay conditions should also have been noted for the work desired.

This comment is estimated to have low qualitative value.

## Case 5 Analysis

### *Comment 1:*

If this change were made in the field it would have resulted in a change of:

2 feet additional width (1 ¼ inch CL2 Asphalt Surface, 3 inch CL2 Asphalt Base) for a distance of approximately 9000 LF.

The original SY of 1 ¼ inch CL2 Asphalt Surface was 105,592 SY. The additional would be 2000 SY.

The original SY of 3 inch CL2 Asphalt Base was 211,495 SY. The additional would be 2000 SY.

Because these additional quantities do not change the bid quantity by 25%, there would not be a price adjustment for the change order. The issue would still necessitate issuing a change order for quantity and perhaps the contractor may dispute the price. Therefore, a quantitative value cannot be placed this comment, but qualitatively, with consideration given to the maintenance issues that would have resulted if the paving was not to the face of the guardrail.

This comment is estimated to have medium qualitative value.

### *Comment 2:*

This comment mentions the removal of guardrail also addressed by comment 2 and the type 7 end treatment was covered in comment 5, but it does mention other missing bid items that if added by change order would have resulted in paying a premium:

#### Guardrail Delineators

For 10,100 LF (permanent & temporary guardrail), using mono-color white delineators every 75 LF, would add 135 delineators. The value for this item is:  $10\% \times \$5.77 \times 135 = \$78$

#### Video Pipe Inspection

This would have covered 3575 LF of pipe.

The value would have been:  $10\% \times 3575 \text{ LF} \times \$4.70/\text{LF} = \$1,680$

Total value of this comment: \$1,758

This comment is estimated to have low qualitative value.

### *Comment 3:*

While this comment is hard to value the switch for an excavation project to and embankment project can result in costly changes to KYTC if proper language or notes are not included in the plans. This comment is estimated to have medium qualitative value.

### *Comment 4:*

There is approximately 480 LF of guardrail to be removed. Without a bid item, this could have resulted in a change order. This comment is worth



$$480\text{LF} \times 110\% \times \$1.43/\text{LF} = \$755$$

Plus removing 1 end treatment at:

$$110\% \times \$122.43 = \$135$$

$$\text{Total} = \underline{\$890}$$

This comment is estimated to have medium qualitative value.

*Comment 5:*

Changing to the cheaper guardrail option shows a resulting savings of:

$$\$2,012.58 \text{ (Type 1)} - \$612.60 \text{ (Type 2A)} = \underline{\$1,400}$$

This comment is estimated to have medium qualitative value.

*Comment 6:*

It appears there needs to not only be a bid item for resetting fence but perhaps installing fence.

Resetting fence would have added:

$$110\% \times 20\text{LF} \times 6.35/\text{LF} = \$140$$

Installing new fence would have added:

$$110\% \times 80\text{LF} \times 7.87/\text{LF} = \$690$$

$$\text{Total savings by the comment} = \underline{\$830}$$

This comment is estimated to have medium qualitative value.

*Comment 7:*

The existing pipe to safeload would take: 2 CY of safeloading material. Since safeloading is not a bid item, if this work were added by change order, this comment is valued at:

$$10\% \times 2\text{CY} \times \$204.85 = \underline{\$41}$$

This comment is estimated to have medium qualitative value.

*Comment 8:*

The end terminal change would have cost:

$$110\% \times \$1,000.02 \text{ (Type 7)} - \$43.81 \text{ (Terminal Section No.1)} \times 6 \text{ (number of treatments)} = \underline{\$6,330}$$

This comment is estimated to have medium qualitative value.

*Comment 9:*

Without switching the bid item the Contractor may have argued that there was an omission and they should be able to bid the wedging quantity at a change order price.

The prices would have been 110% x \$19.15/TON. The approximation of wedging would have been about 150 TONS. Therefore the savings from this comment is \$3,160.

This comment is estimated to have low qualitative value.

