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Kentucky Transportation Center

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Updating the Kentucky Contract Time Determination System

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The Federal Highway Administration requires State Transportation Agencies to have a formal method to estimate contract time for highway construction projects. To meet this requirement many states use an integrated scheduling system to estimate project durations based on assumed productivity rates and generic job logic. The current work investigated the accuracy of two of these systems found that both systems accuracy in predicting the duration of Kentucky Transportation Cabinet projects was greater than ±200%. In response to this poor accuracy, a parametric project duration estimating tool was developed based on a multivariate regression analysis of bid item quantities and engineering and construction estimate. Five regression models were develop to estimate contract time for large projects (great than $1,000,000) based on key bid item quantities; limited access (±22% median error), open access (±35% median error), new route (±55% median error), bridge rehabilitation (±77% median error), and bridge replacement(±17% median error). It was not possible to develop a parametric estimating tool for predicting the duration of small projects (less than $1,000,000) as it appears that the duration of small projects is determined by factors outside of bid item quantities.</td></tr>
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1.0 Introduction

The Kentucky Contract Time Determination System (KY-CTDS) was implemented on February 9, 2000 with the intention of providing a tool to assist the Cabinet in estimating contract time for Kentucky Department of Transportation (KY-DOT) projects. Estimating contract times accurately can create a significant benefit to all parties involved. By completing work in a timely manner, both the agency and the traveling public are beneficiaries. The state agency does not incur additional administrative or inspection costs typically seen on over-length projects. Also, the public does not incur additional road user costs associated with delayed projects. Road users are affected by possibly having an extended travel distance, additional travel time, and potentially a decrease in safety (Williams 2006). Contract time is important to all aspects of a project. An unreasonably short contract time can raise the bid prices, restrict qualified bidders from submitting bids, potentially reduce quality of the work, and increase the possibility of legal disputes. On the other hand, contract times that are too long are a general inconvenience for the traveling public and encourage less qualified contractors to submit a bid (Williams 2006).

The Federal Highway Administration (FHWA) stresses the importance of accurate contract time. They require individual states to develop and implement contract time determination procedures for construction projects through 23 CFR 635.121. Suggestions to assist in implementing the procedures are provided in the FHWA Guide for Construction Contract Time Determination Procedures (FHWA 2011). The guide gives multiple suggestions of factors to consider on a project-by-project basis when determining a contract time (Williams 2006). The incentives associated with determining an accurate and reasonable contract time are paramount to the success of the state agency, the department of transportation.

The KY-CTDS was developed from a previous system that was written as a mainframe application, which was then updated to a personal computer based application. The personal computer-based application contained the same core scheduling logic, without upgrade, and remained the same mainframe machine structured logic, containing only one project template (Hancher 2000). From this pc-based structure, a more relevant computer based program was developed in 2001 using Microsoft Excel and Microsoft Project, both commercially available software packages and accessible to the Kentucky Transportation Cabinet (KTC). What resulted from the study was a more user friendly system that included six templates with built-in logic and productivity rates for each work activity. The system provided both tabular and graphical documentation useful in the planning process (Hancher 2000). The research team hosted a conference to provide training on how to use the newly developed system and provided all attendees with the six templates electronically, as well as a copy of the operating manual.

Since the system was launched in 2001 the accuracy of the system in predicting contract time has not been checked, and the system has not been updated. The work described herein examines the current use of the system and analyzes the accuracy of the system in predicting project duration. The outline for this report will encompass portions of the overall research project. This includes but is not limited to the literature review, evaluation of the current system's use, and an analysis of system accuracy on past cabinet projects. The literature review will examine other states' current procedures in determining contract time for department of transportation projects, and other general but interesting topics for discussion related to determination of contract time for highway construction projects. The use of the current system was evaluated through meeting(s), a survey, and interviews with persistent users. Analyzing the current system involved a comparison of actual project duration data supplied by the cabinet with durations obtained from the system using quantities from bid tabs also supplied by the Cabinet. The analysis also included another system for comparison, the State X Time Determination System, in which the contract time among the sample of the Cabinet's project were also estimated using another state's contract time determination system. The final objective of the current work was to recommend improvements to the existing contract time determination system.

The research updated the KY-CTDS by completing the following objectives:

A. Identified the extent of use of the KY-CTDS by Cabinet personnel for planning highway projects. This information quantified the use of the tool and, if use was not widespread, identified reasons for underutilization of the tool.
B. Identified the accuracy of the tool on completed projects by comparing the project's actual schedule and duration with predicted schedule and duration from the KY-CTDS. This identified any deficiencies in the original system templates, work item productivities, and/or generic project logic.
C. Identified recommended updates to the original system including software, databases, and project templates. This information ensures that the system is updated with recent productivity data from Cabinet and commercial data sources (e.g. RS Means).
D. Identified potential expansions of the original system to better reflect current and future cabinet projects.

1.1 Practices at Other State Departments of Transportation

The research time examined practices at other state Departments of Transportation (DOT) through a review of published literature on their methods for determining contract time. A spreadsheet including what states were found, and reference files, is shown in the State

Breakdown of Contract Time Determination Systems in Appendix A. The tools and methods in use at DOTs were categorized into one of the following categories: archived production rates (i.e the system relies solely on production rates for critical activities), pre-determined logic (the system uses predetermined schedules and separate production rates), or integrated scheduling (the system has an integrated production rate and schedule logic based on bid item quantities). Of the 50 states, 29 DOT contract time determination systems were available for examination. The categorical break down was as follows: 48 percent use some form of integrated scheduling, 28 percent use archived production rates and 17 percent develop a contract time based on pre-determined logic. The additional 7 percent accounted for the two systems that didn't necessarily fit into one of the three categories. A breakdown of which states fell into each category is displayed in the State Classifications in Appendix A, while Figure 1 below illustrates the difference in each of the three categories. A system considered to be in the integrated scheduling category would use both archived production rates and pre-determined logic. A system in the archived production rate category would not make use of a pre-determined logic, which would eliminate said system from being in the integrated scheduling category.

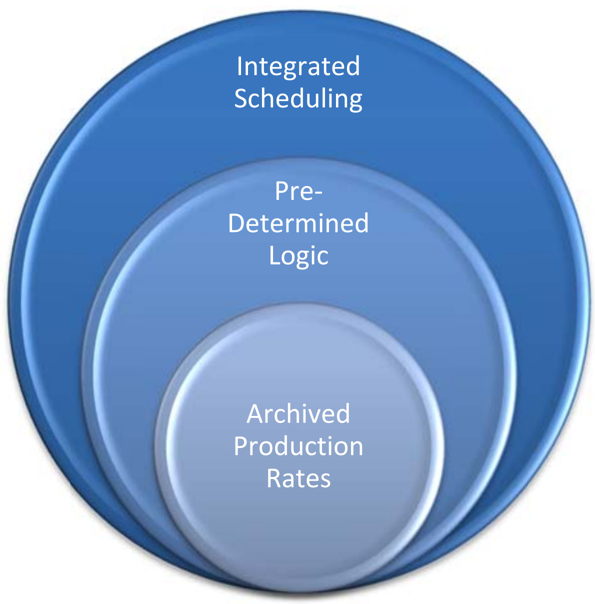

Figure 1: Encompassing System Classifications

Some form of archived production rates were found in most of the systems examined in the literature review, but systems included in this category were typically limited on any further method to aid in contract time determination.

The second category used was for states that had implemented a system using a pre-determined logic. These systems could have a pre-determined logic for work scheduling and phasing while using another method for determining work durations. For the most part, systems involving a pre-determined logic had some type of productivity rates; whether general or specific to state highway projects they were used to calculate activity durations within the logic. Of the three categories for this research project, the least number of systems fell into pre-determined logic, which is most likely due to the wide variety of possibilities when considering what and how activities correlate with one another. For that reason, states take an approach of a project-by-project basis when determining the logic instead of having a generic template. Systems examined in the review often had templates associated with project types commonly encountered in their state. Templates could range from a couple to more than a dozen options and each could have a different logic and/or production rate associated with the individual work activities.

Integrated scheduling was the most abundant category utilized by state department of transportation's method for determination of contract time examined in the literature review. Systems that were categorized here may have also used pre-determined logic in combination with archived production rates; but further action had to be seen that showed a way of integrating the multiple components that create a contract time. It seems the trend is leaning toward states having a method that involves integrated scheduling for determination of contract time. The Kentucky's Contract Time Determination System (KY-CTDS) falls into the integrated scheduling category and is described in more detail in section 3.

With each category, there are many possibilities for using each method; some systems are developed within the department while others may pursue more commercially available systems that are already structured to perform scheduling tasks. Combinations of the methods are seen in an attempt to create a customized system to best suit each department's needs. This could range from a way to input current productivity rates, to determining logic based on certain aspects of a project, to inputting working day calendars based on holidays and weather conditions in a given region. Some programs found use Microsoft software such as, Access, Excel, and Project where variability in inputs is fairly easy but complex data interaction can be limited, while others use systems developed by professional software developers such as Primavera and FieldManager which can create much more complex components, but tend to limit user defined inputs that may vary from project to project.

2.0 Current Use

An online survey was used to examine the current use of the KY-CTDS to estimate contract duration within the Kentucky Transportation Cabinet. To determine our sample population for the survey, contacts were made through each of the Cabinets' 12 districts through their respective engineering branch managers. Upon contacting these individuals, it was requested that each branch manager identify potential users of the existing contract time determination system within their district. After receiving replies from the majority of the districts, 36 potential KY-CTDS users were identified.

Once exemption from the Institutional Review Board (IRB) was filed and approved with the UK Office of Research Integrity, the survey was distributed. A copy of the IRB approval letter is included in Appendix B. For distribution purposes, Qualtrics, a survey software, was used to generate a user-friendly survey that allowed the question types needed for a successful survey. Qualtrics had the capability to track completed surveys individually and multiple options for reporting results in aggregate form to include statistical parameters associated with multiple-choice questions. The reporting format could be organized in a way that made it straightforward to sieve through results and comments.

Participants had approximately three weeks to complete the survey with a one-week reminder sent out before the survey was to become inactive. Of the 36 individuals contacted, 23 surveys were completed with varying levels of detail. The survey was comprised of 24 questions, which varied from simple multiple choices, to matrix style, to more complex thought required writing oriented questions. The results received from the survey gave a range of answers that helped to define the current status and use of the system across the state. A copy of the survey is included in Appendix B, KY-CTDS Update Survey.

2.1 Survey Results of Current Use

Survey results showed that 85 percent of participants are familiar with the KY-CTDS, yet only 50 percent use the system to estimate contract time (Figures 2-3).

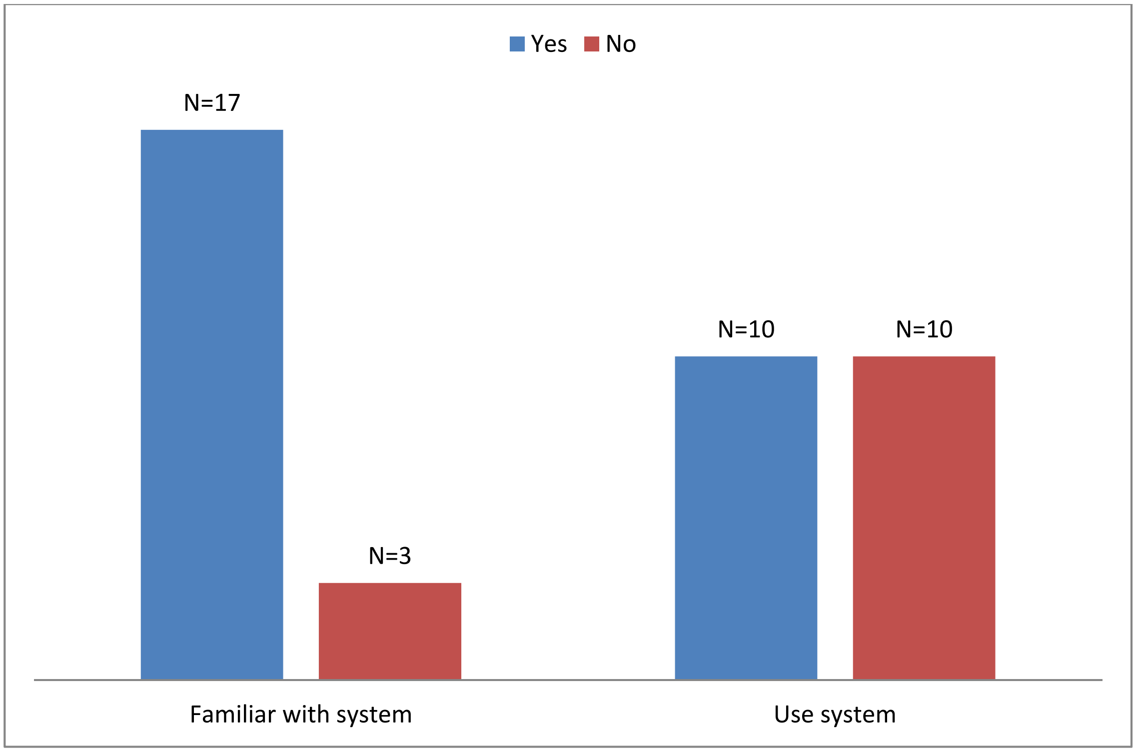

Figure 2: KY-CTDS Familiarity and Use

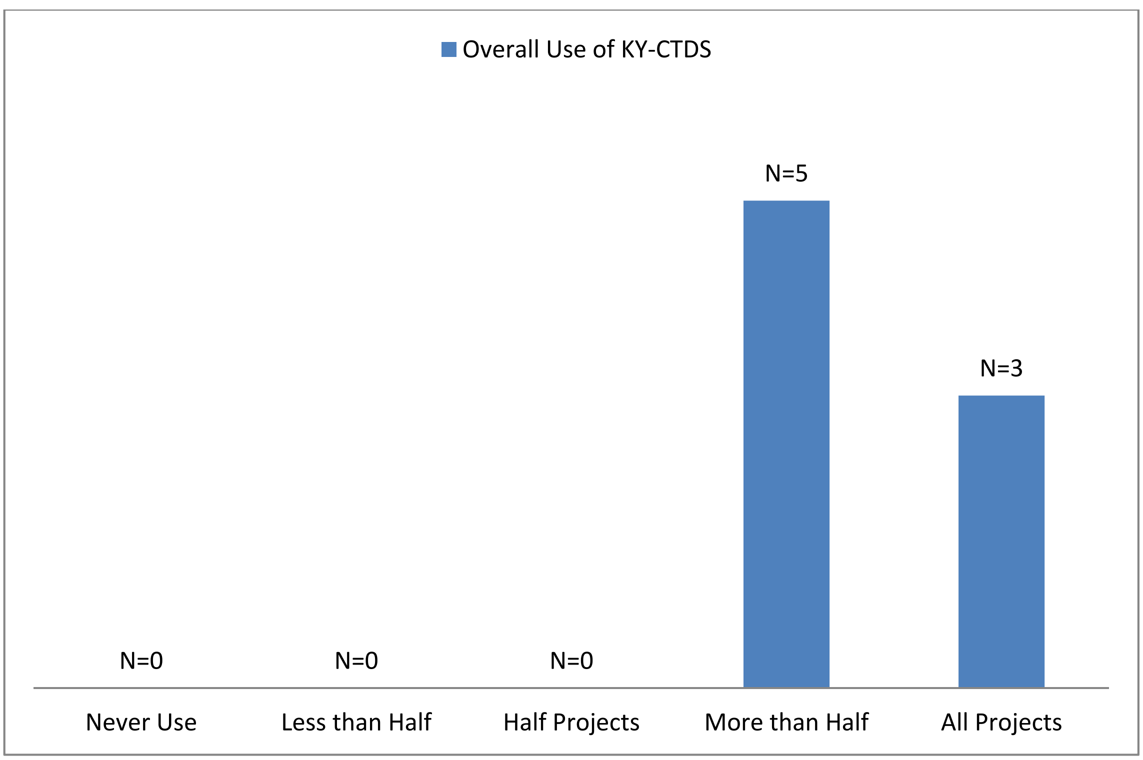

Figure 3: Overall Use

The next few survey questions dealt with the effectiveness of certain system components and the time required to estimate contract time for a given project. The general consensus from the system effectiveness question was that the system provides a good starting point for construction personnel, but modifications to productivity rates and logic are sometimes adjusted to better suit project conditions. A summary of the responses is shown in Figures 4-6.

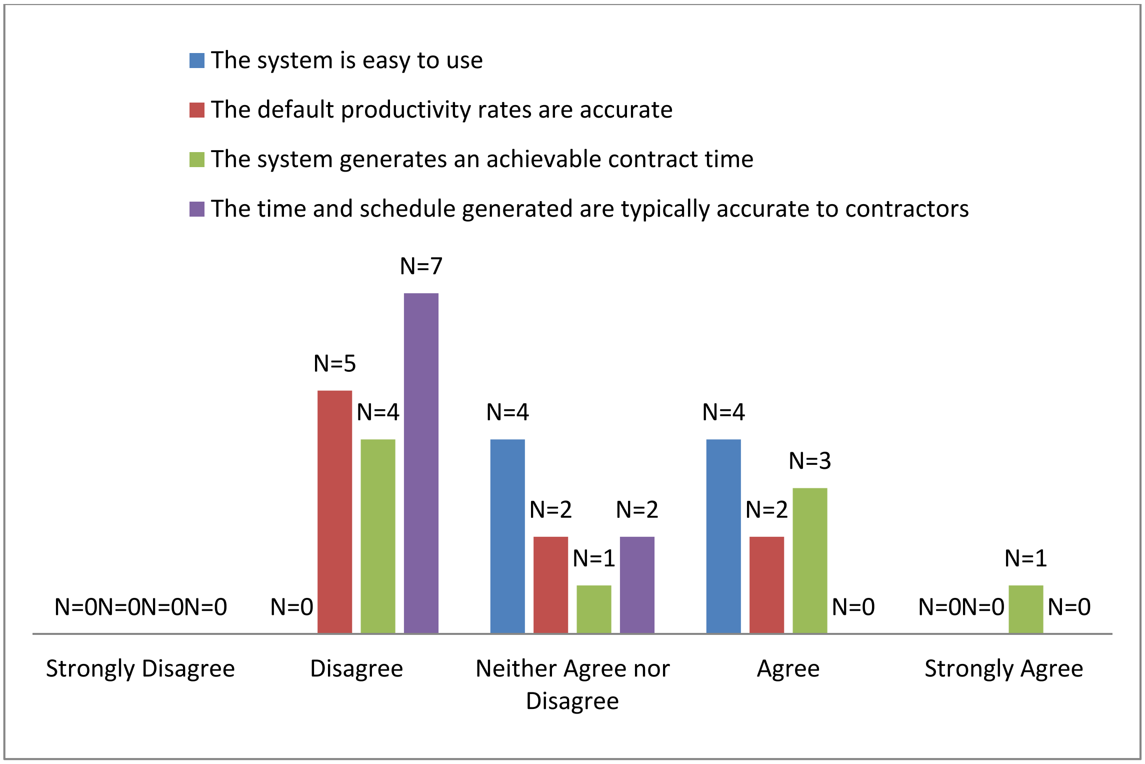

Figure 4: KY-CTDS Effectiveness

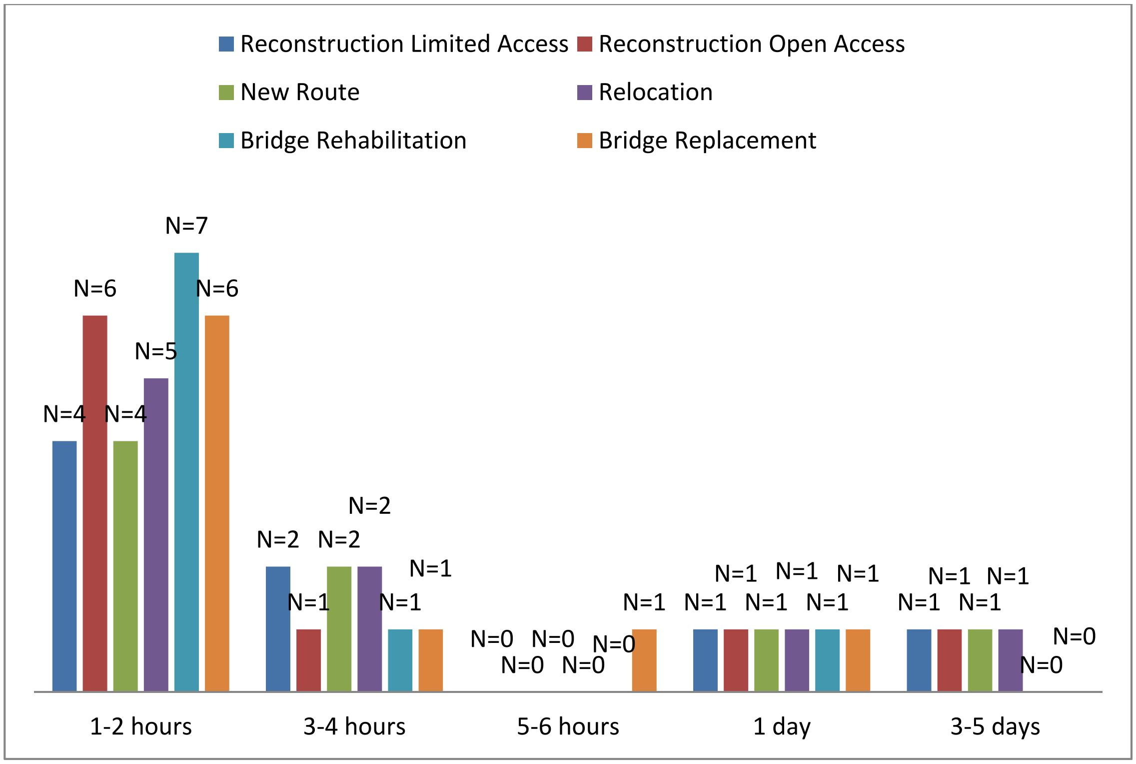

Figure 5: Time to Complete (<$500,000)

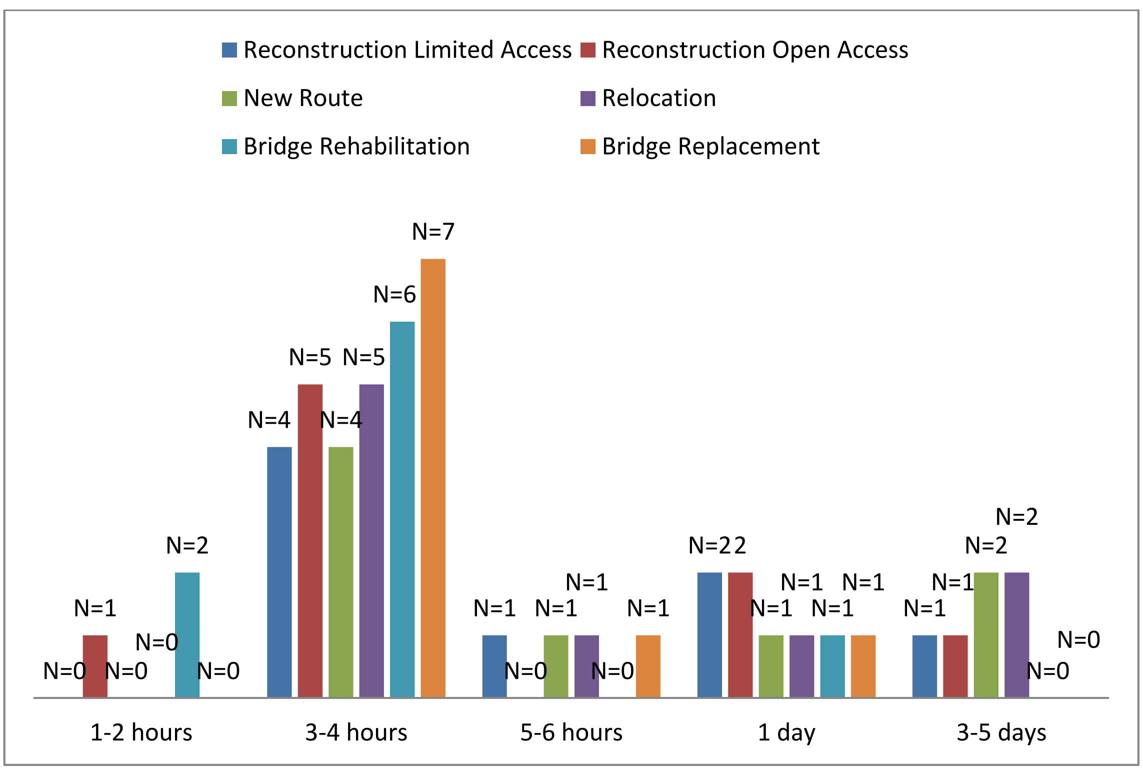

Figure 6: Time to Complete (>$500,000)

The next few questions in the survey focused on the default productivity rates included in the system. Although the productivity rates were set to reflect highway construction projects, the system is flexible enough to allow users to adjust the rates. The overall impression from users was that the productivity rates do need to be adjusted. Users who adjust the rates seemed to use past projects and experience in addition to consulting with construction personnel to identify what they considered to be a more accurate productivity rate. These aspects could account for a significant increase in project duration and including them should be heavily considered when developing a schedule that is used to set contract time. These items were unknown from the perspective of the research team and with many ways to include items, such as holidays, seasons, and weather, the question could potentially provide information that would relate to an update in the system. The results are shown in Figure 7.