*Comment 10:*

If the earthwork to do the temporary widening was not included, the result would be an overrun in quantity but most likely at the bid price. If the earthwork was included but not called out as temporary there is potential it could have resulted in added cost but not likely. In both cases, this comment cannot be valued.

This comment is estimated to have low qualitative value.

*Comment 11:*

An added note to identify rock quantities for the working platform adds clarity but no quantifiable cost.

This comment is estimated to have low qualitative value.

*Comment 12:*

This comment also cannot be valued because quantities could not be determined from the plans. It is also likely that changing between these bid items would have resulted in much immediate savings to the work aside from more flexibility and clarity to rectify the situation as the field staff saw fit. Paying by the unit will incentivize the contractor to do as little as possible where paying by the quantity allows KYTC field staff to control the situation. These situations are red flags because if there is a conflict, they can become costly to KYTC. Due to the potential of dispute avoidance, this comment is estimated to have medium qualitative value.

*Comment 13:*

This comment cannot be valued. It is likely, that designs review of the plans showed the unregistered bid item of junk removal. The comment noting it is needed will ensure there is some means of paying for what was noted in the geotechnical report as a possible landfill or junkyard. Attempting to have it covered by the earthwork bid items may result in claims for geotechnical issues. Having a bid item for this work will clarify the situation and provide protection from claims. Due to the potential of dispute avoidance, this comment is estimated to have medium qualitative value.

**Case 6 Analysis**

*Comment 1:*

This comment does not provide a quantifiable value but by providing clarification. This comment is estimated to have low qualitative value.

*Comment 2:*

If flowable were not noted, yet required by specification, the contractor could argue for an addition by change order. If noted, the cost for that operation would be included in the pipe price. In the case of a change order, the savings of this comment is approximately:

$$13\text{CY} \times 10\% \times \$94.93/\text{CY} = \$125$$

This comment is estimated to have low qualitative value.

*Comment 3:*

Quantities do not appear to be included for work required by the geotechnical notes. This work would therefore be done by change order. The resulting savings by this comment is:

Channel Lining Class III

$$62 \text{ TONS} \times 10\% \times \$29.13/\text{TON} = \$180$$

Geotextile Fabric Type I

$$928 \text{ SY} \times 10\% \times \$2.04/\text{SY} = \$190$$

For an approximate savings of \$370.

This comment is estimated to have low qualitative value.

*Comment 4:*

This comment addresses potential safety concerns during the diversion of traffic, i.e. extreme edge drop-offs, this comment cannot be valued quantitatively.

This comment is estimated to have medium qualitative value.

*Comment 5:*

Having improper coordinates in the plans can lead to costly mistakes in the field leading to disputes and potential claims. This comment cannot be valued quantitatively because it only involves the location of a ROW marker.

This comment is estimated to have low qualitative value.

*Comment 6:*

Having improper coordinates in the plans can lead to costly mistakes in the field leading to disputes and potential claims. While this comment cannot be valued quantitatively, its qualitative value is medium.

*Comment 7:*

Most temporary structures for diversions do not need to maintain the hydraulic opening of the existing structure. If the hydraulic opening is correct, the resulting costs to the project may be large. If the opening can be scaled down then this comment would provide substantial value in

both cost and time. While this comment cannot be valued quantitatively, its qualitative value is high.

Also, if the temporary structures is reduced in scale and the previous comment is not addressed, this comment also provides value in terms of lowering the stakes for the contractor and potentially reducing chances for claims related to this issue.

*Comment 8:*

If the note to clarify that temporary drainage structures are incidental to the diversion is not added, this could potentially become a dispute resulting in a change order or potential claim. Using the change order approach to estimate the value of this comment, and considering if incidental the cost would be included in another bid item, this comment saves the project:

To maintain the required hydraulic opening, something to the order of 15, 60" culvert pipes would be needed. The estimated temporary structure would cost:

$$10\% \times \$167.26/\text{LF} \times 28\text{LF} \times 15 = \underline{\$7,025.}$$
 (see next comment)

This comment is estimated to have medium qualitative value.

*Comment 9:*

This comment for increasing entrance widths will improve safety and access for those entrances. While there is no quantifiable value for this comment the qualitative value is considered low.

*Comment 10:*

The fence that would need to be replaced due to the diversion is approximately 400 LF. The savings if this work were added by change order is:

$$10\% \times 400\text{LF} \times \$10/\text{LF} = \underline{\$400}$$

This comment is estimated to have low qualitative value.

*Comment 11:*

This comment makes the correction of using an older form of the bid items. There is not quantifiable value the qualitative value is low.

*Comment 12:*

While the quantities are represented in the plans it is poor practice to have repeating bid items in plans. This comment adds clarity but no quantifiable value the qualitative value is low.

*Comment 13:*

This route does not warrant the Type V pavement markers. Eliminating this work saved:

$$30 \times \$22.86/\text{EACH} = \underline{\$685}$$

This comment is estimated to have low qualitative value.

*Comment 14:*

This comment may not have added quantifiable value but it does clarify the situation and point out to the designer that there is a specific bid item for wrapping pipe. The qualitative value of this comment is low.

*Comment 15:*

This comment is difficult to quantify. It is difficult to determine if rock roadbed quantities are included for the daylighting as mentioned in the comment and shown in the detail. However, the detail does conflict the typical section and this could have led to project disputes or claims, and therefore the qualitative rating of this comment is medium.

**Case 7 Analysis**

*Comment 1:*

The drawings show extra paving under the guardrail. Heeding this comment and only paving to the face of the guardrail would save 400 SF of pavement design or the following:

Class 2 Base: 16 TONs x \$64.73/TON = \$1036

Class 2 Surface: 3 TONs x \$72.37/TON = \$217

Total: \$1253

This comment is estimated to have low qualitative value.

*Comment 2:*

Adding bid item for staking:

Because this bid item is a Lump sum and will vary widely by project the savings would be 10% x 0.35% x Project cost based on average unit bid price percentages.

\$400,000(Project estimate) x 10% x 0.35% = \$200

This comment is estimated to have low qualitative value.

*Comment 3:*

Adding Seeding and Protection

10% x 8785 SY x \$0.33 = \$289.90

This comment is estimated to have low qualitative value.

*Comment 4:*

Adding Temporary Mulch

10% x 1283 SY x \$0.14 = \$18

This comment is estimated to have low qualitative value.

*Comment 5:*

To add erosion control and channel lining this comment saved:

Channel Lining Class III

$$10\% \times 16 \text{ TON} \times \$29.13 = \$46.61$$

Erosion Control Blanket

$$10\% \times 1283 \text{ SY} \times \$1.04 = \$133.43$$

Total: \$180.04

This comment is estimated to have low qualitative value.

*Comment 6:*

If sod was added by change order the value of this comment would be:

$$10\% \times 111 \text{ SY} \times \$4.95 = \underline{\$55}$$

This comment is estimated to have low qualitative value.

*Comment 7:*

Adding barricades for traffic control would have avoided adding them by change order at 10% premium. Also, it would have clarified if they were meant to be part of MOT or not...avoiding a dispute claim.

$$4 \times 10\% \times \$171.49 = \underline{\$68.60}$$

This comment is estimated to have low qualitative value.

*Comment 8:*

This comment was addressed in comment 11, adding the bid item for pavement removal.

This comment is estimated to have low qualitative value.

*Comment 9:*

The omission of the bid items to satisfy the geotechnical note would have been added at the 10% premium for a change order. Based on that, this comment would be valued at:

Geotextile Fabric Type 4:

$$1156 \text{ SY} \times 10\% \times \$1.56 = \$180.34$$

Stone:

$$110 \text{ TON} \times 10\% \times \$17.64 = \$194.04$$

Total: \$374.38

This comment is estimated to have low qualitative value.

*Comment 10:*

Not clearly indicating areas of pavement to be removed can cause disputes and arguments in the field. The quantitative value of this comment is captured in the previous comment.