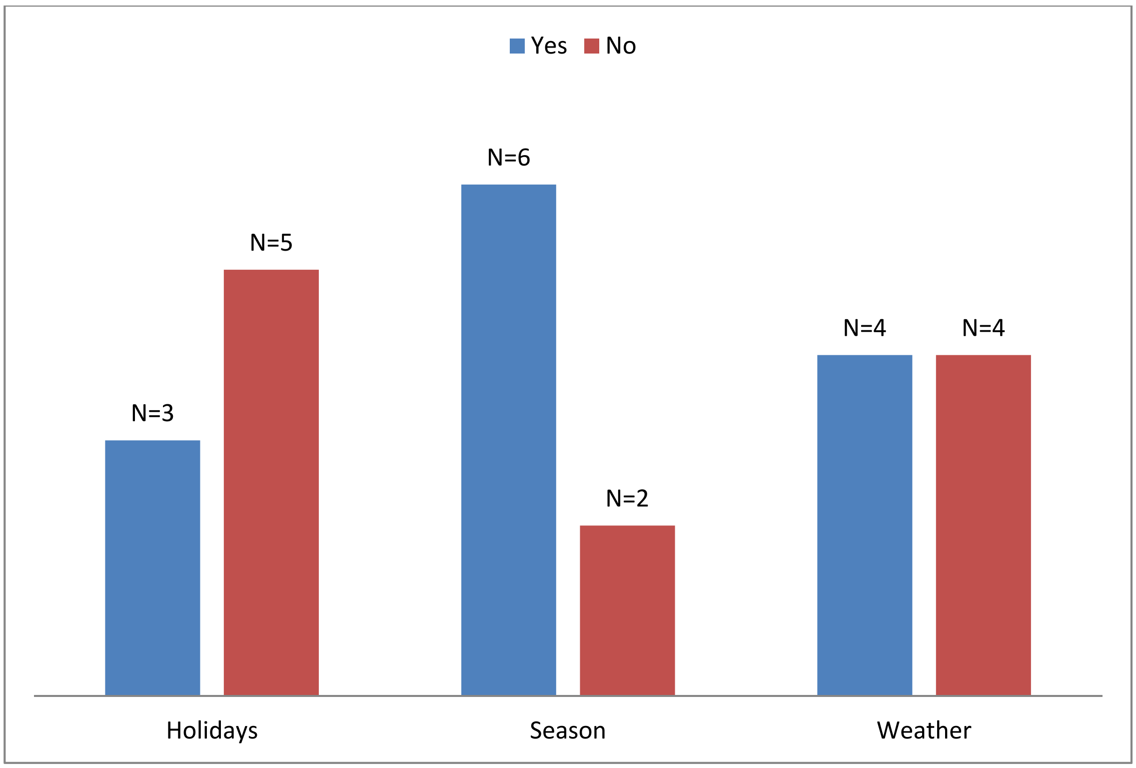

Figure 7: Account for in Schedule Generation

The survey also questioned the respondents concerning the pre-determined precedence logic used in the KY-CTDS. The range of answers provided by survey takers made it difficult to identify any specific problem with the sequencing of the project template. It is worth noting that maintenance of traffic was considered by all survey respondents. Based on responses received, there was no clear answer on how the system's logic, project sequencing, and accountancy for concurrent activities were performing. Full comments received for these questions are included in the Survey Report in Appendix B. An additional question was implemented to gather thoughts and ideas on possible future improvements in the system. Survey takers were asked to rank a set of possible items to include in the system on a scale of 1 to 5, where 1 was most needed and 5 was least needed in the system. The results for potential items to include are shown in Figure 8.

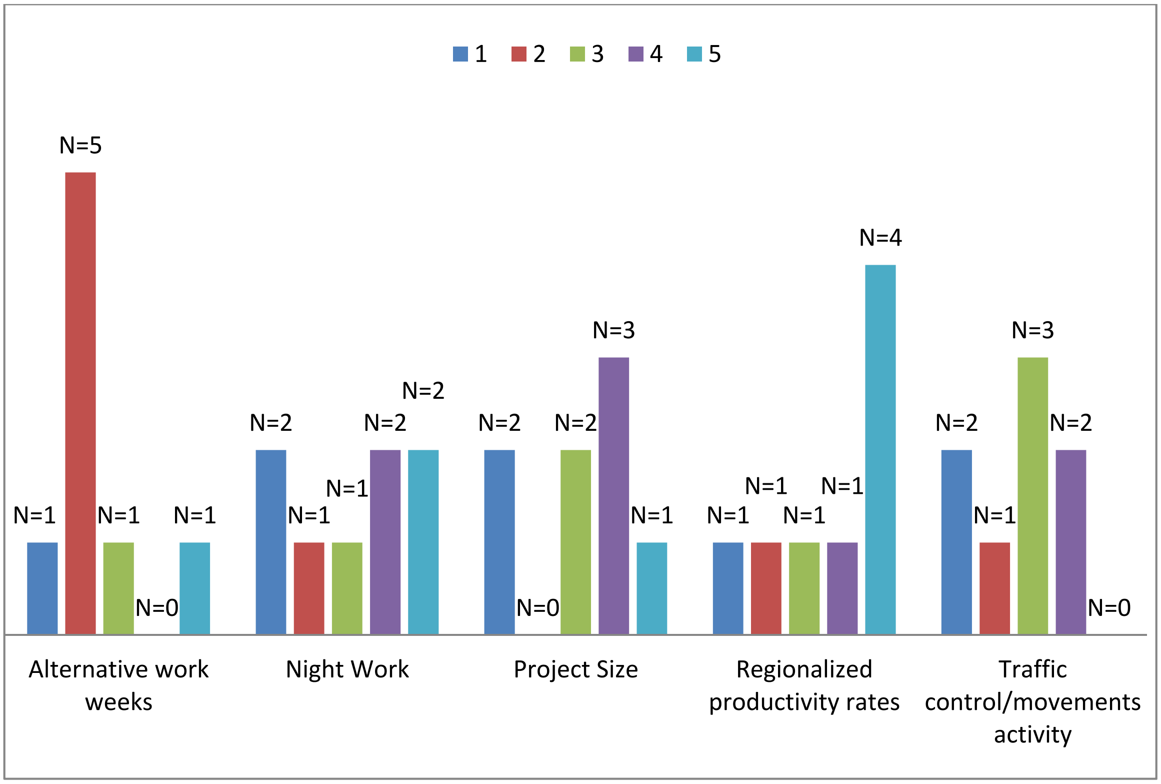

Figure 8: Items to Include

A detailed report including the statistical results associated with each question is displayed in the Survey Report in Appendix B. The current level of detail in the system seems to keep the time required on estimating project duration reasonable with the average time in the two to three hour range for smaller projects and the four to five hour range for larger projects. Survey takers made multiple comments that gave the impression that use of the system did not generate a foolproof project duration that could be directly associated with the contract time for the given project. Although the system is not designed to do such, participants felt that the time and effort spent in arriving at a practical project duration could be reduced by addressing certain problems with the system. Comments made raised questions amongst the research team related to an assortment of the system's aspects. Comments about the productivity rates of certain work activities and pre-determined logic were the most abundant.

Current contract time determination relies on multiple sources of information in addition to using the Kentucky Contract Time Determination System (KY-CTDS). This is a positive sign in the sense that personnel are not simply cranking through design quantities and blindly using the output of the system to set a contract time. On the other hand it can also be a negative issue in that there could be an inconsistency in setting highway project contract times across the state. The system's purpose is not to generate project duration and contract time that is set in stone but to create a logical representation of work activity durations and construction sequencing. The survey results show that this system in its current form does not completely achieve this purpose. Because of this, users rely on past construction experience and similar projects to check productivity rates and sequencing for potential adjustments on the initial duration. As similar as construction projects can get, engineering judgment and experience are essential to accurate project estimating and scheduling. These are just a few qualities that software cannot overcome.

To summarize, the survey revealed that the system is a good starting point for projects that enables the engineer to obtain a rough estimate of how long a project should take to complete. Refining of the system should include productivity rate adjustments and the development of concurrent activity logic to develop an allotted time to be used in contract time determination. Additional items to consider are adding alternative work-weeks to the current schedule templates as well as an activity for phasing and/or traffic movements. Design engineers are using the system to obtain a baseline figure for the number of working days required to complete a given project. They then consult with construction personnel that have field experience to refine the number of working days. The construction personnel look at data from past projects as well as use their own personal judgment based on experience. The designers and construction personnel can then arrive at a number of working days they see fit for the given project. The working days estimate is used to set the contract time. The contractor who was awarded the bid has to finish the project within the allotted time based on the design quantities. A summary of survey comments and key points is shown in the Survey Summary in Appendix B.

3.0 Analysis of the accuracy of the current system

Being able to analyze the accuracy of the Kentucky Contract Time Determination System (KY-CTDS) in an effective manner was a critical step in the project. The research team chose to analyze the system by first focusing on the pre-determined logic. The logic seemed very reasonable for a typical highway construction project. The next step was to take a closer look at the productivity rates. For the most part this was done using the survey results and comments received, but the rates were also compared with another system, the State X Contract Time Determination System. Once the system was initially checked it could then be compared to real data from past projects, which was supplied by the Kentucky Transportation Cabinet. Design quantities from a range of project types completed between 2004 and 2008 were used to test the system and compare durations to the actual project durations. The Kentucky Contract Time Determination System (KY-CTDS) durations were also compared to a modified version of the system, which will be discussed later in this section, as well as with the State X Contract Time Determination System.

The main system used for comparing Kentucky's system to other states was the State X Contract Time Determination System. Full access to their system was granted which included their Microsoft Access based quantity input window and their project scheduling information. The scheduling information was imbedded in the Access file, which exported the data to a Microsoft Project template in a similar fashion to the Kentucky system. The State X system was used because of its accessibility, similarity to the Kentucky system, and ability to be understood and analyzed. The first step was to input all project information in the main screen and then select a template that best fit the project being modeled from a list of 17. Each template's productivity rates were seen when inputting design quantities just as the KY-CTDS does. The pre-determined logic could not be seen until exporting occurred but it could be understood and even adjusted once the schedule was developed from the design quantities.

At first, the design quantities used were taken from randomly chosen projects from each year (2004-2008) to run the system and compare durations. This generated quite a bit of data and gave the team its first real look at the system in action. Once the chosen projects were analyzed using the KY-CTDS and the State X system, the results were exported to Excel for further analysis. The durations were then compared to actual working day durations from another data set that was received from the Cabinet.

The durations produced from the chosen projects were not the least bit accurate. Percent error and percent differences were calculated to compare the actual durations and the KY-CTDS durations. The results were eye opening and demonstrated that the system needed more improvements than originally planned. The research team then took a closer look to see what exactly may be causing the huge errors. It was noticed that several work activities had default durations associated with them that added a significant amount of days to the overall duration, even if that work activity was not part of the scope for the project being considered. For these defaults to not affect the project duration given by the system a value of zero had to be input into the design quantities causing the user input value to override the system default. The work activities with default durations and their associated durations are shown in Table 1.

Table 1: Default Durations

Work Activity	Default Duration (days)
Initial Traffic Control	2
Diversion	6
Erect Temporary Bridge	8
Remove Existing Structure	3
Cofferdams	15
Remove Temporary Bridge	4
Major Traffic Signals	15
Final Clean-Up	10
Phasing Allowance	3

Once this potential flaw in the system was discovered, the projects were then re-run eliminating most, but not all of the default durations. Traffic control, final cleanup, and phasing allowance were left in the system because the bid tab sheets, which contained the design quantities, did not specify quantities associated with these activities. There was also no way for the research team to tell if the default durations were reasonable without much greater detail of the project. Therefore, some allowance for the activities seemed reasonable to leave included in the schedule. Removing the other default durations essentially removed 45 days from the overall duration, which could make a significant impact on determining the contract time for a project, especially smaller projects. The same projects without the default durations mentioned were compared once again to the actual time required to complete the project. The percent error and percent difference were calculated again and this time the results were improved but still nowhere near the accuracy the system needs to be to maintain proper usage.

At this point in the analysis, the majority of the projects that had been considered were resurfacing jobs, which fell into the open access template. This was a coincidence that occurred when randomly choosing projects from the bid tabs due to the sheer magnitude of resurfacing jobs that are bid each year in the state of Kentucky compared to the other types of projects. A decision was made to separate all projects in the data received into the template each would use to aid in setting a contract time. Doing this would help in further analyzing the accuracy of the system, being able to check each template on an individual basis. The breakdown of projects for further analysis was as follows for each template: open access – 31 projects, limited access – 13 projects, bridge rehabilitation – 15, bridge replacement – seven. The new route template and the relocation template were not used in any project analysis because these types of projects were not included in the dataset. Each of the sampled projects was then analyzed using the contract time systems to estimate duration and compared to the actual duration. Each project was run with the system's current set up, including default durations and then again without the default durations. The first set of durations was labeled as the "KY-CTDS As-Is" system and the latter labeled as the "KY-CTDS Modified" system. For a separate comparison, the projects were put through the State X Contract Time Determination System. Using the proper template for each project, these outputs were labeled as the "State X" system. For each of the three systems described the duration was compared with the actual project duration using percent error and percent difference calculations. Additional statistical parameters were calculated for each template comparing the range of errors including the mean, median and mode, as well as the standard deviation and variance. Shown below are samples of each system from an average project that was encountered over the course of the analysis. Figures 9-10 display the Excel and Project Templates for the KY-CTDS As-Is system; no adjustments were made to the templates. They were simply opened as received and design quantities inputted. A summary page for assumptions and productivity rates can be found in Appendix C on the System Assumptions and Productivity Comparison pages.

OPEN ACCESS			Input Design Quanti	Default Production	Default Activity	Production Rate Overri	Activity Duration	Calculated Activity
Item No	Activity	Unit						
1	Initial Traffic Control	Days		1	2			2
2	Clearing & Grubbing	Acres	3	3	0	3		1
3	Diversion (By-Pass Detour)	Days		1	6			6
4	Roadway Excavation	CY		5,000	0	5,000		0
5	Embankment in Place	CY	533	4,000	0	4,000		1
6	Drainage Pipe	LF	552	200	0	200		3
7	Box Culverts, Class A Concrete	CY		30	0	30		0
8	Erect Temporary Bridge	Days		1	8			8
9	Remove Existing Structures	Days		1	3			3
10	Cofferdams	Days		1	15			15
11	Structure Excavation	CY		300	0	300		0
12	Piling	LF		300	0	300		0
13	Sub-Structure, Class A	CY	4	40	0	40		1
14	Concrete Beams	LF		600	0	600		0
15	Steel Beams	Lb.		20,000	0	20,000		0
16	Super-Structure, Class AA	CY		20	0	20		0
17	Remove Temporary Bridge	Days		1	4			4
18	Major Retaining Walls	SF		1,000	0	1,000		0
19	Sub-grade Stabilization	SY		8,000	0	8,000		0
20	Stone Base	Ton	298	1,500	0	1,500		1
21	Drainage Blanket	Ton		1,200	0	1,200		0
22	Asphalt Base, Leveling, &	Ton	696	1,200	0	1,200		1
23	Curb & Gutter	LF	479	500	0	500		1
24	Entrance Pavement	SY		100	0	100		0
25	Barrier Walls, Slip Form	LF		500	0	500		0
26	Asphalt Repair	Ton	30	50	0	50		1
27	Concrete Repair	SY		30	0	30		0
28	Concrete Paving	SY		4,000	0	4,000		0
29	Asphalt Surface	Ton	307	1,000	0	1,000		1
30	Sheet Signs	Ea		30	0	30		0
31	Panel Signs	Ea		1	0	1		0
32	Major Traffic Signals	No of		15	15			15
33	Lighting,Total Installation	Ea		2	0	2		0
34	Guardrail	LF	88	1,500	0	1,500		1
35	Finish Seeding	SY	3,150	4,000	0	4,000		1
36	Pavement Marking	LF	14,000	10,000	0	10,000		2
37	Final Clean-Up	Days		1	10			10
38	Phasing Allowance	No of Phase		1	3			3

Figure 9: KY-CTDS As Is Quantities

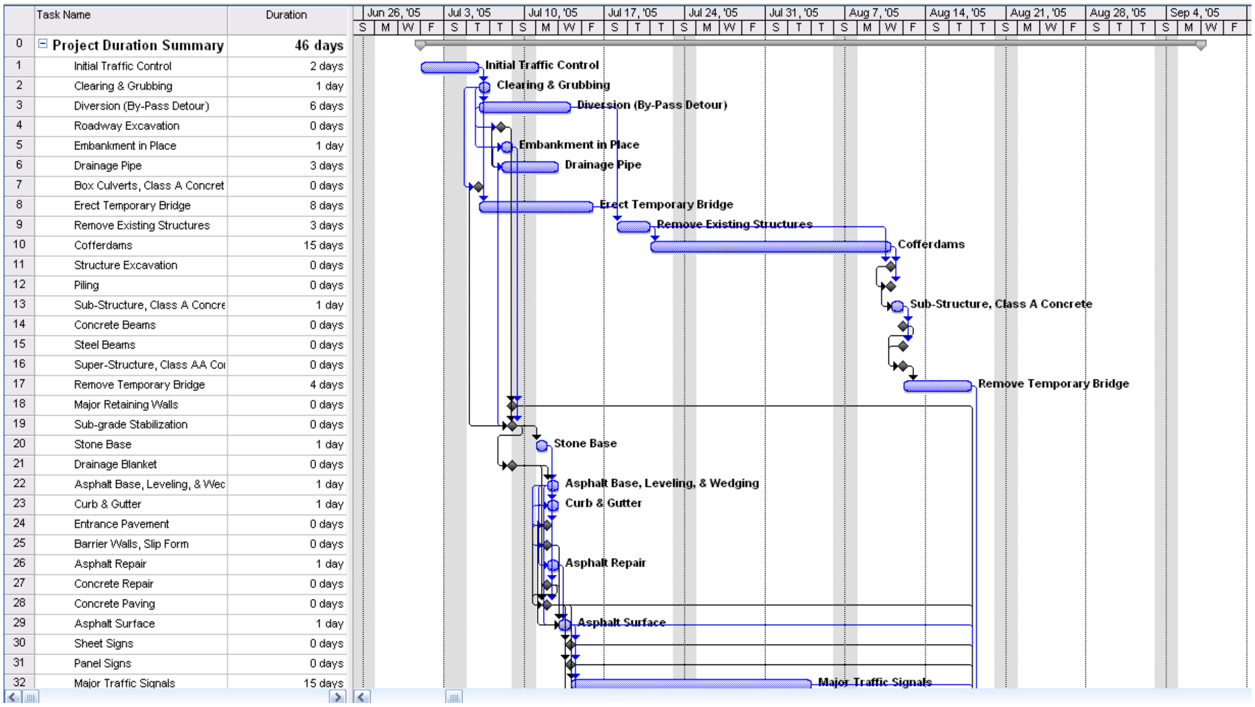

Figure 10: KY-CTDS As-Is Schedule

Figures 11-12 show the Kentucky system again but this time the modifications to the default durations were included as previously discussed. By doing this, the duration on this particular project was reduced from 46 days to 23 days.

OPEN ACCESS			Input Design Quanti	Defaul t Produ ction	Defaul t Activit y	Produ ction Rate Overri	Activit y Durati on	Calcul ated Activit y
Item No	Activity	Unit						
1	Initial Traffic Control	Days		1	2			2
2	Clearing & Grubbing	Acres	3	3	0	3		1
3	Diversion (By-Pass Detour)	Days	0	1	6			0
4	Roadway Excavation	CY		5,000	0	5,000		0
5	Embankment in Place	CY	533	4,000	0	4,000		1
6	Drainage Pipe	LF	552	200	0	200		3
7	Box Culverts, Class A Concrete	CY		30	0	30		0
8	Erect Temporary Bridge	Days	0	1	8			0
9	Remove Existing Structures	Days	0	1	3			0
10	Cofferdams	Days	0	1	15			0
11	Structure Excavation	CY		300	0	300		0
12	Piling	LF		300	0	300		0
13	Sub-Structure, Class A	CY	4	40	0	40		1
14	Concrete Beams	LF		600	0	600		0
15	Steel Beams	Lb.		20,000	0	20,000		0
16	Super-Structure, Class AA	CY		20	0	20		0
17	Remove Temporary Bridge	Days	0	1	4			0
18	Major Retaining Walls	SF		1,000	0	1,000		0
19	Sub-grade Stabilization	SY		8,000	0	8,000		0
20	Stone Base	Ton	298	1,500	0	1,500		1
21	Drainage Blanket	Ton		1,200	0	1,200		0
22	Asphalt Base, Leveling, &	Ton	696	1,200	0	1,200		1
23	Curb & Gutter	LF	479	500	0	500		1
24	Entrance Pavement	SY		100	0	100		0
25	Barrier Walls, Slip Form	LF		500	0	500		0
26	Asphalt Repair	Ton	30	50	0	50		1
27	Concrete Repair	SY		30	0	30		0
28	Concrete Paving	SY		4,000	0	4,000		0
29	Asphalt Surface	Ton	307	1,000	0	1,000		1
30	Sheet Signs	Ea		30	0	30		0
31	Panel Signs	Ea		1	0	1		0
32	Major Traffic Signals	No of	0	15	15			0
33	Lighting,Total Installation	Ea		2	0	2		0
34	Guardrail	LF	88	1,500	0	1,500		1
35	Finish Seeding	SY	3,150	4,000	0	4,000		1
36	Pavement Marking	LF	14,000	10,000	0	10,000		2
37	Final Clean-Up	Days		1	10			10
38	Phasing Allowance	No of Phase		1	3			3

Figure 11: KY-CTDS Modified Quantities

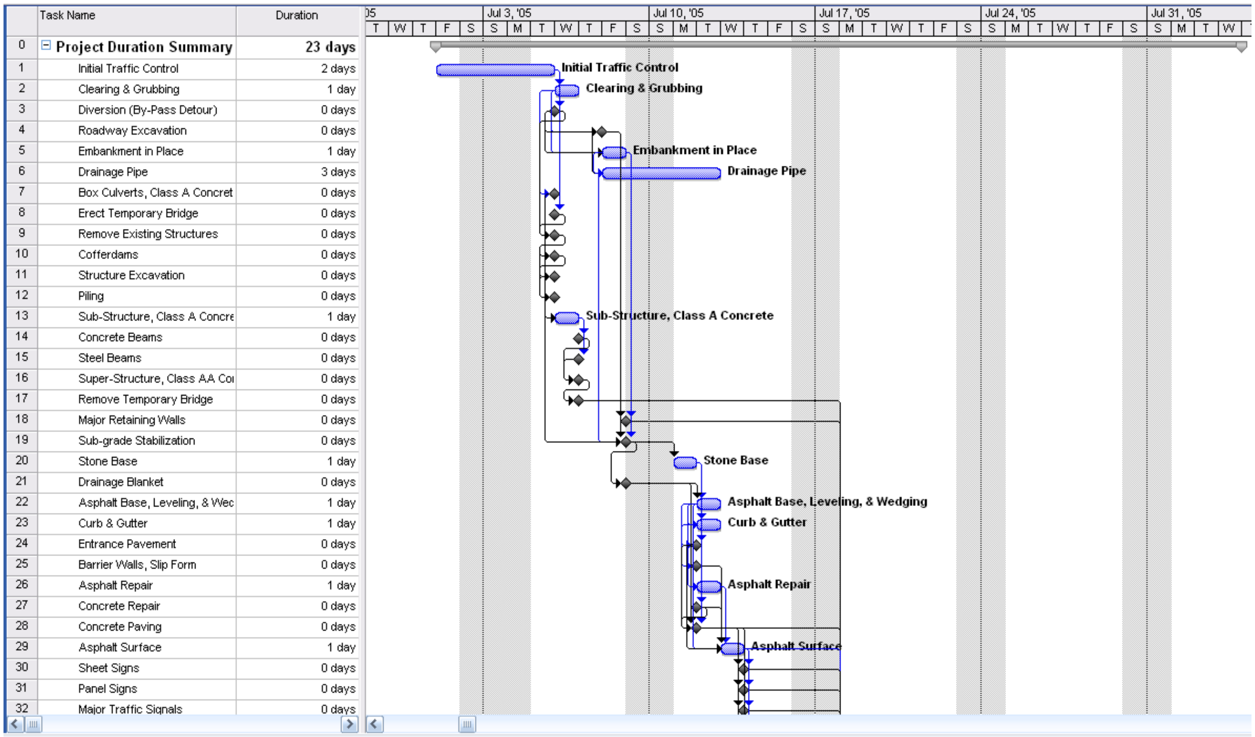

Figure 12: KY-CTDS Modified Schedule

Figures 13-14 depict the user interface for State X. The same project used in the previous figures was used here yielding an output of 15 days. Between the three different systems the estimation of project duration ranged from 15 days to 45 days; a 300 percent increase.

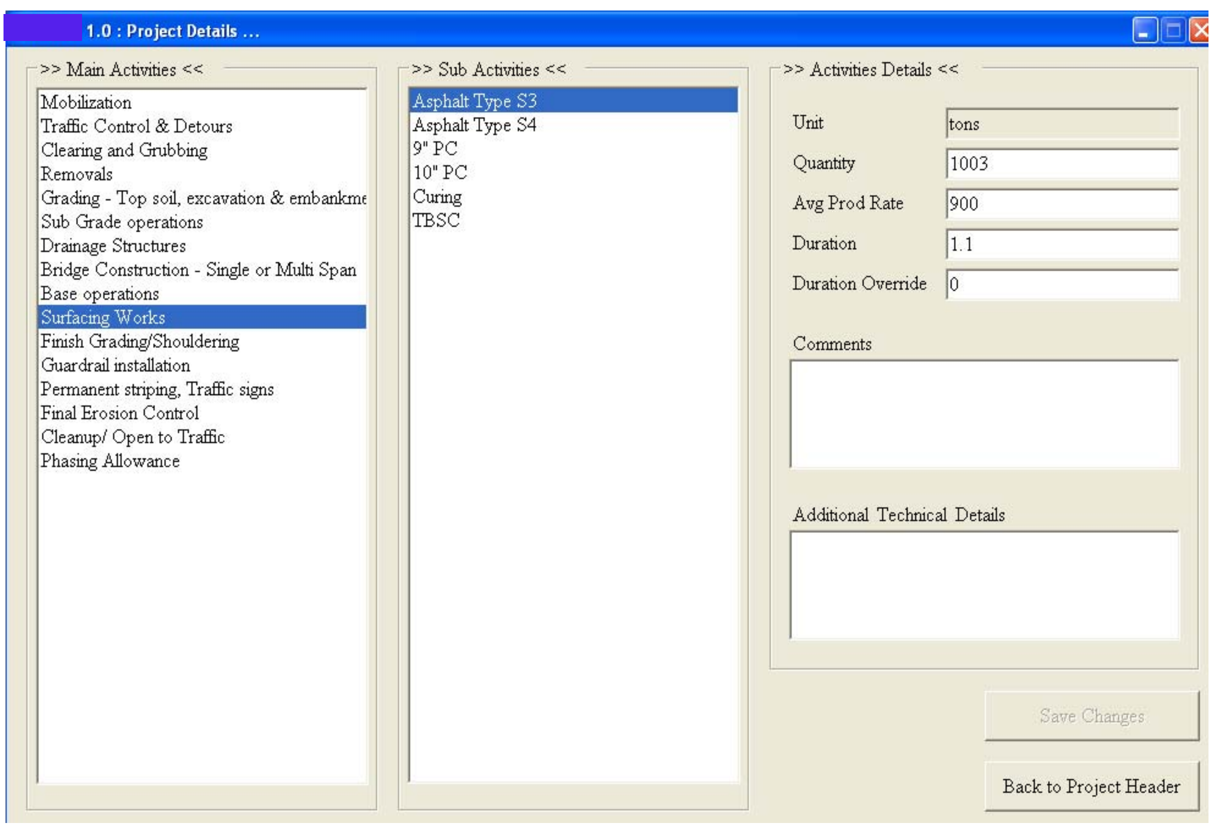

Figure 13: State X Design Quantity Inputs

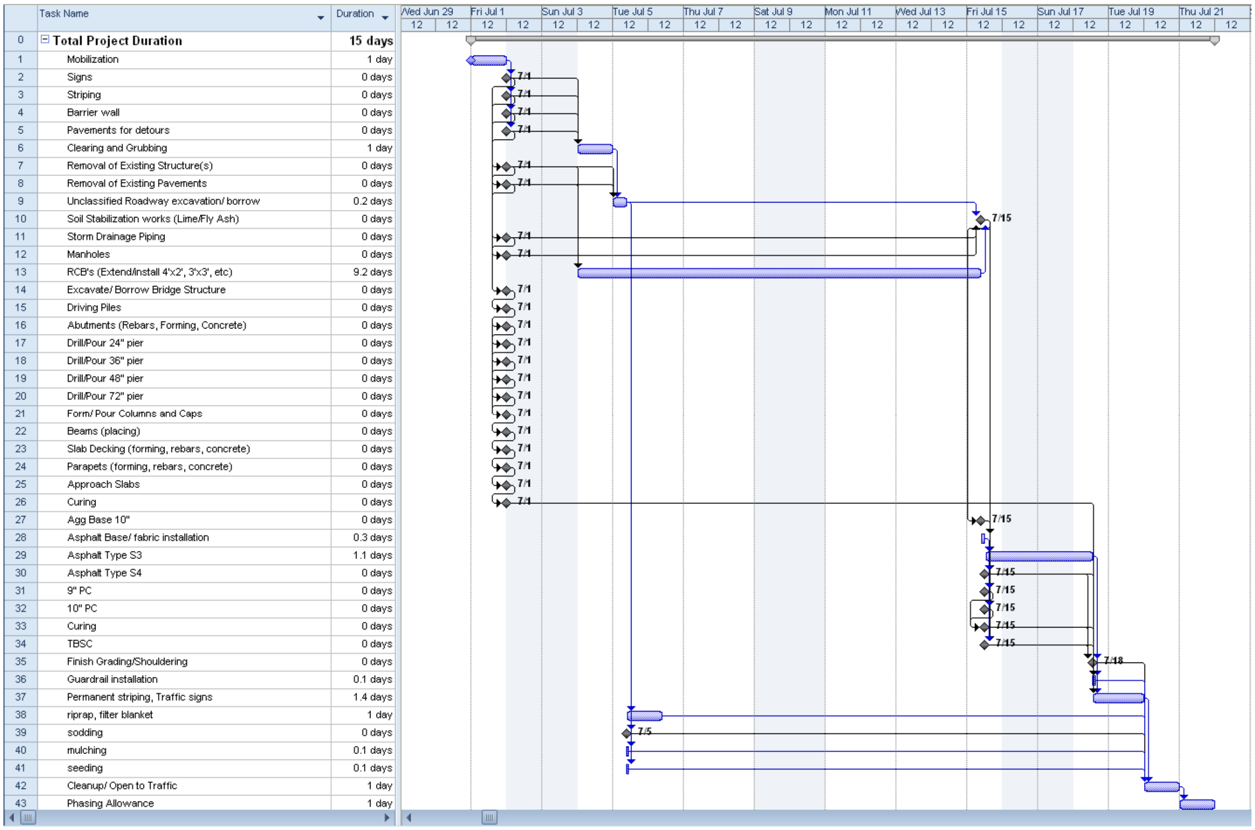

Figure 14: State X Sample Schedule

The overall impression from this portion of the analysis was that the performance of the KY-CTDS is sub-par on multiple levels. Table 2 compares the percent error for predicting project durations that each system generated. A complete look at the breakdown of the projects, the durations output from each system and how they compare with the actual project durations is shown in the Project Analysis: Actual Duration vs. System Duration in Appendix C.

Table 2: Summary of Percent Error by Template Type

Percent Error by Template Type (%)			
Template	KY-CTDS as-is	State X	KY-CTDS modified
Limited Access	346	77	61
Open Access	200	76	162
Bridge Rehabilitation	62	44	53
Bridge Replacement	53	70	75

The percent errors associated with each project from a given template were broken into ranges shown in histogram format, i.e. 20-40 percent error, 40-60 percent error, etc. for an easier understanding of the typical accuracy for a given template. This process was completed for each template and also in aggregate form including all projects considered for each template, all of which are shown in the Cumulative Histograms in Appendix C.

4.0 Regression models to predict contract duration

The analysis of the current KY-CTDS demonstrated that the accuracy of the system is not suitable for estimating contract time. A potential solution considered by the research team was an alternate form for estimating project duration using parametric modeling. Instead of inputting numerous design quantities into the system, an accurate parametric model would take a few of the most critical quantities associated with a project and use these quantities to estimate a project's duration. An equation is obtained from performing a regression analysis on the chosen quantities, which can then be used, if accurate enough, to predict future projects of similar scope.

Using the unit bid tabulations found on the KYTC website, project data from several projects was examined using statistical analyses. The data consisted of engineer's estimates and design quantities collected from Unit Bid Tabulations between 2002 and 2011 with a total of 4,414 projects. Each project was separated into one of the four categories mentioned above; open access, closed access, new route, bridge rehabilitation, and bridge replacement. The categorized projects would help to determine if there were any correlations between the amounts of materials used, engineer's estimate, and project durations. Project duration was then calculated based on 2,589 projects' start and completion dates from Project Information available on the KYTC Website. The various materials, durations, and engineer's estimates were then used to formulate a regression analysis.

At the beginning stages of the data analysis it was difficult to attain an accurate regression model that could depict a linear relationship between data points. Multiple trial and error calculations were conducted in order to find the appropriate independent and dependent variables to use. Originally, the objective was to find a uniform system that could predict project durations with high accuracies using linear regressions. Some of the results were promising, as the R^2 [1] values were around 80 percent at the beginning stages of the analysis. After further investigation, it was found that several outliers were affecting the data sets, which inevitably affected the accuracy of the linear relationship. The data represented in the SPSS models showed a vast difference between large and small projects. Formatting data sets could accurately represent a relationship between the project duration and the engineer's estimate. In order to specifically represent these relationships, the data was separated into two formats. Large

[1] R2, which is also known as the coefficient of determination, measures the amount of variation in the dependent variable explained by a regression's independent variables.

projects would be represented by project durations and engineer's estimates greater than 100 days and greater than one million dollars, respectively. In addition, the small projects would be represented by project durations less than one hundred days and less than one million dollars.

After separating the respective data, the regression analysis on the separated data sets continued. Similar to the regression analysis used before, the data for large projects showed promising results, while the smaller projects showed a great amount of variance. After further discussion, the regression models could not accurately depict any relationship with respect to the durations of smaller projects. However, when looking at the analysis for large projects, there were few, if any, discrepancies found. The regression analyses used a series of formulations to identify model variables to include in the validation equations for the specified project types. Section 4.2 presents the project type, sample size, model variables, validation (percent error median), and R^2 values.

The methodology used was successfully validated for the project types, except for the new route and bridge rehabilitation. Also, the linear relationships for all of the projects did fairly well as the R^2 value did not drop below 0.80, which shows strong correlations. When using these models, it should be noted that there are certain errors associated with each project type, and the validations and estimated durations should reflect that accordingly. In addition, several of the project types did not a produce a significant sample size, which could have negatively impacted the data. This is another impact that should be assessed when analyzing and formulating the final durations for specific projects. Projects that have large sample sizes will generally reflect a rational estimation that can be used with fairly good accuracy. The equations represented in the next section will give a common understanding of how each model can be used with their given equations.

4.1 Regression model equations used in estimating project durations

The regression models helped predict, with some variability, the accuracy of estimated project durations for certain transportation projects. These estimated durations are products of the equations derived from the regression analysis using model variables and project durations. Each equation used is project specific and should only be used for their project type category. These equations have shown moderate to great accuracy and should help users estimate project durations in an efficient manner. The equations listed in the tables located in Section 4.2 specify which equations should be used, along with the model variables. The durations are heavily dependent on these model variables, which is why they are vital in the estimated durations. Again, the estimated durations should be used with some caution, as there will be some variability in the final analysis. In addition, Kentucky was separated into Eastern and Western regions to help differentiate geological conditions. The districts that are west to I-75 are considered as Western Kentucky, and the districts east to I-75 are considered as Eastern Kentucky. For those districts that are passed through by I-75, if the majority of the land lies to the west of I-75, they are deemed as Western Kentucky; otherwise they are classified as Eastern Kentucky. Validations were used based on a uniform technique. The validation method is to compare the durations predicted by regression models with the actual project durations. If the sample size was large enough, 80 percent of projects were randomly selected to run the regression, and the rest of the 20 percent of projects were used for validation. If the sample size was not large, all projects were used for regression and validation. The analysis result included the mean and median of the percent difference and percent error.

4.2 Regression Results

The following regression results demonstrate and outline how each categorized roadway project should be estimated. The tables provide the constants and the input variables in the regression analysis that allowed for the calculation for durations. The input variables are described in the model section of the tables, which indicate exactly what variables are important to the specific project type and should be used in the estimations. Furthermore, the unstandardized B constant represents the value that the variables will be multiplied against. Each project type has a specific R^2 value in addition to an equation. The rest of the values represented in the table, excluding the R^2 value, are generally insignificant to implementation of developing an estimate and are not used in the equations. A Limited Access example of using the formulated regression equation is given below. Contract ID number 09-1307 is used for the purposes of this example. Table 4, which is for Limited Access projects for more than one million dollars, displays the given variables for the model, Engineers Estimate, Roadway Excavation (Dirt_Work_Roadway Excv), and Storm Sewer. These variables are to be specifically used for that type of project. The variables for the input parameter from the contract ID were 49,453,199 for Engineers Estimate (2005 Dollars), 0 CY for Roadway excavation, and 0 Tons for Storm Sewer. The example equation for project ID number 09-1307 is:

$$Duration = 145.821 + [9.493E-6 * EngineersEstimate(2005Dollars) + 3.552E-4 * DirtWork\_RoadwayExcav + .023 * StormSewer]$$

The given values should be used in the equation in order to render estimated contract duration.

$$Duration = 145.821 + [9.493E - 6 * 49,453,199 + 3.552E - 4 * 0 + .023 * 0]$$

Duration= 615.28=616 Days

The equation estimates that the project should have taken 615 days, with an actual duration of 544 days.

It should be noted that the adjusted R^2 value and validation results show that this specific equation is not entirely accurate. In the example just given, an R^2 value of .916, and a percent error of 7.4 was found. Using equations with these characteristics will typically render values with high accuracy. Table 3 is provided as a reference for all of the project types and the tables. Tables 4-21 which are summarized in table 3 display the models, the coefficients, the variables, and the regression equation validations for each type of project. Also table 25 summarizes all of the regression equations for each type of project. In addition, it should be noted that some project types do not have a vast amount of sample projects. Low sample sizes can tend to skew or alter data, which may result in uncertainties with respect to the given equations. As mentioned earlier, these equations should not be used across project types, because they are specific to their own entity. Using equations for projects that do not match their own will output data that cannot be correctly represented.

Table 3: Project Type Reference Table

Table Number	Project Type
4	Limited Access (All Projects)
5	Limited Access (Greater than 1 Million Dollars)
6	Limited Access (Greater than 3 Million Dollars)
7	Open Access (All Projects)
8	Open Access (Greater than 1 Million Dollars)
9	Open Access (Greater than 2 Million Dollars)
10	New Route (All Projects)
11	New Route (Greater than 1 Million Dollars)
12	New Route (West Kentucky)
13	New Route (Central Kentucky)
14	New Route (Eastern Kentucky)
15	New Route (Western Kentucky and Greater than 1 Million Dollars)
16	New Route (Eastern Kentucky and Greater than 1 Million Dollars)
17	Bridge Rehabilitation (All Projects)
18	Bridge Rehabilitation (Western Kentucky)
19	Bridge Rehabilitation (Greater than 1 Million Dollars)
20	Bridge Replacement (All Projects)
21	Bridge Replacement (Greater than 1 Million Dollars)

Limited Access

All 36 projects

Table 4: Limited Access (All Projects)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	144.344	28.057		5.145	0	55.507	0	0.845
Engineer Estimate	9.57E-06	0	0.445	4.216	0			
Dirt Work_Roadway	3.55E-04	0	0.52	6.012	0			
Storm Sewer	0.023	0.009	-0.252	2.669	0.013			

Validation:

All projects were used for validation due to small sample size

% Error: Mean 53.31%, Median 27.33%

% Difference: Mean 28.57%, Median -1.21%

Equation: Contract Duration= 144.344 + 9.57E-6* Engineer's Estimate (2005 dollar) + 3.54E-4* DirtWork_Roadway Excv. (CY) + 0.023* Storm Sewer (LF)

31 projects with engineer's estimates greater than 1 Million

Table 5: Limited Access (Greater than 1 Million Dollars)

Model	Unstandardized Coefficients		Standardized Coefficients	95% Confidence Interval for B		t	Sig.	Goodness of Fit		
	B	Std. Error	Beta	Lower Bound	Upper Bound			F	Sig.	Adj R^2
(Constant)	145.821	33.684	.	75.965	215.677	4.329	0	48.184	0	0.85
Engineering Estimates	9.49E-06	0	0.435	4.39E-06	1.46E-05	3.86	0.001			
DirtWork_Roadway Excav.	3.55E-04	0	0.538	2.28E-04	4.82E-04	5.796	0			
Storm Sewer	0.023	0.009	0.262	0.0044	0.0413	2.576	0.017			

Validation:

31 projects

% Error: Mean 70.36%, Median 28.89%

% Difference: Mean 48.73%, Median 8.13%

Equation: Contract Duration= 145.821 + 9.493E-6* Engineer's Estimate (2005 dollar) + 3.552E-4* DirtWork_Roadway Excv. (CY) + 0.023* Storm Sewer (LF)

Equation: Contract Duration Lower Bound= 75.965 + 4.393E-6* Engineer's Estimate (2005 dollar) + 2.281E-4* DirtWork_Roadway Excv. (CY) + 0.0044* Storm Sewer (LF)

Equation: Contract Duration Upper Bound= 215.677 + 1.459-6* Engineer's Estimate (2005 dollar) + 4.823E-4* DirtWork_Roadway Excv. (CY) + 0.04130* Storm Sewer (LF)

Valid ranges for predictors in order to better predict the duration value:

- Engineer Estimates (in 2005 Dollar Value): 1,324,349 – 49,453,199
- DirtWork_Roadway Excav. (CY): 0 to 2,480,215
- Storm Sewer (LF): 0 to 18,46

23 projects with more than 3 million engineer's estimation

Table 6: Limited Access (Greater than 3 Million Dollars)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	188.096	29.566		6.362	0	66.162	0	0.916
Dirt Work_Roadway	3.57E-04	0	0.609	8.022	0			
Asphalt_Base	0.002	0	0.457	5.983	0			
Concrete Pavement	0.007	0.008	0.361	5.115	0			

Validation:

23 projects

% Error: Mean 32.87%, Median 21.53%

% Difference: Mean 13.21%, Median 3.96%

Equation: Contract Duration= 188.096 + 3.57E-4* DirtWork_Roadway Excv. (CY) + 0.002* Asphalt Base (Ton) + 0.007* Concrete Pavement (SQ. YD.)