This comment is estimated to have low qualitative value.

*Comment 11:*

Leaving old pavement can cause an unsightly and potentially hazardous situation. Removing this pavement by change order would create a value for this comment of:

$$1088 \text{ SY} \times 10\% \times \$6.99 = \underline{\$760.50}$$

This comment is estimated to have low qualitative value.

*Comment 12:*

Providing a north arrow, does not add quantitative value but would potentially save time by clarification and easing the orientation of the plans to the jobsite. This comment is estimated to have low qualitative value.

*Comment 13:*

This comment brought to light what could have been a serious maintenance issue that would have been much more costly to fix after the fact than during construction. If this work would have been added by change order it would have been at a 10% premium so an estimate of the savings of this comment is:

4 concrete flumes

$$10\% \times 4 \times \$3,589 = \$1,436$$

Approximately 40 feet of island header curb

$$10\% \times 40\text{LF} \times \$21.01/\text{LF} = \$84$$

$$\text{Total} = \underline{\$1,520}$$

This comment is estimated to have medium qualitative value.

**Case 8 Analysis**

*Comment 1:*

Adding the missing bid item would be done by change order and result in the following savings.

$$10\% \times 1 \times \$5499.55 = \underline{\$550}$$

This comment is estimated to have low qualitative value.

*Comment 2:*

For the missing pipe quantities, a change order would have been used to add the quantities. Because the quantities would change the totals by more than 25% a price adjustment would have been allowed.

The approximate savings of the comment is:

Pipe at STA 1+060:  $10\% \times 70.5 \text{ LF} \times \$119.71/\text{LF}$  (48in culvert pipe) +  $10\% \times 2 \times \$2300$  (headwalls) = \$1304

Pipe at STA 1+172:  $10\% \times 156.5 \text{ LF} \times \$80.24/\text{LF}$  (24in culvert pipe) +  $10\% \times 2 \times \$1169.24$  (headwalls) = \$1490

Total: \$2794.00

This comment is estimated to have low qualitative value.

*Comment 3:*

Again there is confusion relating to the materials that KYTC will supply. Details should be added to explain to the contractor the types and sizes of the material that will be supplied and whether any additional materials are need for the related items. There is not a method to quantitatively value these comments but the qualitative value is medium.

*Comment 4:*

This comment adds value as it illustrates that there is quite a bit of confusion regarding work previously completed, work included in this project, and items supplied by the KYTC versus those the Contractor will have to procure. Project that entail pieces and subparts of other projects are often a coordination concern and must be detail to an extent beyond standard projects. There is not a method to quantitatively value these comments but the qualitative value is medium.

*Comment 5:*

This comment definitely adds value because it indicates that work has been omitted from one the summary sheets which most contractors use when preparing a bid. It is not clear in the project plans what work is existing and what work is omitted and therefore this comment cannot be valued quantifiably. This comment is estimated to have medium qualitative value.

*Comment 6:*

Adding a note to indicate that the contractor is expected to coordinate with the adjacent project contractor will clarify that situation exists on this project. There may likely still be issues related to this situation but potentially not an outright dispute that the situation should have been noted. This comment cannot be values quantitatively but would have a qualitative vale of medium.

*Comment 7:*

This particular project has segments previously completed through other projects. Rework is not expected but is likely to be needed. Without the recommended note the contractor would request a change order for any changes in the grade work. The work would use existing project



bid items so the quantifiable value is \$0, but qualitatively low to avoid disputes and the time and effort necessary to process a change order.

*Comment 8:*

Clarifying when work is involved on a project or not is very important. Because there is some ambiguity here there may be grounds for the contractor to file a claim regarding a miscommunication of work. Typically, the bid quantities would hold but there is not a sound method for placing a quantifiable value and for the amount of work the qualitative value is medium.