Open Access

289 sample projects (approximate 80% of 362 projects)

Table 7: Open Access (All Projects)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	53.125	6.951		7.643	0	208.488	0	0.894
Engineer's Estimate (2005 dollar)	2.10E-05	0	0.297	5.624	0			
Dirt Work_Roadway Excv	2.46E-04	0	0.312	10.833	0			
Culvert Pipe	0.072	0.009	0.238	7.58	0			
PVC Pipe	0.053	0.011	0.109	4.961	0			
Stone Base_Crushed Stone	0.008	0.001	0.233	7.051	0			
Dirt Work_Str. Exv. Rock	-0.288	0.061	-0.165	-4.718	0			
Class A Concrete	0.079	0.024	0.124	3.293	0.001			
Storm Sewer	0.027	0.006	0.141	4.89	0			
Asphalt_Level & Wedge	0.038	0.008	0.121	4.978	0			
Striping	-2.93E-04	0	-0.067	-2.564	0.011			
Asphalt_Surface	-0.005	0.002	-0.073	-2.183	0.03			

Validation:

73 projects (the rest 20% projects):

% Error: Mean 189.59%, Median 75.89%

% Difference: Mean 150.35%, Median 45.66%

Equation: Contract Duration= 53.125 + 2.095E-5* Engineer's Estimate (2005 dollar) + 2.46E-4* DirtWork_Roadway Excv. (CY) + 0.072* Culvert Pipe (LF) + 0.053* PVC Pipe (LF) + 0.008* Stone Base_ Crushed Stone (Ton) – 0.288* Dirt Work_Str. Exv. Rock (CU. YD.) + 0.079* Class A Concrete (CU. YD.) + 0.027* Storm Sewer (LF) + 0.038* Asphalt_Level & Wedge – 2.93E-4* Striping (LF) -0.005* Asphalt Surface (Ton)

Project with more than 1 million estimates (total 78)

Table 8: Open Access (Greater than 1 Million Dollars)

Model	Unstandardized Coefficients		Standardized Coefficients	95% Confidence Interval for B	95% Confidence Interval for B	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta	Lower Bound	Upper Bound			F	Sig.	Adj R^2
(Constant)	173.642	29.048		115.429	231.855	5.978	0	73.267	0	0.891
Engineer's Estimate (2005 dollar)	1.19E-05	0	0.174	2.25E-06	2.15E-05	2.473	0.017			
Dirt Work_Roadway Excv	2.92E-04	0	0.395	2.18E-04	3.66E-04	7.91	0			
PVC Pipe	0.048	0.017	0.138	0.015	0.082	2.892	0.005			
Stone Base_Crushed Stone	0.006	0.001	0.22	0.004	0.009	4.597	0			
Storm Sewer	0.036	0.006	0.316	0.024	0.048	6.031	0			
Culvert Pipe	0.075	0.017	0.28	0.042	0.11	4.456	0			
Striping	-0.001	0	-0.124	-0.001	-2.35E-04	-2.876	0.006			

Validation:

78 projects

% Error: Mean 61.26%, Median 34.98%

% Difference: Mean 26.34%, Median 1.23%

Equation: Contract Duration= 173.642 + 1.188E-5* Engineer's Estimate (2005 Dollars) + 2.92E-4* DirtWork_Roadway Excv. (CY) + 0.048 PVC Pipe (LF) + 0.006*Stone Based_Crushed Stone (Ton) + 0.036* Storm Sewer (LF) + 0.075* Culvert Pipe (LF) -0.001* Striping (LF)

Equation: Contract Duration Lower Bound= 115.429 + 2.251E-6* Engineer's Estimate (2005 Dollars) + 2.177E-4* DirtWork_Roadway Excv. (CY) + 0.015 PVC Pipe (LF) + 0.004*Stone Based_Crushed Stone (Ton) + 0.024* Storm Sewer (LF) + 0.042* Culvert Pipe (LF) -0.001* Striping (LF)

Equation: Contract Duration Lower Bound= 231.855 + 2.150E-5* Engineer's Estimate (2005 Dollars) + 3.655E-4* DirtWork_Roadway Excv. (CY) + 0.082 PVC Pipe (LF) + 0.009*Stone Based_Crushed Stone (Ton) + 0.048* Storm Sewer (LF) + 0.110* Culvert Pipe (LF)+2.347E-4* Striping (LF)

Valid ranges for predictors in order to better predict the duration value:

- Engineer Estimates (in2005 Dollar Value): 1,010,369 – 44,822,186
- DirtWork_Roadway Excav. (CY): 0 to 11,117,520
- PVC Pipe (LF): 0 to 10,751
- Stone Base_ Crushed Stone: 0 to 315,504
- Storm Sewer (LF): 0 to 15,843
- Culvert Pipe (LF): 0 to 7,047
- Striping (LF): 0 to 227,976

Project with more than 2 million estimates (total 43)

Table 9: Open Access (Greater than 2 Million Dollars)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	341.65	87.149		3.92	0.001	15.574	0	0.601
Dirt Work_Roadway Excv	2.91E-04	0	0.561	4.49	0			
Engineer's Estimate	2.22E-05	0	0.343	2.689	0.012			
PVC Pipe	0.075	0.031	0.296	2.407	0.023			

Validation:

43 projects

% Error: Mean 60.82%, Median 23.36%

% Difference: Mean 38.76%, Median 2.92%

Equation: Contract Duration= 341.65 + 2.91E-4* DirtWork_Roadway Excv. (CY) + 2.22E-5* Engineer's Estimate (2005 Dollars) + 0.075* PVC Pipe (LF)

New Route

314 new route projects in total.

80% of the projects were included in the linear regression model

Table 10: New Route (All Projects)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	41.74	6.775		6.161	0	243.783	0	0.652
Engineer's Estimate (2005 dollar)	2.86E-05	0	0.793	21.513	0			
Asphalt_level & Wedge	-0.032	0.012	-0.096	-2.607	0.01			

Validation:

52 projects

% Error: Mean 206.09%, Median 69.78%

% Difference: Mean 177.56%, Median 36.96%

Equation: Contract Duration= 41.74 + 2.862E-5* Engineer's Estimate (2005 Dollars) – 0.032* Asphalt_level & Wedge (Ton)

34 projects with more than $1 million estimates

Table 11: New Route (Greater than 1 Million Dollars)

Model	Unstandardized Coefficients		Standardized Coefficients	95% Confidence Interval for B	95% Confidence Interval for B	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta	Lower Bound	Upper Bound			F	Sig.	Adj R^2
(Constant)	39.289	32.322			105.728	1.216	0.235	57.018	0	0.9
Engineer's Estimate (2005 dollar)	6.89E-05	0	2.665	0	8.11E-05	11.683	0			
Steel Reinf.	-0.001	0	-0.781	0	-1.76E-04	-3.04	0.005			
DirtWork_Granular Emb	-0.018	0.003	-0.756	0	-0.011	-5.244	0			
Perforated Pipe	-0.01	0.003	-0.652	0	-0.004	-3.369	0.002			
Striping	-.4.51E-4	0	-0.126	0	-2.27E-06	-2.066	0.049			

Validation:

34 projects:

% error: Mean 72.31%, Median 54.69%;

% difference: Mean28.02%, Median 10.70

Equation: Contract Duration= 39.289 + 6.894E-5* Engineer’s Estimate (2005 Dollars) – 1.758E-4* Steel Reinf. (LB) – 0.018*DirtWork_Granular Emb (CU. YD.) – 0.010* Perforated Pipe (LF) – 4.51E-4* Striping (LF**)**

Equation: Contract Duration Lower Bound= 0

Equation: Contract Duration= 105.72 + 8.107E-5* Engineer's Estimate (2005 Dollars) – 0.001* Steel Reinf. (LB) – 0.011* DirtWork_Granular Emb (CU. YD.) – 0.004* Perforated Pipe (LF) – 2.272E-6* Striping (LF**)**

Valid ranges for predictors in order to better predict the duration value:

- Engineer Estimates (in2005 Dollar Value): 1,005,941 – 44,039,093
- Steel Reinf (Ton): 0 to 1,736,325
- DirtWork_Granular Emb (CY): 0 to 62,597
- Perforated Pipe (LF): 0 to 84,001
- Striping (LF): 0 to 325,000

Figure E-1: Map of Kentucky Districts

West Kentucky: District 1, 2, 3 and 4;

Central Kentucky: District 5, 6, 7 and 8;

East Kentucky: District 9, 10, 11 and 12.

New Route-West Kentucky (24 projects)

Table 12: New Route (West Kentucky)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	66.825	17.098		3.908	0.001	116.79	0	0.913
DirtWork_Roadway Excv.	0.001	0	0.564	7.852	0			
Culvert Pipe	0.082	0.011	0.55	7.667	0			

Validation:

18 projects (removing 6 outliers with extremely short durations):

% error: Mean 66.02%, Median 43.79%;

% difference: Mean 36.46%, Median 2.81%

Equation: Contract Duration= 66.825 + 0.001* DirtWork_Roadway Excv. (CU YD) + 0.082* Culvert Pipe (LF)

New Route-Central Kentucky (50 projects)

Table 13: New Route (Central Kentucky)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	25.206	9.295		2.712	0.009	334.143	0	0.874
Engineer's Estimate (2005 dollar)	4.07E-05	0	0.936	18.28	0			

Validation:

50 projects w/o removing outliers

% error: Mean 287.25%, Median 60.75%;

% difference: Mean 270.73%, Median 49.83%

Equation: Contract Duration= 25.206 + 4.069E-5* Engineer’s Estimate (2005 Dollars)

New Route-East Kentucky (45 projects)

Table 14: New Route (Eastern Kentucky)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	14.02	8.199		1.71	0.095	236.276	0	0.845
Engineer's Estimate (2005 dollar)	6.96E-05	0	0.921	15.371	0			

Validation:

45 Projects without removing any outlier

% error: Mean 148.98%, Median 61.60%;

% difference: Mean 114.21%, Median 34.03%

Based on the discussion dated on February 21st, west Kentucky were districts located to the west of I-75 and east Kentucky are districts located to the east of the I-75. 3.4- to 3. Analyses were based on the aforesaid definition

Equation: Contract Duration= 14.020 + 6.964E-5* Engineer's Estimate (2005 Dollars)

New Route – West Kentucky and Engineers' Estimate > 1M (16 Projects)

Table 15: New Route (Western Kentucky and Greater than 1 Million Dollars)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	173.561	48.044		3.613	0.004	18.551	0	0.715
Engineer's Estimate (2005 dollar)	1.41E-05	0	0.74	5.178	0			
StoneBase_Crushed Stone	0.005	0.002	0.414	2.896	0.013			

Validation:

16 Project for validation

% error: Mean 91.12%, Median 33.37%;

% difference: Mean 67.32%, Median 9.12%

Equation: Contract Duration= 173.561 + 1.406E-5* Engineer's Estimate (2005 Dollars) – 0.005* StoneBase_Crushed Stone (Ton)

New Route – East Kentucky and Engineers' Estimate > 1M (7 Projects)

Table 16: New Route (Eastern Kentucky and Greater than 1 Million Dollars)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	81.874	103.285		0.793	0.472	16.142	0.016	0.752
Engineer's Estimate (2005 dollar)	3.87E-05	0	0.895	4.018	0.016			

Validation:

7 Projects for validation

% error: Mean 77.29%, Median 45.35%;

% difference: Mean 55.53%, Median 33.45%

Equation: Contract Duration= 81.874 + 3.87E-5* Engineer's Estimate (2005 Dollars)

Bridge Rehabilitation (64 Projects)

Table 17: Bridge Rehabilitation (All Projects)

Model	Unstandardized Coefficients		Standardized Coefficients	95% Confidence Interval for B	95% Confidence Interval for B	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta	Lower Bound	Upper Bound			F	Sig.	Adj R^2
(Constant)	26.933	11.266		4.406	49.461	2.391	0.02	269.43	0	0.812
Engineer's Estimate (2005 dollar)	5.60E-05	0.015	0.903	4.92E-05	6.28E-05	16.414	0			

Validation:

64 projects without removing outliers

% error: Mean 102.00%, Median 48.73%;

% difference: Mean 73.82%, Median 17.16%

Equation: Contract Duration= 26.933 + 5.602E-5* Engineer's Estimate (2005 Dollars)

Equation: Contract Duration Lower Bound= 4.406 + 4.919E-5* Engineer's Estimate (2005 Dollars)

Equation: Contract Duration Upper Bound= 49.461+ 6.284E-5* Engineer's Estimate (2005 Dollars)

Valid ranges for predictors in order to better predict the duration value:

- Engineer Estimates (in2005 Dollar Value): 73,732 – 23,739,686

Bridge Rehabilitation-West Kentucky (9 projects)

Table 18: Bridge Rehabilitation (Western Kentucky)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	58.719	33.773		1.739	0.126	220.73	0	0.965
Engineer's Estimate	6.33E-05	0	0.985	14.857	0			

Validation:

% error: Mean 106.45%, Median 66.90%;

% difference: Mean 81.74%, Median 66.90%

Equation: Contract Duration= 58.719 + 6.327E-5* Engineer's Estimate (2005 Dollars)

Bridge Rehabilitation-Central Kentucky (19 projects)

No good fit model was identified as the adjusted R-square is less than 0.35

Bridge Rehabilitation-East Kentucky (9 projects)

No variable with more than 2 non-zero values can enter the regression model based on SPSS.

Bridge Rehabilitation-Engineers’ Estimate > 1M (6projects)

Table 19: Bridge Rehabilitation (Greater than 1 Million Dollars)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	-70.033	140.108		-0.5	0.643	31.686	0.01	0.805
Engineer’s Estimate	6.15E-05	0	0.919	4.657	0.01			

Validation:

5 projects (Removing 1 sample with large engineer’s estimate and very short duration)

% error: Mean 60.06%, Median 77.26%;

% difference: Mean -50.44 %, Median -77.26%

Equation: Contract Duration= -70.033 + 6.145E-5* Engineer’s Estimate (2005 Dollars)

Bridge Rehabilitation-Engineers’ Estimate > 2M (3projects)

Due to small sample size, regression model was not developed.

Bridge Replacement

All 36 projects

Table 20: Bridge Replacement (All Projects)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta			F	Sig.	Adj R^2
(Constant)	144.61	17.255		8.381	0	71.709	0	0.862
Engineer's Estimate (2005 dollar)	2.06E-05	0	0.253	2.749	0.01			
Dirt Work_Granular Emb	0.092	0.011	0.618	8.711	0			
Dirt Work_Roadway Excv	0.006	0.001	0.471	5.339	0			

Validation:

All 36 projects:

% error: Mean 57.77%, Median 35.77%

% difference: Mean 32.27%, Median 0.47%

Equation: Contract Duration= 144.610 + 2.064E-5* Engineer's Estimate (2005 Dollars) + 0.092* DirtWork_Granular Emb (Ton) + 0.006* DirtWork_Roadway Excv (Ton)

Bridge Replacement – Engineer's Estimate >=1M (14 Projects)

Table 21: Bridge Replacement (Greater than 1 Million Dollars)

Model	Unstandardized Coefficients		Standardized Coefficients	95% Confidence Interval for B	95% Confidence Interval for B	t	Sig.	Goodness of Fit		
	B	Std. Error	Beta	Lower Bound	Upper Bound			F	Sig.	Adj R^2
(Constant)	97.155	32.964		22.585	171.725	2.947	0.016	59.341	0	0.936
Class AA Concrete	0.447	0.087	0.59	0.249	0.644	5.114	0.001			
Dirt Work_Granular Emb	0.043	0.011	0.335	0.018	0.068	3.837	0.004			
Engineer's Estimate (2005 dollar)	1.91E-05	0	0.244	1.21E-06	3.70E-05	2.415	0.039			

Validation:

14 projects

% error: Mean 27.36%, Median 17.03%;

% difference: Mean 9.98%, Median 5.67%

Equation: Contract Duration= 97.155 + 0.447* Class AA Concrete (CU YD) + 0.043* DirtWork_Granular Emb + 1.909E-5* Engineer's Estimate (2005 Dollars)

Equation: Contract Duration Lower Bound= 22.585 + 0.249* Class AA Concrete (CU YD) + 0.018* DirtWork_Granular Emb + 1.208E-6* Engineer's Estimate (2005 Dollars)

Equation: Contract Duration= 171.725 + 0.644* Class AA Concrete (CU YD) + 0.068* DirtWork_Granular Emb + 3.696E-5* Engineer's Estimate (2005 Dollars)

Valid ranges for predictors in order to better predict the duration value:

- Class AA Concrete (CY): 0 to 1,534.00

- DirtWork_Granular Emb (CY): 0 to 9,465
- Engineer Estimates (in2005 Dollar Value) : 1,024,236 to 13,080,175

Bridge Replacement – Engineer's Estimate >=2M (4 Projects)

Due to small sample size, regress model was not developed.

4.3 Regression Analysis

The regression analysis provided exceptional results with respect to large projects. This is important because these projects are generally critical. Evaluating the information and being provided an equation simplifies the techniques of processing the materials and computing a duration that may not be realistic. With this information provided, the user of the system can calculate project durations within several minutes, as opposed to several hours or days. We must keep in mind that these are strictly for projects over 100 days and over one million dollars. In addition, there are more specific categories that should be used if a project is located in a specific region or has a larger engineer's estimate. Using these equations is essential for timely submittals, which can be used advantageously in the Kentucky Transportation Cabinet.

5.0 Analysis of additional methods to estimate contract duration

After compiling the information use in the regression analysis, the focus went towards compiling information for smaller projects, which the study defined as being less than 100 days old and budgeted at less than one million dollars. After reviewing previous steps taken in the new and old KYTC systems, it was necessary to begin collecting various productivity rates from various states for comparative analysis. After searching for productivity rates, information from seven different sources, including the FHWA, was collected. The six states included Kentucky, Indiana, State X, Washington, Minnesota, and Florida. Table 7 gives a comparison of the productivity rates with their respective activity. The data was retrieved from their transportation department websites; the sources are shown in the references section of the document.

These production rates would prove to be vital in the next phase of estimating project time durations. Using the given activity relationships and production rates, a correlation between the actual and estimated duration was examined. The same logic generated in the new Kentucky system, using Microsoft Project, would be used to calculate durations. An example is given in Appendix D. Similar to the previous trials, the production rates were entered into the system for their respective activities. Kentucky's production rates were used for activities without given production rates for their respective states. This helped to eliminate any confusions or estimations when using the system. This process was repeated for each state in order to calculate and compare accuracies. Some of the productivity rates had large ranges, while others only showed minimal differences. Originally, it was thought that some of these discrepancies would create a wide range of data that could be applicable to a system. It was later found that the different production rates did not produce duration estimates close enough to the actual duration. The difference in data left the analysis inconclusive and it could not be used for future modeling purposes. Before concluding the analysis, the median values for the various production rates were used to see if there were any similarities. The values in this analysis were not agreeable and therefore could not be used for future reference. Table 8 shows the output generated for each state and their activities.

Several small projects, which met the criteria, were used to produce the necessary information for proper comparison. Each project was individually entered into Microsoft project along with the given states' production rates. The Microsoft Project figure in Appendix D shows the data output. Each bar represents the calculated duration for each activity. After compiling the information, the results were inconclusive and did not represent a model that could be used for future reference. A majority of the projects had percent errors greater than thirty percent, which was not an acceptable value. Table 23 also shows the discrepancy among the data through the percent errors. Percent errors were calculated with respect to the actual duration.

Table 22: Productivity Rate Values

Item No	Activity	Unit	KY	State X	WA	MN	FL	FHWA	IN	Median Production Rate, Unit/Day
1	Initial Traffic Control	Days	1							1
2	Clearing & Grubbing	Acres	3	4	3	3	5	3	1.5	3
3	Diversion (By-Pass Detour)	Days	1							1
4	Roadway Excavation	CY	5,000	2825	1500	2500		1,600		2,500
5	Embankment in Place	CY	4,000	2825	1700		3800	1,097	2,200	2,513
6	Drainage Pipe	LF	200	110	175	300				188
7	Box Culverts, Class A Concrete	CY	30				50	10	50	40
8	Erect Temporary Bridge	Days	1							1
9	Remove Existing Structures	Days	1					3		2
10	Cofferdams	Days	1							1
11	Structure Excavation	CY	300	2825				80		300
12	Piling	LF	300				300	250	300	300
13	Sub-Structure, Class A Concrete	CY	40							40
14	Concrete Beams	LF	600							600
15	Steel Beams	Lb.	20,000							20,000
16	Super-Structure, Class AA Concrete	CY	20							20

Item No	Activity	Unit	KY	State X	WA	MN	FL	FHWA	IN	Median Production Rate, Unit/Day
17	Remove Temporary Bridge	Days	1							1
18	Major Retaining Walls	SF	1,000						153	577
19	Sub-grade Stabilization	SY	8,000	2500				4000		4,000
20	Stone Base	Ton	1,500	310	2000	1500	1600	900	800	1,500
21	Drainage Blanket	Ton	1,200	1000						1,100
22	Asphalt Base, Leveling, & Wedging	Ton	1,200	1000	2000			4,050	500	1,200
23	Curb & Gutter	LF	500						300	400
24	Entrance Pavement	SY	100	220					200	200
25	Barrier Walls, Slip Form	LF	500	1,045					200	500
26	Asphalt Repair	Ton	50							50
27	Concrete Repair	SY	30							30
28	Concrete Paving	SY	4,000	1640			5000	2500		3,250
29	Asphalt Surface	Ton	1,000	900	1000			900	1000	1,000
30	Sheet Signs	Ea	30	30				20		30
31	Panel Signs	Ea	1	30				20		20
32	Major Traffic Signals	No of Intersection	15							15
33	Lighting, Total Installation Luminaires	Ea	2							2
34	Guardrail	LF	1,500	1000			400	750	400	750
35	Finish Seeding	SY	4,000	11,616		48,400	23,500	12100	2500	11,858
36	Pavement Marking	LF	10,000	10,000		15,000	36,960	37,000	6,000	12,500

Item No	Activity	Unit	KY	State X	WA	MN	FL	FHWA	IN	Median Production Rate, Unit/Day
37	Final Clean-Up	Days	1	3						2
38	Phasing Allowance	No of Phase	1	2						2

[a]: Hancher, 2000

[b]: Washington Department of Transportation, 2008

[c]: Minnesota Department of Transportation, 2006

[d]: Florida Department of Transportation, 2002

[e]: FHWA, 2009

[f]:Yi and Wu, 2004

Table 23: KYTC Percent Errors of Different States

	Duration	KY	%error	State X	%erro	WA	%error	MN	%error	FL	%error	FHWA	%error	IN	%error
10-4000	55	6	89	6	89	6	89	6	89	6	89	6	89	6	89
10-3353	11	1	91	1	91	1	91	1	91	1	91	1	91	1	91
10-3319	35	11	69	11	69	11	69	8	77	11	69	11	69	11	69
10-3317	48	4	92	6	88	4	92	4	92	4	92	4	92	4	92
10-3314	26	4	85	4	85	4	85	4	85	4	85	4	85	4	85
10-1044	25	18	28	19	24	22	12	12	52	22	12	22	12	22	12
10-1025	83	4	95	4	95	4	95	4	95	4	95	4	95	4	95
10-1023	46	7	85	8	83	8	83	6	87	8	83	8	83	8	83
10-1022	71	7	90	7	90	7	90	8	89	7	90	7	90	7	90
09-3340	21	18	14	7	67	18	14	10	52	12	43	12	43	12	43
09-3138	28	11	61	12	57	11	61	9	68	11	61	11	61	11	61
09-3135	33	30	9	31	6	30	9	16	52	30	9	30	9	30	9
09-2352	34	19	44	19	44	19	44	11	68	19	44	19	44	19	44
09-2338	89	9	90	10	89	9	90	6	93	9	90	9	90	9	90
09-2325	44	4	91	4	91	4	91	4	91	4	91	4	91	4	91
Average Percent Error			69		71		68		79		70		70		70

$$\text{Percent Error} = \left|\frac{result - accepted\ value}{accepted\ value}\right|$$

Percent errors for the different states ranged from six percent to 95 percent. Typically, the errors were found above 60 percent and did not vary greatly using the productivity rates from different states. The minimal variance was due in part to the project quantities, which were extremely low in most instances. Quantities were divided by the production rates, which would give certain durations for each activity. Low estimated values were calculated for most, if not all of the projects and rendered high percent errors.

The resulting data produced inconclusive results. The original analysis did not suffice, so further investigation was conducted to see if there could be any additional changes made. Relationships between each of the activities left some concern, because this could have some impact on the duration output. Projects were estimated using the KY-CTDS system then using the same projects, were estimated using other systems from Minnesota, Florida, State X, Washington, FHWA, and Indiana, but no major differences were found. Using the logic in Kentucky's system, a comparison was made between the relationships developed in the TXDOT report (Hancher, 2000). The activity relationships were generated in Microsoft Project, which were then inputted with their respective productivity rates. Table 24 shows the generated output for the TXDOT model. Estimated project durations represented in the table are fairly inaccurate. Similar to the Kentucky system, the TXDOT model results were relatively high.

Table 24: TXDOT Duration Output

	Duration	KY	%error	State X	%erro	WA	%error	MN	%error	FL	%error	FHWA	%error	IN	%error
10-4000	55	4	93	4	93	4	93	4	93	4	93	4	93	4	93
10-3353	11	1	91	1	91	1	91	1	91	1	91	1	91	1	91
10-3319	35	11	69	13	63	11	69	10	71	11	69	11	69	11	69
10-3317	48	5	90	8	83	5	90	5	90	5	90	5	90	5	90
10-3314	26	3	88	3	88	3	88	3	88	3	88	3	88	3	88
10-1044	25	15	40	19	24	21	16	11	56	21	16	21	16	21	16
10-1025	83	2	98	2	98	2	98	2	98	2	98	2	98	2	98
10-1023	46	7	85	7	85	7	85	5	89	7	85	7	85	7	85
10-1022	71	5	93	7	90	6	92	7	90	6	92	6	92	6	92
09-3340	21	17	19	18	14	17	19	6	71	17	19	17	19	17	19
09-3138	28	14	50	16	43	12	57	12	57	12	57	12	57	12	57
09-3135	33	29	12	30	9	29	12	14	58	29	12	29	12	29	12
09-2352	34	22	35	22	35	20	41	14	59	20	41	20	41	20	41
09-2338	89	8	91	9	90	8	91	5	94	8	91	8	91	8	91
09-2325	44	3	93	3	93	3	93	3	93	3	93	3	93	3	93
Average Percent Error			70		67		69		80		69		69		69

$$\text{Percent Error} = \left|\frac{result - accepted\ value}{accepted\ value}\right|$$

Table 25: Summary of Regression Equations

Project Type	Regression Equation
Limited Access (All 36 Projects)	144.344 + 9.57E-6* Engineer's Estimate (2005 dollar) + 3.54E-4* DirtWork_Roadway Excv. (CY) + 0.023* Storm Sewer (LF)
Limited Access (>$1M)	145.821 + 9.493E-6* Engineer's Estimate (2005 Dollars)) + 3.552E-4* DirtWork_Roadway Excv. (CY) + .023*Storm Sewer (Lf)
Limited Access (>$3M)	188.096 + 3.57E-4* DirtWork_Roadway Excv. (CY) + 0.002* Asphalt Base (Ton) + 0.007* Concrete Pavement (SQ. YD.)
Open Access (All 289 Projects)	53.125 + 2.095E-5* Engineer's Estimate (2005 dollar) + 2.46E-4* DirtWork_Roadway Excv. (CY) + 0.072* Culvert Pipe (LF) + 0.053* PVC Pipe (LF) + 0.008* Stone Base_ Crushed Stone (Ton) – 0.288* Dirt Work_Str. Exv. Rock (CU. YD.) + 0.079* Class A Concrete (CU. YD.) + 0.027* Storm Sewer (LF) + 0.038* Asphalt_Level & Wedge – 2.93E-4* Striping (LF) -0.005* Asphalt Surface (Ton)
Open Access (>$1M)	173.642 + 1.188E-5* Engineer's Estimate (2005 Dollars) + 2.92E-4* DirtWork_Roadway Excv. (CY) + 0.048 PVC Pipe (LF) + Stone Based_Crushed Stone (Ton) + 0.036* Storm Sewer (LF) + 0.75* Culvert Pipe (LF) -0.001* Striping (LF)
Open Access (>$2M)	341.65 + 2.91E-4* DirtWork_Roadway Excv. (CY) + 2.22E-5* Engineer's Estimate (2005 Dollars) + 0.075* PVC Pipe (LF)
New Route (All 314 Projects)	41.74 + 2.862E-5* Engineer's Estimate (2005 Dollars) – 0.032* Asphalt_level & Wedge (Ton)
New Route (>$1M)	39.289 + 6.894E-5* Engineer's Estimate (2005 Dollars) – 0.001* Steel Reinf. (LB) – 0.018* DirtWork_Granular Emb (CU. YD.) – 0.010* Perforated Pipe (LF) – 4.51E-4* Striping (LF)
New Route (West Kentucky-24 Projects)	66.825 + 0.001* DirtWork_Roadway Excv. (CU YD) + 0.082* Culvert Pipe (LF)
New Route (Central Kentucky-50 Projects)	25.206 + 4.069E-5* Engineer's Estimate (2005 Dollars)
New Route (East Kentucky-45 Projects)	14.020 + 6.964E-5* Engineer's Estimate (2005 Dollars)
New Route (West Kentucky and >$1M-24 Projects)	173.561 + 1.406E-5* Engineer's Estimate (2005 Dollars) – 0.005* StoneBase_Crushed Stone (Ton)
New Route (East Kentucky and >$1M-7 Projects)	81.874 + 3.87E-5* Engineer's Estimate (2005 Dollars)
Bridge Rehabilitation (All 64 Projects)	26.933 + 5.602E-5* Engineer's Estimate (2005 Dollars)
Bridge Rehabilitation (West Kentucky-9 Projects)	58.719 + 6.327E-5* Engineer's Estimate (2005 Dollars)
Bridge Rehabilitation (Central Kentucky- 19 Projects)	No Acceptable Result
Bridge Rehabilitation (East Kentucky-9 Projects)	No Acceptable Result
Bridge Rehabilitation (>$1M-6 Projects)	-70.033 + 6.145E-5* Engineer's Estimate (2005 Dollars)
Bridge Replacement-Engineers' Estimate (All 36 Projects)	144.610 + 2.064E-5* Engineer's Estimate (2005 Dollars) + 0.092* DirtWork_Granular Emb (Ton) + 0.006* DirtWork_Roadway Excv (Ton)
Bridge Replacement-Engineers' Estimate (>$1 million-14 Projects)	97.155 + 0.447* Class AA Concrete (CU YD) + 0.043* DirtWork_Granular Emb + 1.909E-5* Engineer's Estimate (2005 Dollars)

After analysis the research team concluded that the published productivity rates were not suitable for estimating contract time for Cabinet projects using the current system.

5.1 Typical Worksheet for Small Projects

The method of analysis presented has shown not to be accurate for small projects. A series of worksheets was developed for small projects to identify tasks that are critical to that project and to help organize these tasks to produce an estimated duration. It encompasses simple methods that can be used by anyone with given production rates and work item quantities. Methods used in the range calculations are applied in this given worksheet. Projects that are critical should determine some level of importance with respect to this process. These ranges can give some indication of when projects can be completed. A simple finish-start relationship can be established for simplistic purposes. It will give a liberal value, but should provide engineers or users with the necessary information. In addition, the user should either use the provided production rates for ranges or other usable rates. Other useable rates may be established by the project engineer or from reputable manuals or sources. Also if the engineer is more experienced, more complex relationships can be applied for a more accurate duration. There are blank worksheets provided in Appendix D of the document that can be used for future processes. These values should be used very leniently with the provided quantities and production rates. It is critical that the purpose of the worksheets be kept in mind, which is to provide the state with a good method of organizing smaller, simpler projects. The accuracy of the duration the spreadsheets produce is dependent on the engineer filling the worksheets out.

5.2 Range of Values

In addition to the initial analysis, looking at ranges for possible durations was analyzed to see if any relationships could be generated. The duration was analyzed by filling out a series of worksheets that were developed in this study as a straightforward approach for the residing engineer to estimate duration. First, the KYTC Activity Production Rate worksheet was completed (Figure 15). A range of production rates was applied to work Items that are determined by the residing engineer.

KYTC Activity Production Rate				
Project ID# 10-1044		Production Rate		
ID Number	Work Item	Low	Average	High
1	Roadway Excavation	1500	2685	5000
2	Drainage Pipe	110	196	300
3	Substructure, Class A Concrete	40	40	40
4	Asphalt Base, Leveling & Wedging	500	1750	4050
5	Asphalt Surfacing	900	960	1000
6	Pavement Marking	6000	19160	37000

Figure 15: KYTC Activity Production Rate for Project 10-1044

Next the KYTC Conceptual Construction Duration Schedule Worksheet was filled out selecting the low, average, and high production rates from the KYTC Activity Production Rate Worksheet (Figure 16). The Bid Quantity is then divided by the range of production rates to yield a range of values that are the minimum, average, and maximum duration.

Worksheet 1 Project ID# 10-1044		KYTC Conceptual Construction Duration Schedule Worksheet				
ID Number	Work Item	Bid Quantity	Daily Production Rate	Activity Duration Low (Days)	Activity Duration Average (Days)	Activity Duration High (Days)
1	Roadway Excavation	11648 CY	1500-5000 CY/Day	11648/1500=7.76=8	11648/2685=4.33=5	11648/5000=2.33=3
2	Drainage Pipe	344 LF	110-300 LF/Day	344/110=3.12=4	344/196=1.75=2	344/300=1.14=2
3	Substructure, Class A Concrete	7.2 CY	40 CY/Day	7.2/40=.18=1	7.2/40=.18=1	7.2/40=.18=1
4	Asphalt Base, Leveling & Wedging	685 TON	500-4050 TONS/Day	685/500=1.37=2	685/1750=.39=1	685/4050=.17=1
5	Asphalt Surfacing	539 TON	900-1000 TONS/Day	539/900=.60=1	539/960=.56=1	539/1000=.54=1
6	Pavement Marking	5604 LF	6000-37000 LF/Day	5604/6000=.934=1	5604/19160=.29=1	5604/37000=.15=1
*Activity Duration=Bid Quantity/Production Rate						

Figure 16: KYTC Worksheet 1 for Project 10-1044

The KYTC Conceptual Construction Duration Schedule Worksheet (Figure 17) was then filled out to create a simple schedule by applying start/finish relationships to the durations calculated in the KYTC Conceptual Construction Duration Schedule Worksheet.

Worksheet 2 Project ID# 10-1044	KYTC Conceptual Construction Schedule Worksheet						
ID Number	Work Item	Quantity and Unit	Daily Production Rate	Duration (Days)	Preceding Activities & Relationships	Start Time	Finish Time
1	Roadway Excavation	11648 CY	1500-5000 CY/Day	3-8	N/A	0	3-8
2	Drainage Pipe	344 LF	110-300 LF/Day	2-4	1FS	3-8	5-12
3	Substructure Class A Concrete	7.2 CY	40 CY/Day	1-1	2FS	5-12	6-13
4	Asphalt Base, Leveling & Wedging	685 TON	500-4050 TONS/Day	1-2	3FS	6-13	7-15
5	Asphalt Surfacing	539 TON	400-1000 TONS/Day	1	4FS	7-15	8-16
6	Pavement Marking	5604 LF	6000-37000 LF/Day	1	5FS	8-16	9-17

Figure 17: KYTC Worksheet 2 for Project 10-1044

Finally, a summarization of the activity durations was presented in the KYTC Activity Estimation of Duration worksheet (Figure 18). The same system and approach were used with respect to Microsoft Project and small project descriptions. The calculated ranges from Figure 17 were used to compute a range of durations for certain projects. The values were placed into Microsoft project, using the previous project's values and estimated production rates. An example of the Microsoft Project output is located in Appendix D of the document.

KYTC Activity Estimation of Duration						
Project ID# 10-1044						
ID Number	Work Item	Bid Quantity	Production Rate	Estimation of Duration= Bid Quantity/ Production Rate (Rounded up to the nearest Day)		
				Low	Average	High
1	Roadway Excavation	11648 CY	1500-5000 CY/Day	8	5	3
2	Drainage Pipe	344 LF	110-300 LF/Day	4	2	2
3	Substructure Class A Concrete	7.2 CY	40 CY/Day	1	1	1
4	Asphalt Base, Leveling & Wedging	685 TON	500-4050 TONS/Day	2	1	1
5	Asphalt Surfacing	539 TON	900-1000 TONS/Day	1	1	1
6	Pavement Marking	5604 LF	6000-37000 LF/Day	1	1	1

Figure 18: KYTC Activity Estimation of Duration for Project 10-1044

In order to validate this concept, 30 different projects were selected that matched the criteria for small projects, less than one million dollars and less than 100 days. The projects were then entered into the systems with their given production rates and their respective quantities. Figure 17 shows the output generated, from 9-17 days, for project 10-1044, which had an actual project duration of 25 days.

After evaluating the given information and inputting the production rates into the system, the produced range of durations did not give us beneficial outputs. Given the unit bid quantities, we cannot accurately calculate reasonable project durations. There seems to be a great variance that cannot be diminished due to the lack of necessity to make them critical. The only reasonable assessment that can be produced from this information is to create a worksheet for those projects for organizational purposes.

6.0 Conclusion and Recommendations

The analysis of the current version of the KY-CTDS demonstrated that the accuracy of the current system, and a similar system from another state, are not acceptable for setting contract time. In response, a parametric schedule estimate system was developed that displayed greater accuracy than the current KY-CTDS. The issue was investigated using regression analysis, which provided necessary information for a useful solution. Regression analysis suggested the projects should be separated into large and small categories based on their durations and cost.

Figure 19 shows the necessary steps that should be taken in order to predict whether the small or large project model should be used. If the project is greater than one million dollars, then the regression analysis tables should be used with their respective category. However, if the project is less than one million dollars then the steps provided in the figure should be used to estimate the duration in addition to the worksheet provided in Appendix D.

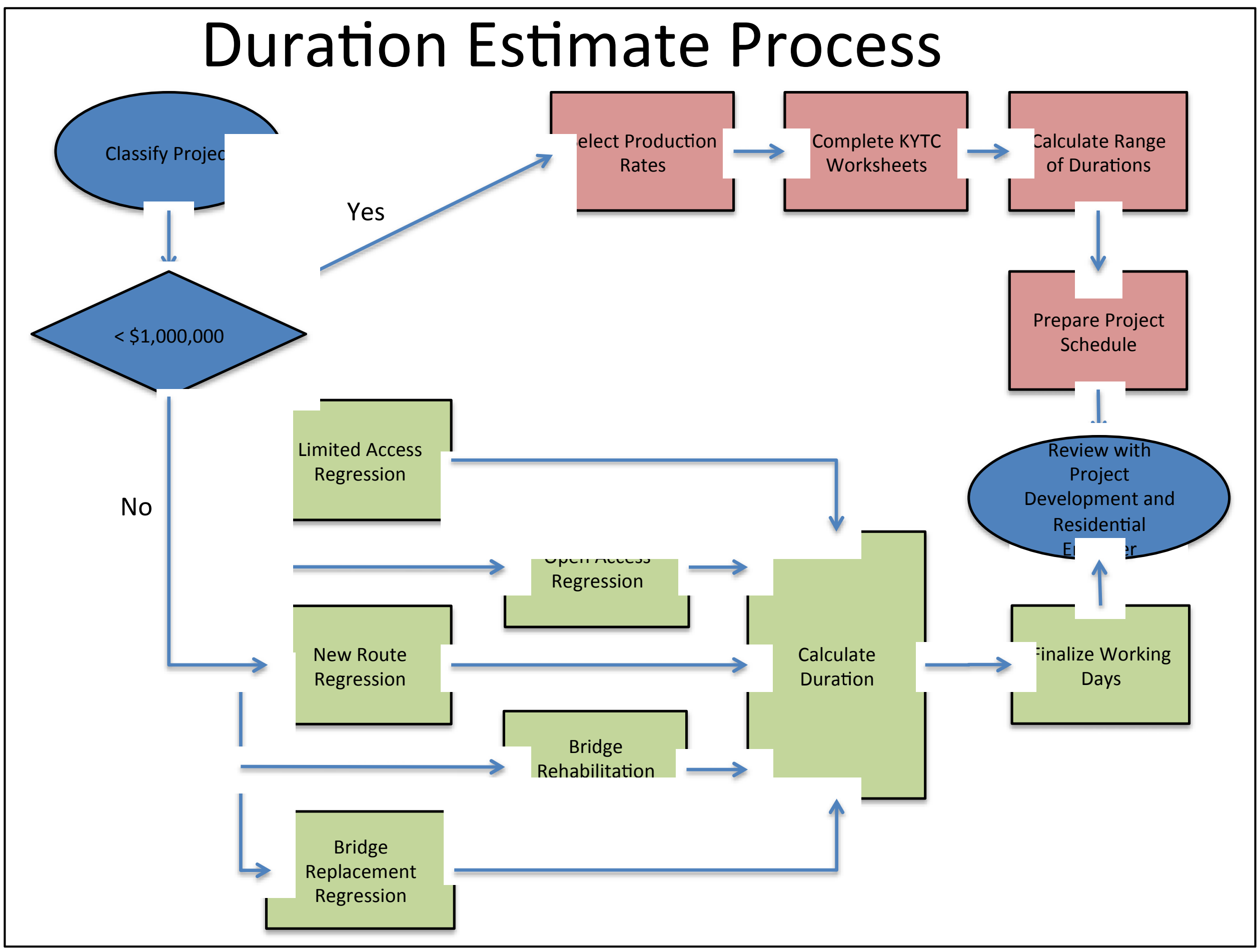

Figure 19: Project Estimate of Duration Flow Chart

This model will provide users with an easy system of separating projects into their necessary categories. The flow chart depicts what steps should be taken and in what order they should be processed. Experience with this flow chart will provide clear and concise information that can be used for future assessment, which will diminish time and expenses.

Collecting and analyzing the information is the most difficult part of the assessment. Applying certain techniques and models continuously provided results that assisted in the formatting of models that would later be explored. This exploration led to the analysis of large and small projects, as discussed above. Using these assessments provided clear indications of what should be constructed in future analyses. Without the regression analysis it would have been difficult to accurately predict durations. This approach gave exceptional statistical data that will be extremely useful in future analyses. It should be noted that these models have not been applied to current or future projects, which will tell whether this system accurately predicts contract time durations. This may be one of the limiting factors in future analysis. It should be noted that productivity is dynamic and has been subject to increases. Increases in production rates will lead to decreases in project times, which may lead to changes in certain system approaches. It may be necessary to update the regression analysis within a respectable timeframe in order to keep up with changes that may occur. The project flow chart is a tool that should stay fairly constant barring major alterations that may occur within the system.

The current contract time determination system has been somewhat unsuccessful in its current stages, which has made it necessary to develop a structure that can be implemented with accuracy. Using the regression model analyses gave an insight into how durations can be estimated for specific projects and their regions. The projects used however, should follow the guidelines set forth. The calculations provided should give clear indications of durations for large projects. It is necessary to use the large projects' restrictions, because these estimations will not work with small projects. Large projects are restricted to those that have an engineer's estimate greater than one million dollars. In addition, if the project is located in a specific area, the regional equation should be used accordingly. Regression analysis has engineered the proper equations to use, which has been proven to work with a high level of accuracy. It is also important to remember that these projects are generally critical, and the implementation of their estimated project durations is important.

As opposed to the large projects, the small project, less than one million dollars, data did not prove to be accurate. There were large discrepancies in data, which made it difficult to properly establish a system that could be used. After further consultation, small projects do not necessarily have to meet strict guidelines. In general, the small project calculations should only be used if the project is deemed to be critical. Implementing this system can create some disorder, and shouldn't be used as a main tool for deriving the project duration ranges. It should be used with extreme caution if it is to be submitted as a final calculation.

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8.0 Appendices

Appendix A

State Breakdown of Contract Time Determination Systems

State Classifications

Appendix B

IRB Approval Letter

KY-CTDS Update Survey

Survey Report

Survey Summary

Follow Up Interview Outline

Appendix C

Project Analysis: Actual Duration vs. System Duration

Statistical Calculations

Cumulative Histograms

Project Durations vs. Asphalt Quantities

System Assumptions

Productivity Comparison: UK-CTDS to State X

Cumulative Analysis Results

Appendix D

Comparison of Productivity Rates

Worksheet for Small Projects

Appendix A

Table A-1

State	System Used	Reference	Year
Arkansas	Manual Method	http://www.clemson.edu/t3s/scdot/pdf/projects/SPR%20652.pdf	Apr-06
Florida	Develop Progress Schedule (CPM, Bar charts) through established production rates	http://www.dot.state.fl.us/construction/SchedulingEng/GuidellinesForEstablishingContractDuration.pdf	
Georgia	Manual Method	http://www.clemson.edu/t3s/scdot/pdf/projects/SPR%20652.pdf	Apr-06
Idaho	Idaho Contract time determination manual	http://itd.idaho.gov/manuals/Online_Manuals/Contract_Time/Contract_Time.htm	
Indiana	Project Development Process (PDP) & Scheduling/Project Management System (SPMS)	http://www.in.gov/indot/files/ProjectDevelopmentProcessManual.pdf	Aug-07
Iowa	Manual Method	http://www.clemson.edu/t3s/scdot/pdf/projects/SPR%20652.pdf	Apr-06
Kentucky	Contract Time Determination System (CTDS)		Jun-00
Louisiana	Lotus 1-2-3; Predetermined controlled activity logic and default production rates estimated by experienced engineers	KCTDS manual	
Maine	Field Manager	http://michigan.gov/som/0,1607,7-192-26847-177201--,00.html	Oct-07
Maryland	In-house Excel program	http://www.clemson.edu/t3s/scdot/pdf/projects/SPR%20652.pdf	Apr-06
Massachusetts	CPM by qualified construction scheduler	http://www.eot.state.ma.us/acceleratedbridges/downloads/projectcontrols.pdf	Dec-08
Michigan	Field Manager	http://michigan.gov/som/0,1607,7-192-26847-177201--,00.html	2003
Minnesota	Standard Production Rates	http://www.dot.state.mn.us/const/determinecontracttime.html	2005
Missouri	Activity schedule charts reviewed by the engineer	http://www.modot.mo.gov/business/standards_and_specs/documents/Master.pdf	1999
Montana	Engineering Information Management System/OPX2	http://www.mdt.mt.gov/other/roaddesign/external/montana_road_design_manual/01_road_design_process.pdf	Jul-08
Nevada	Constructability review	http://www.nevadadot.com/divisions/pdfs/040/CM_Section3.pdf	Jan-09
New Jersey	CPM Progress Schedule on Primavera Suretrak, Primavera Project Planner P3 3.0	http://www.state.nj.us/transportation/eng/documents/scheduling/pdf/Scheduling_Manual_02-15-2002.pdf	Feb-02
New York	Primavera P6 to review Contractor submittal/CPM	https://www.nysdot.gov/main/business-center/contractors/construction-division/construction-repository/CPM_Special_Specification-Type_2_%287-15-2009%29.pdf	Jul-09
North Carolina	Microsoft Excel Cost Estimate Sheet	http://www.ncdot.gov/doh/preconstruct/highway/roadway/eng_coord/	n/a
Ohio	Procedure for Construction Budget Estimating	http://www.dot.state.oh.us/Divisions/ConstructionMgt/Estimating/Pages/default.aspx	May-10
Oklahoma	Contract Time Determination System (CTDS) Access and Project	http://rip.trb.org/browse/dproject.asp?n=25919	2007
Oregon	Scheduling Software Program	http://www.clemson.edu/t3s/scdot/pdf/projects/SPR%20652.pdf	Apr-06
Pennsylvania	Open Plan	ftp://ftp.dot.state.pa.us/public/pdf/pub449.pdf	Apr-04
South Carolina	Primavera	http://www.clemson.edu/t3s/scdot/pdf/projects/SPR%20652.pdf	Apr-06
Texas	Review the local government's time determination process and concur that the process is adequate.	ftp://ftp.dot.state.tx.us/pub/txdot-info/cso/lgpp/construction.pdf	Feb-10
Virginia	Project Cost Estimating System (PCES)		
Washington	CPM by Experienced Personnel/Current Prod. Rates	http://www.wsdot.wa.gov/publications/manuals/fulltext/M22-31/Appendix6.pdf	Nov-08
Wisconsin	FieldManager	http://michigan.gov/som/0,1607,7-192-26847-177201--,00.html	Oct-07
Wyoming	Primavera Suretrak	http://www.clemson.edu/t3s/scdot/pdf/projects/SPR%20652.pdf	Apr-06