*Comment 9:*

Adding this note to clarify there are not additional payments for lane closures clarify that the contractor should not expect additional payment for these efforts. Without the note there is potentially that this would have become a point of dispute and possible change order. If added by change order this comment would save:

$$10\% \times \$1,776.50 \times 2 = \underline{\$355}$$

This comment is estimated to have low qualitative value.

*Comment 10:*

While there is no way to quantifiably value this comment, extended detours due to closures can be very problematic and can effect safety relating to access for emergency vehicles. If the volumes and alternate routes reviews indicate a problem increase liquidated damages for closures would incentivize contractors to minimize closures. This comment is estimated to have medium qualitative value.

*Comment 11:*

Incorrect coordinate information can be very problematic to a project. This comment is more of a clarification than address any error. While not able to quantify its value, qualitatively it is of low value.

*Comment 12:*

It appears only a few locations would need flowable fill for backfill of pipes. An approximate quantity of 46 CY. If added by change order that give this comment the following value:

$$10\% \times 46\text{CY} \times \$94.93/\text{CY} = \underline{\$440}$$

This comment is estimated to have low qualitative value.

**Case 9 Analysis**

*Comment 1:*

Survey and layout information is very important for inclusion in the plans. While this comment cannot be given a quantifiable estimate, qualitatively the value is low.

*Comment 2:*

Having the incorrect bid item description, may have resulted in a dispute with the contractor about what was the correct bid item to be installed. It is likely that a change order would have ensued to install the correct item. The quantitative value of this comment in that case would be:

$$10\% \times 15 \times \$82.71 = \underline{\$124}$$

This comment is estimated to have low qualitative value.

*Comment 3:*

This omitted bid item would have incurred a change order and therefore results in the following savings to this comment.

$$10\% \times 100\text{LF} \times \$30.55/\text{LF} = \underline{\$306}$$

This comment is estimated to have low qualitative value.

*Comment 4:*

Due to the omitted work for removing guardrail, a change order would have been added to address this issue. The savings of this comment is:

$$10\% \times 80\text{LF} \times \$1.43 = \underline{\$12}$$

This comment is estimated to have low qualitative value.

*Comment 5:*

Omitted bid item for signs, would have resulted in a change order for this work. This comment is valued per the following.

$$10\% \times 360\text{SQFT (estimated quantity for temporary signs)} \times \$4.57 = \underline{\$165}$$

This comment is estimated to have low qualitative value.

*Comment 6:*

Demobilization is usually an item that would be set by specification at 1.5% of the project cost or \$1000 at a minimum. If this bid item were added by change order, there is potential that a contractor may request more than the minimum amount. A 10% premium is a very conservative estimate for this amount.

$$10\% \times 1.5\% \times \$900,000 = \underline{\$1,350}$$

This comment is estimated to have low qualitative value.

*Comment 7:*

Structural bid items are normally not duplicated in the general plan summary. While this duplication may have caused some confusion it is not possible to quantify the savings and the qualitative estimate of the comment value is low.

*Comment 8:*

Because the culvert headwall bid item was omitted, it would have been added by change order without this comment. Therefore the value of this comment is:

$$10\% \times 2 \times \$1746.94 = \underline{\$350}$$

This comment is estimated to have low qualitative value.

*Comment 9:*

Conflicting bid items can be problematic. In this case, if the Contractor argued that the plans indicated using Class II channel lining over Class III, the work would be \$0.26 more per ton. Being that the work involved is 51 tons, you might estimate the value of this comment at \$13, but the qualitative value avoiding potential disputes or questions regarding the conflicting items, is medium.

*Comment 10:*

This comment is value in order to have quantities of stone available for different maintenance of construction items. Letting designers know they need to account for these items also adds value. Due to the small quantity added, their as-bid quantity would not have increased such that a change order to add these quantities would have warranted a price adjustment. Therefore, this comment cannot be valued quantitatively but because a change order may have been needed to add the quantity, it has a qualitative value of low.