State Classifications

Table A-2

Method Used	**Number of States**	**Percentage**
Archived Production Rates	8	28%
Pre-Determined Logic	5	17%
Integrated Scheduling	14	48%
Other	2	7%
Total	**29**	**100%**

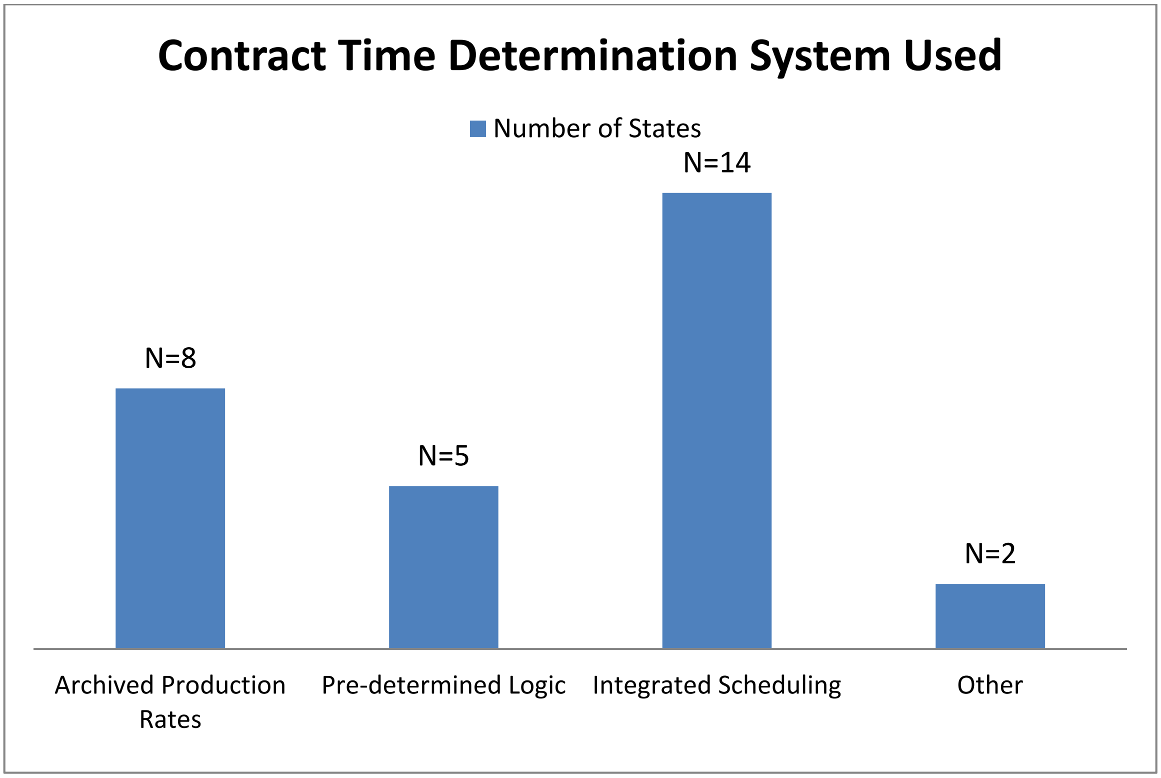


Figure A-1

<u>Archived Productivity Rates</u>
Georgia
Maryland
Minnesota
Nevada
North Carolina
Ohio
Texas
Washington

<u>Other</u>
Arkansas
Iowa

<u>Pre-Determined Logic</u>
Florida
Louisiana
Massachusetts
Missouri
Oregon

<u>Integrated Scheduling</u>
Idaho
Indiana
Kentucky
Maine
Michigan
Montana
New Jersey
New York
Pennsylvania
South Carolina
Virginia
Wyoming
Wisconsin

Appendix B

UK
UNIVERSITY OF
KENTUCKY

Office of Research Integrity
IRB, IACUC, RDRC
315 Kinkead Hall
Lexington, KY 40506-0057
859 257-9428
fax 859 257-8995
www.research.uky.edu/ori/

EXEMPTION CERTIFICATION

MEMO:	Tim Taylor, Civil Engineering 151A Raymond Bldg. PI phone #: (859)323-3680
FROM:	Institutional Review Board c/o Office of Research Integrity
SUBJECT:	Exemption Certification for Protocol No. 10-0887-X4B
DATE:	January 13, 2011

On January 11, 2011, it was determined that your project entitled, *Updating the Kentucky Contract Time Determination System (KY-CTDS) KYSPR 11-411*, meets federal criteria to qualify as an exempt study.

Because the study has been certified as exempt, you will not be required to complete continuation or final review reports. However, it is your responsibility to notify the IRB prior to making any changes to the study. Please note that changes made to an exempt protocol may disqualify it from exempt status and may require an expedited or full review.

The Office of Research Integrity will hold your exemption application for six years. Before the end of the sixth year, you will be notified that your file will be closed and the application destroyed. If your project is still ongoing, you will need to contact the Office of Research Integrity upon receipt of that letter and follow the instructions for completing a new exemption application. It is, therefore, important that you keep your address current with the Office of Research Integrity.

For information describing investigator responsibilities after obtaining IRB approval, download and read the document "PI Guidance to Responsibilities, Qualifications, Records and Documentation of Human Subjects Research" from the Office of Research Integrity's Guidance and Policy Documents web page [http://www.research.uky.edu/ori/human/guidance/htm#PIresp]. Additional information regarding IRB review, federal regulations, and institutional policies may be found through ORI's web site [http://www.research.uke.edu/ori]. If you have questions, need additional information, or would like a paper copy of the above mentioned document, contact the Office of Research Integrity at (859) 257-9428.

KY-CTDS Update Survey

1. You have been selected to participate in this questionnaire. Your participation is purely voluntary. You do not have to participate; there will be no repercussions in the event that you do not participate. Results will be reported in aggregate summaries. YOUR RESPONSES IN THIS SURVEY WILL BE KEPT STRICTLY CONFIDENTIAL.

Please provide us with your position or title within the Kentucky Department of Transportation.

Position/Title (1)

2. Are you familiar with the Kentucky Contract Time Determination System (KY-CTDS)?

❍ Yes (1)

❍ No (2)

3. Do you use the Kentucky Contract Time Determination System (KY-CTDS)?

❍ Yes (1)

❍ No (2)

If No Is Selected, Then Skip To If you are familiar with the system a...

4a. Please indicate your district's overall use of the Kentucky Contract Time Determination System (KY-CTDS).

	Never Use (1)	Less than Half (2)	Half Projects (3)	More than Half (4)	All Projects (5)
Overall Use of KY-CTDS (1)	❍	❍	❍	❍	❍

4b. Comments:

5a. How would you agree with the following statements regarding the overall effectiveness of the system based on the times you have used it?

	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
The system is easy to use (1)	❍	❍	❍	❍	❍
The default productivity rates are accurate (2)	❍	❍	❍	❍	❍
The system generates an achievable contract time (3)	❍	❍	❍	❍	❍
The time and schedule generated are typically accurate to contractors (4)	❍	❍	❍	❍	❍

5b. Comments:

6. For each of the system templates, how long does it take to generate a time and schedule for projects LESS THAN $500,000?

	1-2 hours (1)	3-4 hours (2)	5-6 hours (3)	1 day (4)	3-5 days (5)	Other (6)
Reconstruction Limited Access (1)	❍	❍	❍	❍	❍	❍
Reconstruction Open Access (2)	❍	❍	❍	❍	❍	❍
New Route (3)	❍	❍	❍	❍	❍	❍
Relocation (4)	❍	❍	❍	❍	❍	❍
Bridge Rehabilitation (5)	❍	❍	❍	❍	❍	❍
Bridge Replacement (6)	❍	❍	❍	❍	❍	❍

7. For each of the system templates, how long does it take to generate a time and schedule for projects GREATER THAN $500,000?

	1-2 hours (1)	3-4 hours (2)	5-6 hours (3)	1 day (4)	3-5 days (5)	Other (6)
Reconstruction Limited Access (1)	❍	❍	❍	❍	❍	❍
Reconstruction Open Access (2)	❍	❍	❍	❍	❍	❍
New Route (3)	❍	❍	❍	❍	❍	❍
Relocation (4)	❍	❍	❍	❍	❍	❍
Bridge Rehabilitation (5)	❍	❍	❍	❍	❍	❍
Bridge Replacement (6)	❍	❍	❍	❍	❍	❍

8. Do you use the default productivity rates already in place in the system?

- ❍ Yes (1)
- ❍ No (2)

If No Is Selected, Then Skip To If not, how do you determine activity...If Yes Is Selected, Then Skip To If so, do you feel the default rates ...

9. If so, do you feel the default rates need to be adjusted?

10. If not, how do you determine activity productivity rates?

11. Any additional comments on productivity rates?

12. Do you account for the following in generating your schedule?

	Yes (1)	No (2)
Holidays (1)	❍	❍
Season (2)	❍	❍
Weather (3)	❍	❍

13. Does the default schedule logic used in the project templates accurately reflect the actual work sequence?

14. How well does the schedule logic account for concurrent activities?

15. Do you account for maintenance of traffic in your schedule? If so, how?

16. Does the critical path generated by the default project templates accurately reflect actual projects?

17. Please rank the following to potentially include in the Kentucky Contract Time Determination System expansion. Rank the following 1-5. 1 indicates most needed in system, 5 indicates the least needed in the system. Please use each rank only once.

______ Alternative work weeks instead of only M-F, 8-hour days (1)

______ Night Work (2)

______ Project Size (3)

______ Regionalized productivity rates (4)

______ Activity in schedule for traffic control/movements (5)

18. Any additional comments regarding the Kentucky Contract Time Determination System (KY-CTDS)?

19. If you are familiar with the system and don't use it, please indicate why?

20. How do you determine the contract time for a project?

21. Do you use productivity rates or other means to determine activity durations? If so, please explain your method.

22. If you use productivity rates, do you use historical data, contractor input, or experience? Please explain.

23. Do you have any recommendations for additional users of the system that would be willing to complete this survey? If so, could you please provide the necessary contact information?

Name (1)

Title (2)

District (3)

Email Address (4)

Phone Number (5)

24. Are you willing to further discuss your experience with the Kentucky Contract Time Determination System with the research team? If so, can you please provide the following contact information?

Name (1)

Email Address (2)

Phone Number (3)

Survey Report

My Report
Last Modified: 03/07/2011
Response Set: KYTC Employees

1. You have been selected to participate in this questionnaire. Your participation is purely voluntary. You do not have to participate; there will be no repercussions in the event that you do not participate. Results will be reported in aggregate summaries. YOUR RESPONSES IN THIS SURVEY WILL BE KEPT STRICTLY CONFIDENTIAL. Please provide us with your position or title within the Kentucky Department of Transportation.

Position/Title
Design Section Supervisor
Planning Supervisor
Transportation Engineering Assistant II
Transportation Engineer Supervisor
Project Manager
Trans Eng Tech III
TE II
TEBM Project Development
Transportation Engineering Branch Manager for Project Development
TEBM PD&P, Br I
Transportation Engineering Branch Manager for Project Development
TE Supervisor
EIT II/Design Engineer
Transportation Engineering Branch Manager for Project Development
EIT II
Design/Engineer-in-Training II
EIT II
EIT II

Project Manager
Transportation Engineering Branch Manager

Statistic	Value
Total Responses	20

2. Are you familiar with the Kentucky Contract Time Determination System (KY-CTDS)?

#	Answer		Response	%
1	Yes		17	85%
2	No		3	15%
	Total		20	100%

Statistic	Value
Min Value	1
Max Value	2
Mean	1.15
Variance	0.13
Standard Deviation	0.37
Total Responses	20

3. Do you use the Kentucky Contract Time Determination System (KY-CTDS)?

#	Answer		Response	%
1	Yes		10	50%
2	No		10	50%
	Total		20	100%

Statistic	Value
Min Value	1
Max Value	2
Mean	1.50
Variance	0.26
Standard Deviation	0.51
Total Responses	20

4. Please indicate your district's overall use of the Kentucky Contract Time Determination System (KY-CTDS).

#	Question	Never Use	Less than Half	Half Projects	More than Half	All Projects	Responses	Mean
1	Overall Use of KY-CTDS	0	0	0	5	3	8	4.38

Statistic	Overall Use of KY-CTDS
Min Value	4
Max Value	5
Mean	4.38
Variance	0.27
Standard Deviation	0.52
Total Responses	8

5. Comments:

Text Response
Used on all Design projects to set contract time before letting. Don't know if it was used by Maintenance for projects they initiated.
I use the system to get started and then start making changes based on past experience and knowledge.

Statistic	Value
Total Responses	2

6. How would you agree with the following statements regarding the overall effectiveness of the system based on the times you have used it?

#	Question	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Responses	Mean
1	The system is easy to use	0	0	4	4	0	8	3.50
2	The default productivity rates are accurate	0	5	2	2	0	9	2.67
3	The system generates an achievable contract time	0	4	1	3	1	9	3.11
4	The time and schedule generated are typically accurate to contractors	0	7	2	0	0	9	2.22

Statistic	The system is easy to use	The default productivity rates are accurate	The system generates an achievable contract time	The time and schedule generated are typically accurate to contractors
Min Value	3	2	2	2
Max Value	4	4	5	3
Mean	3.50	2.67	3.11	2.22
Variance	0.29	0.75	1.36	0.19
Standard Deviation	0.53	0.87	1.17	0.44
Total Responses	8	9	9	9

7. Comments:

Text Response
We sometimes have to adjust the sequencing based on the maintenance of traffic plans.
Usually had to meet with resident engineer to help set productivity rates based on their experience.
Production rates for some of the items (seeding and striping) seem to be extraordinarily under-estimated yielding exorbitant results. The estimate does not factor in parallel work items. I.e. grading can occur while clearing and grubbing take place. In fact the contractor cannot open up the entire project. Which makes final dressing too long as well, since a good portion of a long project will have been seeded well before paving is completed.
The system can be a good starting point but you have to modify it extensively to get a phasing of construction events that is accurate. Each project is different and requires modifications. You can not just plug numbers in that program and get an achievable contract time. If the user does not have enough knowledge of construction and the phasing of work, I always suggest having some one from Construction to assist.
The contract time it gives is really used as a starting point. Project development meets with construction and to get some ideas on how much time should be given and the contract time goes up or down from there.

Statistic	Value
Total Responses	5

8. For each of the system templates, how long does it take to generate a time and schedule for projects LESS THAN $500,000?

#	Question	1-2 hours	3-4 hours	5-6 hours	1 day	3-5 days	Other	Responses	Mean
1	Reconstruction Limited Access	4	2	0	1	1	0	8	2.13
2	Reconstruction Open Access	6	1	0	1	1	0	9	1.89
3	New Route	4	2	0	1	1	0	8	2.13
4	Relocation	5	2	0	1	1	0	9	2.00
5	Bridge Rehabilitation	7	1	0	1	0	0	9	1.44
6	Bridge Replacement	6	1	1	1	0	0	9	1.67

Statistic	Reconstruction Limited Access	Reconstruction Open Access	New Route	Relocation	Bridge Rehabilitation	Bridge Replacement
Min Value	1	1	1	1	1	1
Max Value	5	5	5	5	4	4
Mean	2.13	1.89	2.13	2.00	1.44	1.67
Variance	2.41	2.36	2.41	2.25	1.03	1.25
Standard Deviation	1.55	1.54	1.55	1.50	1.01	1.12
Total Responses	8	9	8	9	9	9

9. For each of the system templates, how long does it take to generate a time and schedule for projects GREATER THAN $500,000?

#	Question	1-2 hours	3-4 hours	5-6 hours	1 day	3-5 days	Other	Responses	Mean
1	Reconstruction Limited Access	0	4	1	2	1	0	8	3.00
2	Reconstruction Open Access	1	5	0	2	1	0	9	2.67
3	New Route	0	4	1	1	2	0	8	3.13
4	Relocation	0	5	1	1	2	0	9	3.00
5	Bridge Rehabilitation	2	6	0	1	0	0	9	2.00
6	Bridge Replacement	0	7	1	1	0	0	9	2.33

Statistic	Reconstruction Limited Access	Reconstruction Open Access	New Route	Relocation	Bridge Rehabilitation	Bridge Replacement
Min Value	2	1	2	2	1	2
Max Value	5	5	5	5	4	4
Mean	3.00	2.67	3.13	3.00	2.00	2.33
Variance	1.43	1.75	1.84	1.75	0.75	0.50
Standard Deviation	1.20	1.32	1.36	1.32	0.87	0.71
Total Responses	8	9	8	9	9	9

10. Do you use the default productivity rates already in place in the system?

#	Answer		Response	%
1	Yes		7	78%
2	No		2	22%
	Total		9	100%

Statistic	Value
Min Value	1
Max Value	2
Mean	1.22
Variance	0.19
Standard Deviation	0.44
Total Responses	9

11. If so, do you feel the default rates need to be adjusted?

Text Response
Yes
Default rates are as good as we can get without detailed productivity analysis and data from contractors
The default rates do need to be adjusted
Yes
Yes, on some items I tend to back calculate rates or estimate reasonable production rates.
For some of the items the default rate does need to be adjusted.

Statistic	Value
Total Responses	6

12. If not, how do you determine activity productivity rates?

Text Response
I do vary the defaults occasionally based on prior experience and comments.
Guess
Check with previously constructed projects' time
Consult with construciton personnel and change based on proejct characteristics
Consult with District Construction personnel. Rates need to be ball-parked a little closer
Analyze the task and what it involves then generate what I believe it will take the contractor. And factor in the construction season also.

Statistic	Value
Total Responses	6

13. Any additional comments on productivity rates?

Text Response
Some items are unclear what they include. Entrance Pavement - is that concrete entrances or all entrances.
Some of the activities rates are determined by experiance and knowing what certain contractors can or cannot do.

Statistic	Value
Total Responses	2

14. Do you account for the following in generating your schedule?

#	Question	Yes	No	Responses	Mean
1	Holidays	3	5	8	1.63
2	Season	6	2	8	1.25
3	Weather	4	4	8	1.50

Statistic	Holidays	Season	Weather
Min Value	1	1	1
Max Value	2	2	2
Mean	1.63	1.25	1.50
Variance	0.27	0.21	0.29
Standard Deviation	0.52	0.46	0.53
Total Responses	8	8	8

15. Does the default schedule logic used in the project templates accurately reflect the actual work sequence?

Text Response
Not always
No
Most of the time. We sometimes have to modify the times and actual work sequence.
Not always, some can be done consecutively
Sometimes had to be modified.
No.   Do not know how to account for items in 12. We wind up using the Working Day estimate and estimating 18 days a month from April to November to guesstimate completion date/schedule.
Absolutely not. That is what I spend more time on than anything is getting the work sequence acceptable. This is where new users can really mess up.
As far as I can tell. I sometimes believe that there should be more activities listed.

Statistic	Value
Total Responses	8

16. How well does the schedule logic account for concurrent activities?

Text Response
Some are good, some not real good.
The concurrenct activities in the program do not make sence, and some of the activities that have to be after each other are not automatically after each other.
It does an okay job.
Not very well
Not very well, had to tweak logic at times.
Poorly. Items must be fully completed prior to dependant activity to begin.
It is fair. But we must realize that some activities can be concurrent on one project, but may not on another. Again, very important the user be familiar with the construction activities required on the project.
Some adjusting is required depending on the work and how the project is planned to be built.

Statistic	Value
Total Responses	8

17. Do you account for maintenance of traffic in your schedule? If so, how?

Text Response
Mainly in the initial traffic control box.
Yes, we add a couple of days
Yes but most usually we modify the actual time
Yes, what activities are on-going at the particular MOT phase
Adding days to Phasing and final cleanup or doign separate calcs for each phase.
Yes. Phasing/detours
Yes. Edit the days needed by how extensive the MOT is.
Yes, experience.

Statistic	Value
Total Responses	8

18. Does the critical path generated by the default project templates accurately reflect actual projects?

Text Response
Sometimes.
No
Maybe not
Don't know.
Pretty closely with the exception of concurrent activities.
I don't think so. You may get close at times. Smaller projects are probably fairly accurate. Larger ones, no.
Most of the time.

Statistic	Value
Total Responses	7

19. Please rank the following to potentially include in the Kentucky Contract Time Determination System expansion. 1 indicates most needed in system, 5 indicates the least needed in the system. Please use each rank only once.

#	Answer	1	2	3	4	5	Responses
1	Alternative work weeks instead of only M-F, 8-hour days	1	5	1	0	1	8
2	Night Work	2	1	1	2	2	8
3	Project Size	2	0	2	3	1	8
4	Regionalized productivity rates	1	1	1	1	4	8
5	Activity in schedule for traffic control/movements	2	1	3	2	0	8
	Total	8	8	8	8	8	-

Statistic	Alternative work weeks instead of only M-F, 8-hour days	Night Work	Project Size	Regionalized productivity rates	Activity in schedule for traffic control/movements
Min Value	1	1	1	1	1
Max Value	5	5	5	5	4
Mean	2.38	3.13	3.13	3.75	2.63
Variance	1.41	2.70	2.13	2.50	1.41
Standard Deviation	1.19	1.64	1.46	1.58	1.19
Total Responses	8	8	8	8	8

20. Any additional comments regarding the Kentucky Contract Time Determination System (KY-CTDS)?

Text Response
There are to many templants. I have been using this program since its inception for close to a hundred different projects from $250,000 turn lanes to $50,000,000 interstate projects and all of them could be completed with the same templant.
What is the differences/advantages to using the different logic files? I'd like to see zeroed items drop out of the logic to eliminate confusion when bridge info shows up, but bridges/coffer dams are not included.

Statistic	Value
Total Responses	2

21. If you are familiar with the system and don't use it, please indicate why?

Text Response
No longer use. Was on Design from 1997-2009 and used at that time.
Design engineer would generate working day estimate and then come talk to me to see if it was appropriate for upcoming letting of project.
Contract time for project is assigned by Project Developement personnel and they typically will use program and then adjust time for work based on input from PD&P personnel and their experience performing similar type work.
Our designers would typically use it
We have found some inaccuracies with it's calculation of contract time. We have developed our own spreadsheet based on similiar projects and work closely with the District Construction Staff when determining contract time.

Statistic	Value
Total Responses	5

22. How do you determine the contract time for a project?

Text Response
In the end after we have ran the program and have an idea for the schedule we talk to construction and develop the amount of time needed based on 120 working days per year. We determine through our discussion if it is a one month project, a one year project, or a two year project and assign the number of working days we think is appropriate.
The KY-CTDS and then verify with construction based on their experience.
Use CTDS to get a ballpark figure and discuss with Construction to dial it in.
I used past experience guided by my engineering judgement.
Base on work experiences with similar type of work and any other type of project scheduling conflicts with local area. Also try to figure if work will be suitable for smaller type contractors with limited equipment available to perform work.
Typically I don't, but our designers use the system. They also have our construction personnel review the plans and provide insight. Ultimately, we have construction review our recommendations and then reach a compromise.
Meet with TEBM for Project Delivery and discuss all phases of the project and based on experience determine the amount of time required for the phasing.
The District has developed a spreadsheet with average activity times. This method is used as our baseline and we fine tune project time by working with our Construction Staff.
I've worked closely with the construction engineer and past construction projects that include similar work.

Statistic	Value
Total Responses	9

23. Do you use productivity rates or other means to determine activity durations? If so, please explain your method.

Text Response
We use our experiance with past projects of a similiar size and scope.
I use my past experience as the Construction Branch Manager to determine production rates given certain conditions and details related to a project.
Yes, based on experiences of previous jobs in same area will know most contractors that will be working on specific type of work and how much they will produce in a typical day both max and min. given the location of job and where materials will be coming from.
See above
We just use the rates that we've witnessed for the contractors in our area, which could have some inaccuracy if an unknown contractor with bigger, more advanced equipment were to get a project. However, I've never seen an unfamilar contractor win a major project.
Both productivity rates and contract times from similar projects.