*Comment 11:*

This comment addresses two concerns. One that entrance radii should always be noted on the plans for clarity. Second when entrances are narrow and entail small radii, large vehicles may have trouble navigating these turns. Often, these issues are not discovered in the field until constructed/or partially constructed allowing some level of public use. As such, it is difficult to determine what the added costs that change order would have incurred so no quantitative estimate is possible. Due to the time required to solve this problem in the field and potential for remobilization costs, the qualitative value of this comment is medium.

*Comment 12:*

Locations of the right-of-way monuments need to have clear and accurate survey information. If this is not shown on the plans it may not lead additional costs to the project, but it would lead to frustration and added time for the project engineer and contractor. While this comment cannot be valued quantitatively, its qualitative value is low.

*Comment 13:*

This comment presents a drastic savings opportunity to the designer. There is no way to calculate a value stemming from this comment, but it is heeded and if the geotechnical report supports that the area is stable, the opportunity to reduce the right-of-way required and the amount of earthwork in the project could result in significant savings to the project. The qualitative value of this comment is medium.

*Comment 14:*

While again there is no way to quantify savings from this comment, it does present an opportunity to improve safety, reduce construction impacts, improve access, and simply product

a better product. Because the changes would not necessarily result in a large monetary savings to the project, the qualitative value is estimated at medium.

*Comment 15:*

This comment points out a vertical alignment error. There is potential that if the wrong number was used over excavation would have resulted. Correcting this error ensures that will not happen. The over excavation could also have led to design issues related to the supporting roadway facilities of guardrail, drainage systems, etc. The qualitative value of this comment is estimated at medium. The quantitative value limited only to the over excavation of earthwork is estimated at:

$$6\text{CY} \times \$3.60/\text{CY} = \underline{\$21.60}$$

This small value does not accurately represent the potential impacts of this comment.

*Comment 16:*

The omission of an entrance could be a costly change order. Below is an estimate of this savings of this comment using 10% as the premium that would have been charged by change order. The actual change would incur more costs than those represented below.

Guardrail Alterations:

$$10\% \times 30\text{LF} \times \$15.49/\text{LF} \text{ (added guardrail)} + 10\% \times \$43.81 \text{ (added terminal section)} = \$51$$

Pavement Additions:

DGA Base:

$$35.5 \text{ SY} \times 4\text{in} \times 115\text{LB}/\text{SY}/\text{in TON}/2000\text{LB} = 8.2 \text{ TON} \times 10\% \times \$19.15/\text{TON} = \$16$$

Pavement Base:

$$31.1\text{SY} \times 3\text{in} \times 110\text{LB}/\text{SY}/\text{in TON}/2000\text{LB} = 5.13 \text{ TON} \times 10\% \times \$61.35/\text{TON} = \$32$$

Pavement Surface:

$$31.1\text{SY} \times 1.25\text{in} \times 110\text{LB}/\text{SY}/\text{in TON}/2000\text{LB} = 2.14 \text{ TON} \times 10\% \times \$72.37/\text{TON} = \$16$$

Total estimated savings: \$115

This comment is estimated to have medium qualitative value.

*Comment 17:*

Adding the notes concerning pavement edge drop off and minimum lane widths provide clarity and safety to the project. Without being clearly stated it leaves the point up for contention and may cause arguments in the field concerning these issues and possibly adding work to the contract. This comment cannot be quantitatively valued but it would have a qualitative value of medium.

*Comment 18:*

There is no way to quantitatively value this comment but it does indicate that the MOT phasing is not possible. In other words, the project cannot be constructed as designed. While MOT phasing is often changes by the Contractor, the initial plan must still be feasible. The qualitative value of this comment is medium.

*Comment 19:*

This recommendation would provide clarity regarding grade and side slopes for the subject entrance. No quantifiable value can be estimated and the qualitative value is low.

*Comment 20:*

The specification required backfill of this pipe using flowable fill would have required a change order if it were not noted in the plans. The value of this comment is therefore:

$$10\% \times 8.33 \text{ CY} \times \$94.93/\text{CY} = \underline{\$79}$$

This comment is estimated to have low qualitative value.