Statistic	Value
Total Responses	6

24. If you use productivity rates, do you use historical data, contractor input, or experience? Please explain.

Text Response
Experience of resident engineers.
We use similar recent projects for comparison and see how they underran/overran contract time and adjust accordingly.
Historical data and experience
Experience, see response to question 21.
We use historical data and expertise from our construction inspectors
Basically, just experience.
Depending on the nature of the project, all three listed above.

Statistic	Value
Total Responses	7

Survey Summary

- 17 of 20 – 85 percent familiar with the Kentucky Contract Time Determination System (KY-CTDS)
- 10 of 20 – 50 percent use the Kentucky Contract Time Determination System (KY-CTDS)
- Of users (8 responses), five use on more than half of projects and three use on all of projects
- Average time required for projects less than $500,000: approx 2-3 hours
- Average time required for projects greater than $500,000: approx: 4-5 hours
- Account for the following: Yes/No
    - Holidays: 3/5
    - Season: 6/2
    - Weather: 4/4

Comments

- System used as a starting point with changes made on past experience and knowledge
- Phasing and sequencing are changes are often required to get a more accurate contract time
- System does not account for some work items that can be done in parallel
    - Grading/Clear and Grub
    - Final Dressing
- Production rates are under estimated for seeding and striping
- A general consensus from the survey was that the default rates need to be adjusted
    - Varied based on prior experience and consultation with construction personnel
    - Look at individual tasks to determine change from default
    - Check with completed projects
    - Some items have an unclear scope of work
    - Contractor abilities are considered at times
- Comments covered a broad spectrum reflecting the schedule logic compared to actual work sequence
    - Answers: Absolutely not, No, Not Always, Sometimes, As far as I can tell, Most of the time

- Schedule accounting for concurrent activities also had a range of responses
    - Answers: Concurrent activities do not make sense, Poorly, Not very well, Ok job, Some are good and some are not, It is fair
- Traffic maintenance is generally accounted for by adding a certain number of days based on the MOT, Phasing and detour requirements and overall experience
- The critical path generated by the project templates related to actual projects had answers across the board
    - Answers: No, Maybe not, Don't know, Sometimes, Pretty close except concurrent activities, Most of the time
- Smaller projects better than larger projects
- All projects completed could be done with the same template so there are too many templates.
- The activities not included in a given project should drop out to avoid confusion
- Why not being used?
    - Design Engineers use and then come talk to construction
    - Project Development personnel use and then adjust based on other personnel input and experience
    - Developed own spreadsheet based on similar projects due to inaccuracy of system's calculation of contract time and work closely with construction staff

<u>Overall survey theme</u>

The system is a good starting point on most projects that enables the engineer to obtain a rough estimate of how long a project should take to complete. Refining of the system should include productivity rate adjustments and concurrent activity i.e. logic adjustment. Additional items to consider are adding in alternative work weeks to project template and an activity for phasing and/or traffic movements.

Design engineers use the system to obtain a baseline figure for the number of working days required to complete a given project. They then consult with construction personnel that have field experience to refine the number of working days. The construction personnel look at data from past projects as well as use their own personal judgment based on experience. The designers and construction personnel can then arrive at a number of working days they see fit for the given project.

Follow Up Interview Outline

Introduction

Good morning/afternoon. First of all we want to thank you for your time to meet with us to discuss the Kentucky Contract Time Determination System (KY-CTDS). The information you can provide to us will greatly aid our research efforts to update and improve the current system. We want to make it clear that your participation in this interview is purely voluntary and that your answers will not in any way be linked to you. Any report that may include any of your answers to our questions will be reported in aggregate form therefore nothing will be associated with your name, title, district, etc. Are you ready to begin the survey?

Follow Up Interview Questions

What are the biggest problems you have encountered with the Kentucky Contract Time Determination System (KY-CTDS)?

What features of the system do you find most useful?

What parts of the system could be improved?

What would you suggest to improve the logic and critical path generated from the system?

What recommendations would you make to increase the accuracy of the productivity rates?

Traffic maintenance seemed to be a reoccurring issue in the past. What would you suggest is the best way to include this activity accurately into the work schedule?

In your experience what role does project size play in determining contract durations?

In what way would you suggest to include alternative work weeks and night work into the template and still keep the system easy to use?

Would you rather see more templates based on project conditions or fewer templates with more inputs that relate to the actual project conditions?

Appendix C

Table C-1

Project ID	Actual Start	Actual Finish	Actual Duration	KYCTDS As-Is	% Difference	% Error	OKCTDS	% Difference	% Error	KYCTDS Modified	% Difference	% Error
Open Access												
04-0072	12-Jul-04	28-Nov-05	361	104	111%	71%	115.3	103%	68%	104	111%	71%
04-0103	13-Jun-05	24-Jun-05	10	45	127%	350%	18	57%	80%	32	105%	220%
04-0121	8-Jul-04	10-Sep-04	47	45	4%	4%	7.5	145%	84%	18	89%	62%
04-1000	9-Jul-04	14-Oct-05	331	52	146%	84%	122.4	92%	63%	52	146%	84%
04-1203	26-May-05	10-Jan-06	164	61	92%	63%	39.7	122%	76%	31	136%	81%
04-2002	9-Jul-04	11-Jul-04	1	45	191%	4400%	7.1	151%	610%	20	181%	1900%
04-2003	28-Jun-04	1-Jul-04	4	45	167%	1025%	5.5	32%	38%	18	127%	350%
04-2011	12-Jul-04	12-Aug-04	24	66	93%	175%	51.3	73%	114%	44	59%	83%
04-2012	1-Sep-04	3-Sep-04	3	45	175%	1400%	5.9	65%	97%	20	148%	567%
04-2023	26-Apr-05	3-May-05	6	45	153%	650%	18.7	103%	212%	33	138%	450%
04-2025	9-Aug-04	13-Aug-04	5	45	160%	800%	6.6	28%	32%	23	129%	360%
04-2026	26-Apr-05	18-May-05	17	54	104%	218%	40.8	82%	140%	51	100%	200%
04-2027	8-Jul-04	6-Aug-04	22	61	94%	177%	49.1	76%	123%	59	91%	168%
04-2031	6-Jun-05	22-Jun-05	13	45	110%	246%	20.2	43%	55%	33	87%	154%
05-2151	28-Jun-05	20-Jul-05	17	45	90%	165%	18.9	11%	11%	33	64%	94%
05-2131	1-Jul-05	1-Aug-05	22	46	71%	109%	15	38%	32%	23	4%	5%
05-2078	19-Jul-05	9-Aug-05	16	45	95%	181%	27.2	52%	70%	42	90%	163%
05-2150	10-Jun-05	30-Jun-05	15	45	100%	200%	28.5	62%	90%	45	100%	200%
05-2086	15-Jul-05	29-Jul-05	11	45	121%	309%	28.5	89%	159%	44	120%	300%
05-2059	29-Jun-05	29-Jul-05	23	61	90%	165%	47	69%	104%	61	90%	165%
05-2153	1-Jul-05	25-Jul-05	17	120	150%	606%	56.4	107%	232%	30	55%	76%
06-2153	29-Jun-06	17-Aug-06	36	45	22%	25%	37.6	4%	4%	33	9%	8%
06-2179	15-Aug-06	25-Sep-06	30	45	40%	50%	6.9	125%	77%	21	35%	30%
06-2183	7-Aug-06	15-Aug-06	7	45	146%	543%	8.2	16%	17%	23	107%	229%
06-2185	13-Jul-06	18-Aug-06	27	45	50%	67%	7	118%	74%	21	25%	22%
06-2079	11-Oct-06	25-Oct-06	11	45	121%	309%	15.3	33%	39%	30	93%	173%
06-2181	22-Aug-06	14-Sep-06	18	61	109%	239%	33.4	60%	86%	23	24%	28%
06-2187	29-Sep-06	7-Nov-06	28	71	87%	154%	47.4	51%	69%	27	4%	4%
06-2191	8-Aug-06	21-Aug-06	10	51	134%	410%	26.9	92%	169%	28	95%	180%
06-2192	4-Jul-06	20-Jul-06	13	45	110%	246%	20.2	43%	55%	34	89%	162%
06-2194	11-Sep-06	28-Dec-06	79	140	56%	77%	122.4	43%	55%	39	68%	51%

Table C-2

Project ID	Actual Start	Actual Finish	Actual Duration	KYCTDS As-Is	% Difference	% Error	OKCTDS	% Difference	% Error	KYCTDS Modified	% Difference	% Error
Bridge Rehabilitation												
04-1205	7-Jun-04	8-Oct-04	123	64	63%	48%	5.8	182%	95%	38	106%	69%
04-1206	22-Sep-04	11-Feb-05	142	54	90%	62%	15.7	160%	89%	27	136%	81%
04-2901	5-Jul-04	17-Aug-04	43	49	13%	14%	31.9	30%	26%	21	69%	51%
04-2902	18-Aug-04	8-Oct-04	51	52	2%	2%	64.6	24%	27%	24	72%	53%
04-2904	22-Jun-04	21-Jul-04	29	51	55%	76%	48.1	50%	66%	23	23%	21%
06-1233	10-Jul-06	7-Dec-06	109	48	78%	56%	1221.3	167%	1020%	22	133%	80%
06-2913	22-Jun-06	6-Apr-07	207	48	125%	77%	15.3	172%	93%	20	165%	90%
07-1114	9-Jul-07	31-Aug-07	40	45	12%	13%	6.9	141%	83%	19	71%	53%
07-2921	13-Mar-08	19-Apr-08	27	51	62%	89%	58.5	74%	117%	23	16%	15%
07-2925	16-Jul-07	20-Aug-07	26	51	65%	96%	20.6	23%	21%	23	12%	12%
07-2922	20-Jul-07	20-Nov-07	88	61	36%	31%	61.9	35%	30%	33	91%	63%
08-2242	25-Jul-08	11-Aug-08	12	46	117%	283%	7.9	41%	34%	18	40%	50%
08-2923	18-Jun-08	8-Jul-08	15	49	106%	227%	9.6	44%	36%	21	33%	40%
08-2927	14-Jul-08	28-Jul-08	11	50	128%	355%	11.8	7%	7%	22	67%	100%
08-2925	19-Sep-08	7-Nov-08	36	49	31%	36%	51.8	36%	44%	21	53%	42%

Table C-3

Project ID	Actual Start	Actual Finish	Actual Duration	KYCTDS As-Is	% Difference	% Error	OKCTDS	% Difference	% Error	KYCTDS Modified	% Difference	% Error
Limited Access												
04-1104	19-Jul-04	1-Dec-06	620	349	56%	44%	459.1	30%	26%	349	56%	44%
04-1106	21-Jul-04	10-Dec-04	103	52	66%	50%	14.3	151%	86%	22	130%	79%
04-2036	8-Aug-04	24-Sep-04	35	156	127%	346%	7.9	126%	77%	21	50%	40%
04-2039	12-Jul-04	22-Oct-04	75	48	44%	36%	31	83%	59%	29	88%	61%
04-2040	30-Aug-04	22-Sep-04	18	153	158%	750%	8.1	76%	55%	21	15%	17%
05-1200	31-May-05	21-Oct-05	104	143	32%	38%	324.1	103%	212%	143	32%	38%
05-2091	7-Jun-05	15-Nov-05	116	1403	169%	1109%	280.3	83%	142%	255	75%	120%
05-2154	5-Jul-05	11-Oct-05	71	340	131%	379%	197.3	94%	178%	168	81%	137%
06-1028	5-Jul-06	6-Apr-07	198	73	92%	63%	85.2	80%	57%	68	98%	66%
06-1022	12-Jun-06	26-Sep-06	77	461	143%	499%	931.2	169%	1109%	461	143%	499%
07-2205	10-Oct-07	5-Nov-07	19	138	152%	626%	24.4	25%	28%	37	64%	95%
07-2264	6-Aug-07	24-Aug-07	15	89	142%	493%	5.4	94%	64%	23	42%	53%
07-2280	24-Jun-07	7-Aug-07	32	59	59%	84%	7.4	125%	77%	29	10%	9%
13												

Table C-4

Project ID	Actual Start	Actual Finish	Actual Duration	KYCTDS As-Is	% Difference	% Error	OKCTDS	% Difference	% Error	KYCTDS Modified	% Difference	% Error
Bridge Replacement												
04-1102	21-Jul-04	16-May-05	299	74	121%	75%	126.6	81%	58%	46	147%	85%
04-1204	11-Aug-04	28-Mar-05	229	54	124%	76%	17.9	171%	92%	26	159%	89%
06-1229	8-Aug-06	6-Nov-06	65	51	24%	22%	6.5	164%	90%	25	89%	62%
06-1230	13-Jun-06	17-Nov-06	114	54	71%	53%	34.3	107%	70%	28	121%	75%
07-1124	22-Aug-07	23-Oct-07	45	53	16%	18%	7.4	144%	84%	27	50%	40%
07-1219	16-Jul-07	7-Nov-07	83	58	35%	30%	54.4	42%	34%	32	89%	61%
08-1122	11-Jul-08	15-May-09	221	65	109%	71%	122.1	58%	45%	38	141%	83%

Statistical Calculations

% difference = (Predicted Duration- Actual Duration)/Actual Duration *100%

Open Access Statistics

Table C-5

	KY-CTDS as-is	OK-CTDS	KY-CTDS modified
Open Access	*% Error*	*% Error*	*% Error*
Mean	436%	101%	214%
Median	200%	76%	162%
Mode	2.461538	0.553846154	2
Variance	63.87236	1.180894956	11.59255
Std Dev	7.992019	1.086689908	3.404783

Limited Access Statistics

Table C-6

	KY-CTDS as-is	OK-CTDS	KY-CTDS modified
Limited Access	*% Error*	*% Error*	*% Error*
Mean	50%	86%	79%
Median	3.457143	0.774285714	0.4
Mode	#N/A	#N/A	#N/A
Variance	11.58163	8.329674368	1.597642
Std Dev	3.403179	2.886117525	1.263979

Bridge Rehabilitation Statistics

Table C-7

	KY-CTDS as-is	OK-CTDS	KY-CTDS modified
Bridge Replacement	*% Error*	*% Error*	*% Error*
Mean	49%	68%	71%
Median	53%	70%	75%
Mode	#N/A	#N/A	#N/A
Variance	0.066755	0.051421073	0.029946
Std Dev	0.25837	0.22676215	0.173048

Bridge Replacement Statistics

Table C-8

	KY-CTDS as-is	OK-CTDS	KY-CTDS modified
Bridge Replacement	*% Error*	*% Error*	*% Error*
Mean	49%	68%	71%
Median	53%	70%	75%
Mode	#N/A	#N/A	#N/A
Variance	0.066755	0.051421073	0.029946
Std Dev	0.25837	0.22676215	0.173048

Cumulative Histograms

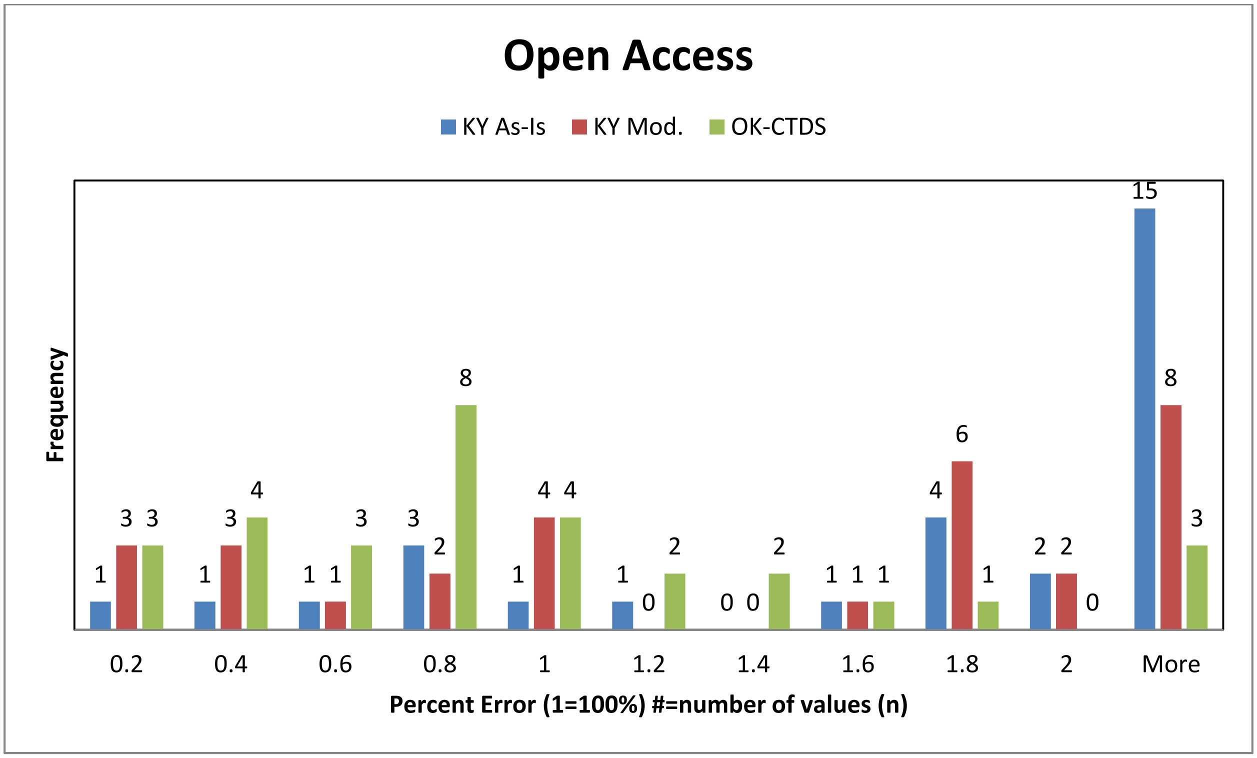


Figure C-1

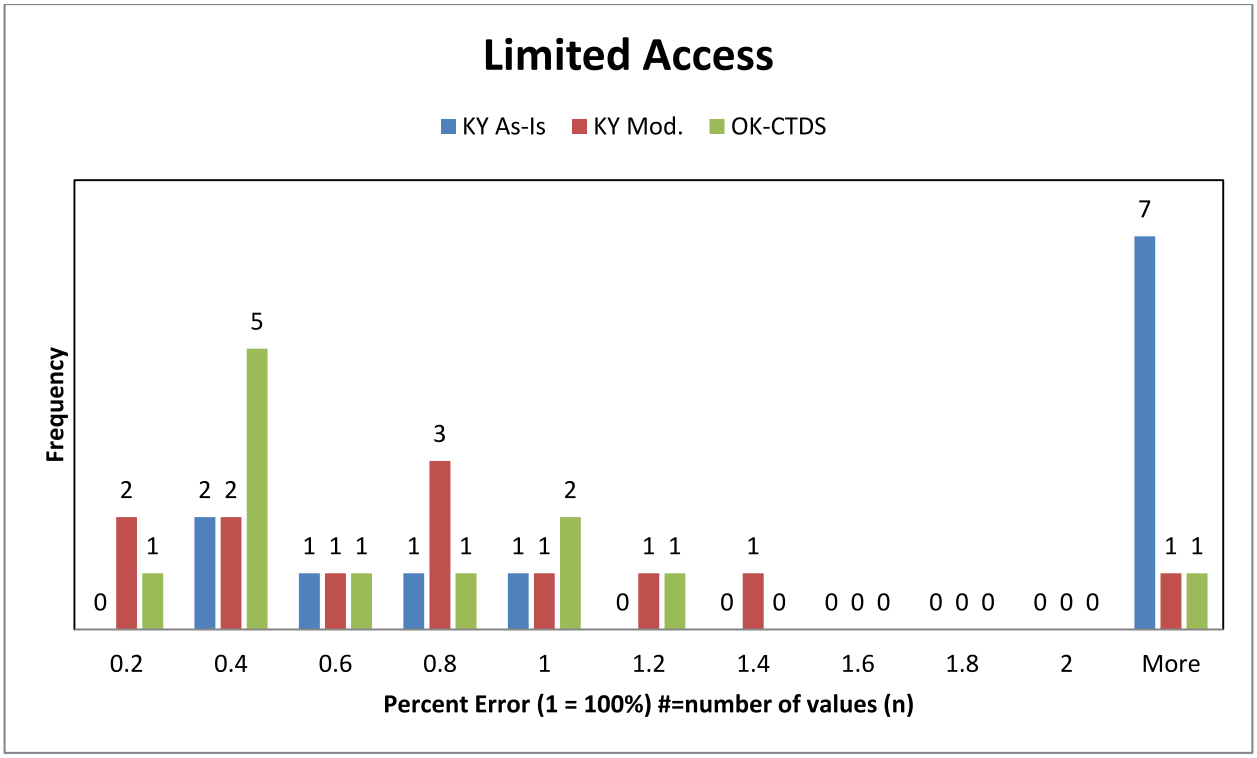


Figure C-2

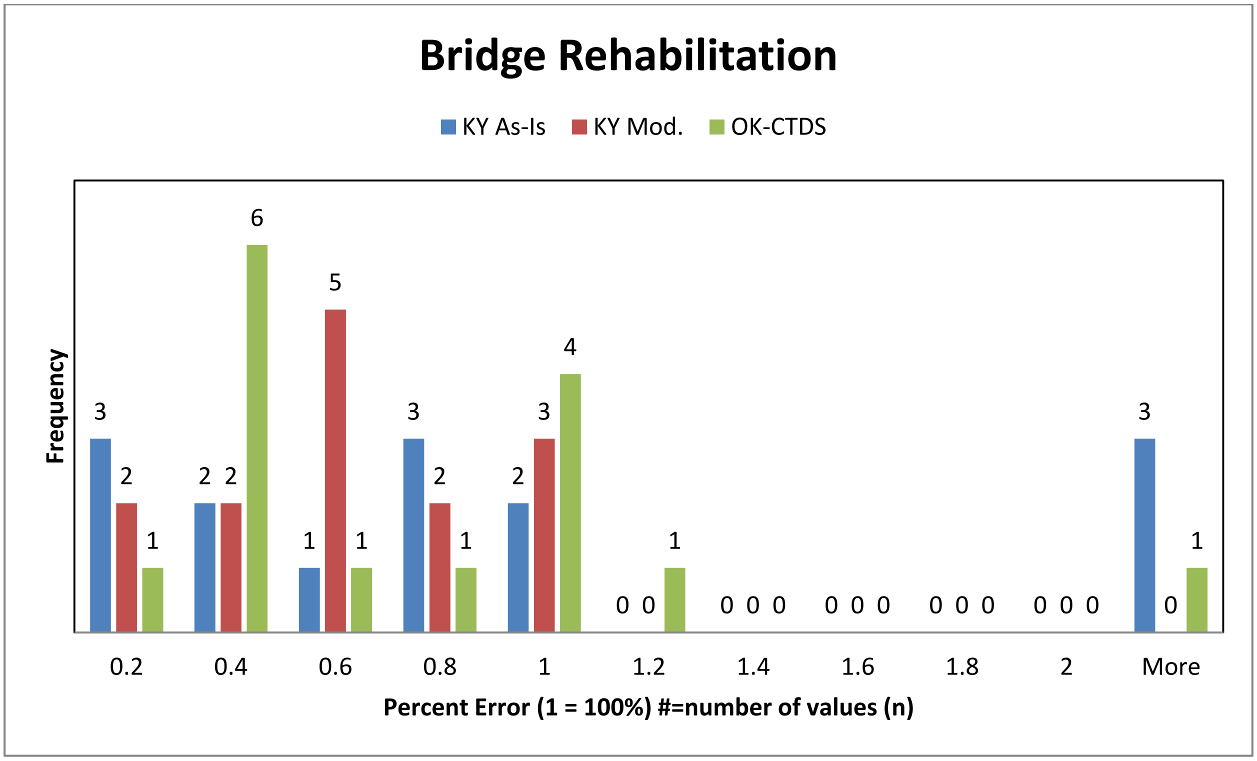


Figure C-3

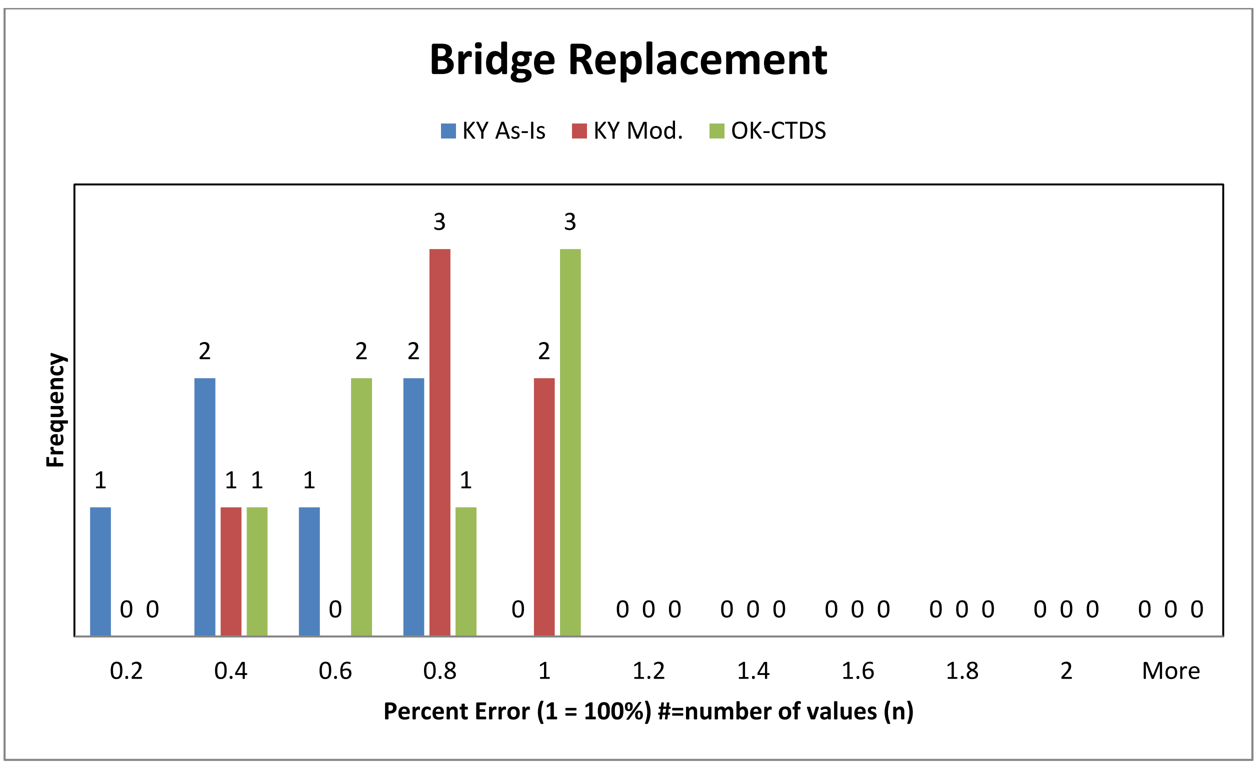


Figure C-4

#=number of values (n)

Project Durations compared to Asphalt Quantities

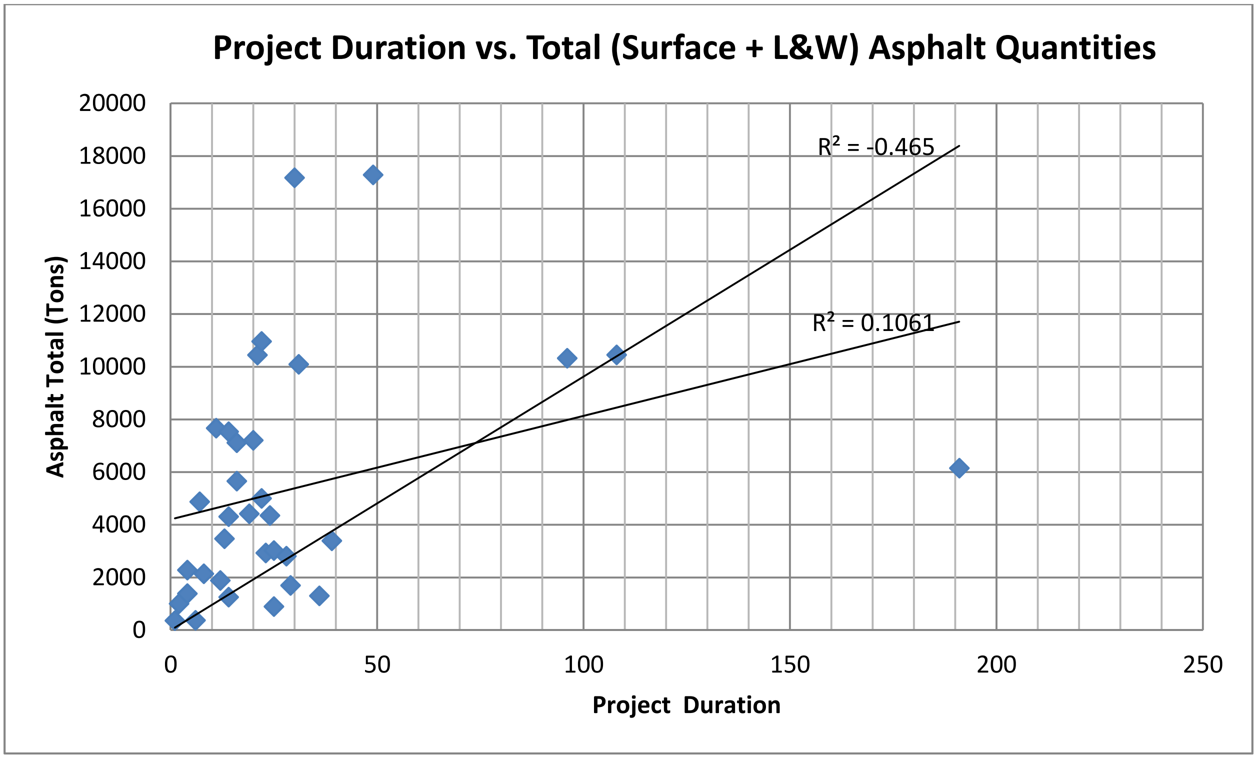


Figure C-5

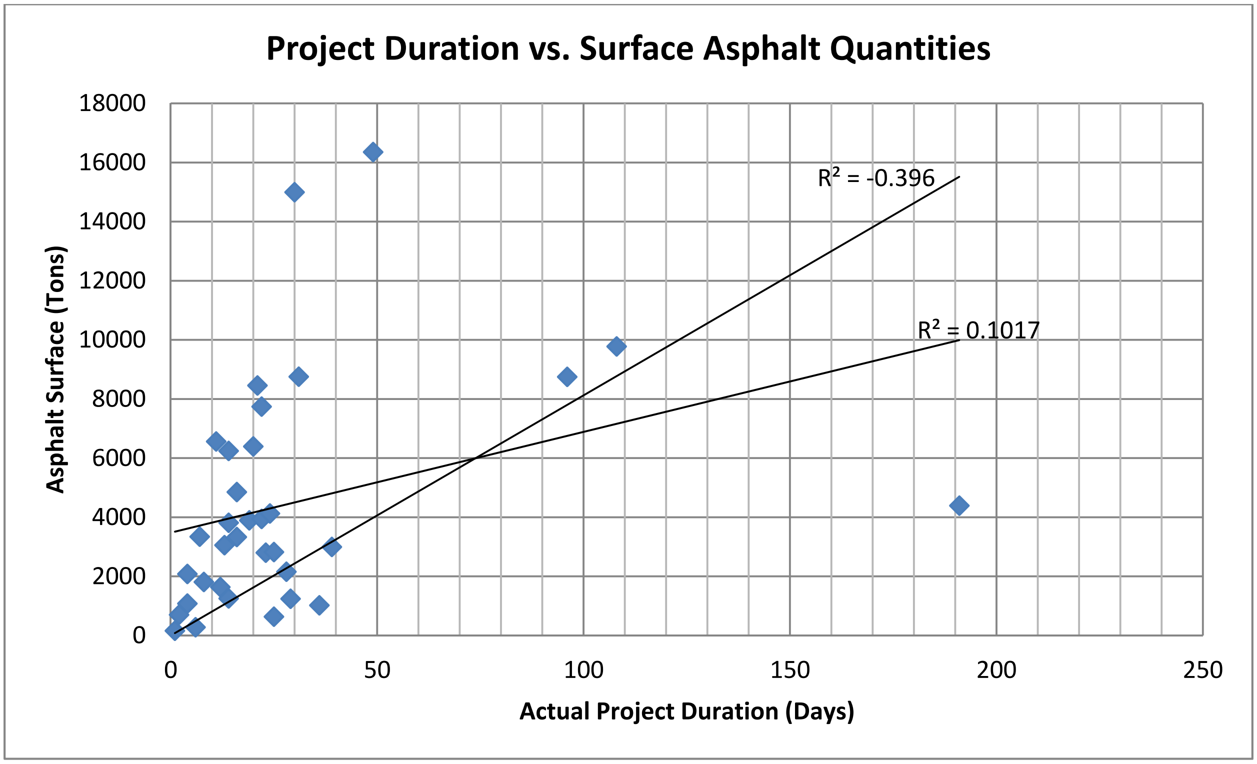


Figure C-6

System Assumptions

KY-CTDS Assumptions

As-Is

Line items with default durations were left alone

If clear and grub (lump sum) was line item made duration = 1 day

Modified

Remove

- Diversion – 6 days
- Erect Temp Bridge – 8 days
- Remove Existing Str – 3 days
- Cofferdams – 15 days
- Remove Temp Bridge – 4 days
- Major Traffic Signals – 15 days

Leave

- Initial Traffic Control – 2 days
- Final Cleanup – 10 days
- Phasing Allowance – 3 days

Milling was initially put in Asphalt Repair (tons). Was moved to Base, Level and Wedging in modified.

Items to consider for parametric estimating

- Open & Limited Access
  - Asphalt surface
  - Asphalt base, level and wedge
  - Asphalt repair
  - Striping
  - Drainage pipe
- Bridge Rehab & Replace
  - Concrete
    - Class A - substructure
    - Class AA – superstructure
  - Piling
  - Concrete & Steel Beams
  - Remove Existing Structure
  - Reinforcing Steel?
- Additional items of concern
  - Remove Structure – lump sum
  - Foundation Prep – lump sum
  - Steel Beams – lump sum

State X Assumption

Assumed durations

- Mobilization = 1 day
- Clearing and Grubbing = 1 day
- Cleanup/Open to Traffic = 1 day
- Phasing Allowance = 1 day

Base operations: DGA = 100 lb/cft, tons converted to cubic feet

Assumed 6” thick to convert to square yards when given quantity in cubic yards

Drainage Structures – storm drainage piping includes installation and removal line items on bid sheet

Class A concrete (substructure) used in Abutments work activity

Class AA concrete (superstructure) used in either surfacing concrete (9”) or bridge deck work activity

Granular embankment, Embankment in Place, Structure Granular Backfill, Roadway Excavation, Structure Excavation – All included in Grading – Top Soil, Excavation and Embankment work activity w/ avg. production rate = 2825 cy/day

Base failure repair = soil stabilization (sy)

Productivity Rate Comparison

Table C-9

KY-CTDS			OK CTDS		
Activity	Current Rate	UNITS	Activity	Current Rate	Units
Initial Traffic Control	1	Days	Mobilization	4	Days
Clearing & Grubbing	3	Acres	Clearing & Grubbing	4	days
Diversion (By-pass Detour)	1	Days	Pavement for detours	862	Tons
Roadway Excavation	5,000	CY	Grading - Top soil, excavation & embankment	2825	cy
Embankment in Place	4,000	CY	Grading - Top soil, excavation & embankment	2825	cy
Drainage Pipe	200	LF	Storm Drainage Pipe	110	lf
Box Culverts,Class A Concrete	30	CY	RCB's	60	lf
Erect Temporary Bridge	1	Days			
Remove Existing Structures	1	Days	Removal Exist Structure	620	days
Cofferdams	1	Days			
Structure Excavation	300	CY	Grading - Top soil, excavation & embankment	2825	cy
Piling	300	LF	Driving Piles	257	lf
Sub-Structure,Class A Concrete	40	CY	Abutments (Rebars, Forms, Conc.)	3.75	cy
Concrete Beams	600	LF	Beams (placing)	575	lf
Steel Beams	20,000	Lb	Beams (placing)	575	lf
Super-Structure,Class AA Concrete	20	CY	Slab Decking (forming, rebars, conc.)	720	sf
Remove Temporary Bridge	1	Days			
Major Retaining Walls	1,000	SF			
Sub-grade Stabilization	8,000	SY	Soil Stabilization	2500	cy
Stone Base	1,500	Tons	Agg Base 10"	310	cy
Drainage Blanket	1,200	Tons	Asphalt Base/Fabric install	1000	tons
Asphalt Base, Leveling, & Wedging	1,200	Tons	Asphalt Base/Fabric install	1000	tons
Curb & Gutter	500	LF			
Entrance Pavement	100	SY	Approach Slabs	220	sy
Barrier Walls, Slip Form	500	LF	Barrier Wall	1,045	LF
Asphalt Repair	50	Tons			
Concrete Repair	30	SY			
Concrete Paving	4,000	SY	Concrete Pavement	1640	sy
Asphalt Surface	1,000	Tons	Asphalt Surface	900	tons
Sheet Signs	30	Each	Signs	30	Days
Panel Signs	1	Each	Signs	30	Days
Major Traffic Signals	15	Days/Intersection			
Lighting,Total Installation Luminaires	2	Each			
Guardrail	1,500	LF	Guardrail install	1000	lf
Finish Seeding	4,000	SY	Seeding	2.4	acres
Pavement Marking	10,000	LF	Permanent striping, Traffic signs	10,000	lf
Final Clean-Up	1	Days	Cleanup/Open to Traffic	3	days
Phasing Allowance	1	Days/Phase	Phasing Allowance	2	days

Cumulative Analysis Results

Table C-10

Project ID	Actual Duration	KYCTDS As-Is	KYCTDS Modified	OKCTDS
Open Access				
04-0072	361	104	104	115.3
04-0103	10	45	32	18
04-0121	47	45	18	7.5
04-1000	331	52	52	122.4
04-1203	164	61	31	39.7
04-2002	1	45	20	7.1
04-2003	4	45	18	5.5
04-2011	24	66	44	51.3
04-2012	3	45	20	5.9
04-2023	6	45	33	18.7
04-2025	5	45	23	6.6
04-2026	17	54	51	40.8
04-2027	22	61	59	49.1
04-2031	13	45	33	20.2
05-2151	17	45	33	18.9
05-2131	22	46	23	15
05-2078	16	45	42	27.2
05-2150	15	45	45	28.5
05-2086	11	45	44	28.5
05-2059	23	61	61	47
05-2153	17	120	30	56.4
06-2153	36	45	33	37.6
06-2179	30	45	21	6.9
06-2183	7	45	23	8.2
06-2185	27	45	21	7
06-2079	11	45	30	15.3
06-2181	18	61	23	33.4
06-2187	28	71	27	47.4
06-2191	10	51	28	26.9
06-2192	13	45	34	20.2
06-2194	79	140	39	122.4
31				

Table C-11

Project ID	Actual Duration	KYCTDS As-Is	KYCTDS Modified	OKCTDS
Limited Access				
04-1104	620	349	349	459.1
04-1106	103	52	22	14.3
04-2036	35	156	21	7.9
04-2039	75	48	29	31
04-2040	18	153	21	8.1
05-1200	104	143	143	324.1
05-2091	116	1403	255	280.3
05-2154	71	340	168	197.3
06-1028	198	73	68	85.2
06-1022	77	461	461	931.2
07-2205	19	138	37	24.4
07-2264	15	89	23	5.4
13				

Table C-12

Project ID	Actual Duration	KYCTDS As-Is	KYCTDS Modified	OKCTDS
Bridge Rehabilitation				
04-1205	123	64	38	5.8
04-1206	142	54	27	15.7
04-2901	43	49	21	31.9
04-2902	51	52	24	64.6
04-2904	29	51	23	48.1
06-1233	109	48	22	1221.3
06-2913	207	48	20	15.3
07-1114	40	45	19	6.9
07-2921	27	51	23	58.5
07-2925	26	51	23	20.6
07-2922	88	61	33	61.9
08-2242	12	46	18	7.9
08-2923	15	49	21	9.6
08-2927	11	50	22	11.8
08-2925	36	49	21	51.8
15				

Table C-13

Project ID	Actual Duration	KYCTDS As-Is	KYCTDS Modified	OKCTDS
Bridge Replacement				
04-1102	299	74	46	126.6
04-1204	229	54	26	17.9
06-1229	65	51	25	6.5
06-1230	114	54	28	34.3
07-1124	45	53	27	7.4
07-1219	83	58	32	54.4
08-1122	221	65	38	122.1
7				

Appendix D

KYTC Activity Production Rate				
Project ID#		Production Rate		
ID Number	Work Item	Low	Average	High

Figure D-2: Small Project KYTC Activity Production Rate Worksheet for projects <$1 Million and <100days

Worksheet 1 Project ID#		KYTC Conceptual Construction Duration Schedule Worksheet				
ID Number	Work Item	Bid Quantity	Daily Production Rate	Activity Duration Low (Days)	Activity Duration Average (Days)	Activity Duration High (Days)
*Activity Duration=Bid Quantity/Production Rate						

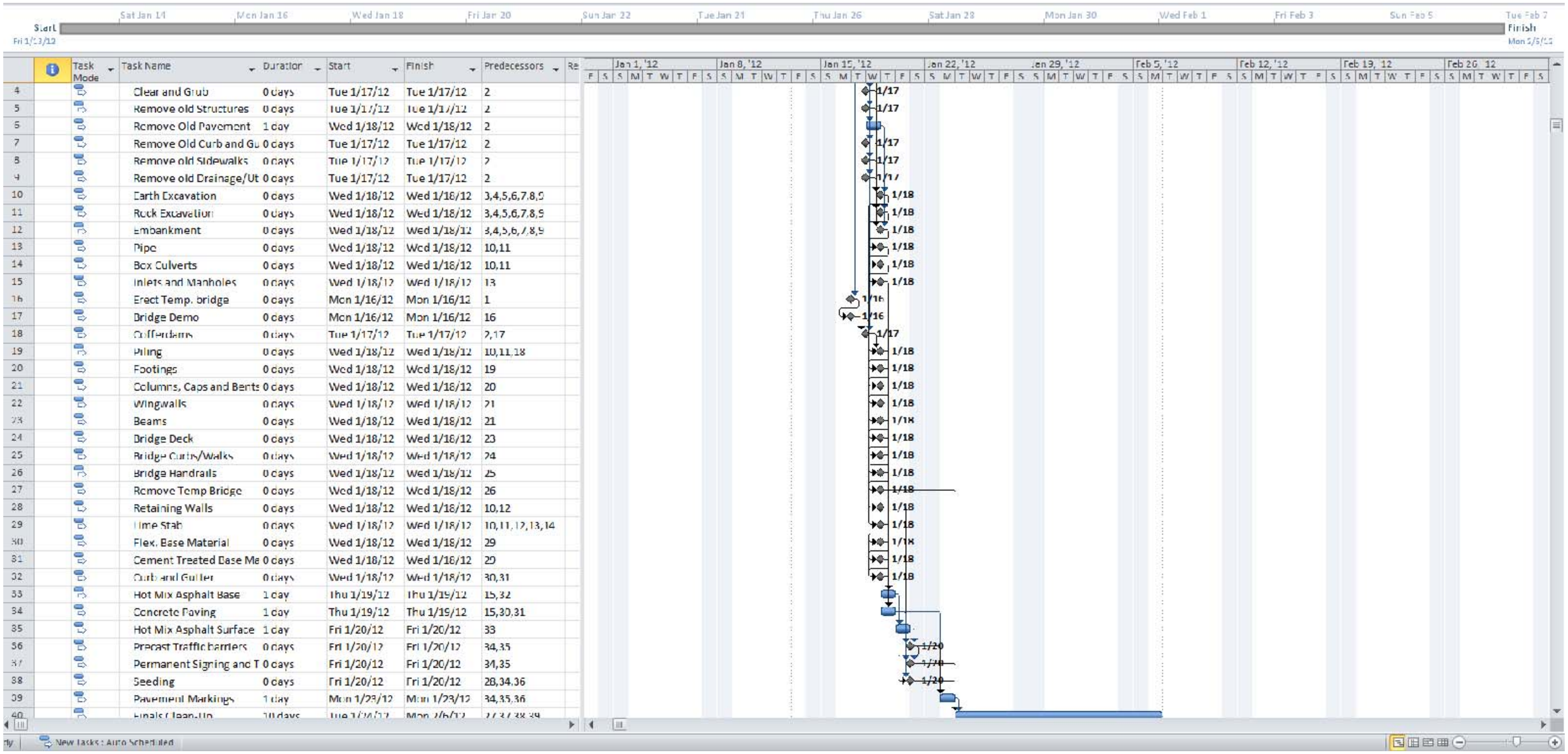
Figure D-3: Small Project KYTC Worksheet 1 for projects <$1 Million and <100days

Worksheet 2 Project ID#		KYTC Conceptual Construction Schedule Worksheet					
ID Number	Work Item	Quantity and Unit	Daily Production Rate	Duration (Days)	Preceding Activities & Relationships	Start Time	Finish Time

Figure D-4: Small Project KYTC Worksheet 2 for projects <$1 Million and <100days

KYTC Activity Estimation of Duration						
Project ID#						
ID Number	Work Item	Bid Quantity	Production Rate	Estimation of Duration= Bid Quantity/ Production Rate (Rounded up to the nearest Day)		
				Low	Average	High

Figure D-5: Small Project KYTC Activity Estimation of Duration Worksheet for projects <$1 Million and <100days



	Task Name	Duration	Start	Finish	Predecessors
4	Clear and Grub	0 days	Tue 1/17/12	Tue 1/17/12	2
5	Remove old Structures	0 days	Tue 1/17/12	Tue 1/17/12	2
6	Remove Old Pavement	1 day	Wed 1/18/12	Wed 1/18/12	2
7	Remove Old Curb and Gu	0 days	Tue 1/17/12	Tue 1/17/12	2
8	Remove old Sidewalks	0 days	Tue 1/17/12	Tue 1/17/12	2
9	Remove old Drainage/Ut	0 days	Tue 1/17/12	Tue 1/17/12	2
10	Earth Excavation	0 days	Wed 1/18/12	Wed 1/18/12	3,4,5,6,7,8,9
11	Rock Excavation	0 days	Wed 1/18/12	Wed 1/18/12	3,4,5,6,7,8,9
12	Embankment	0 days	Wed 1/18/12	Wed 1/18/12	3,4,5,6,7,8,9
13	Pipe	0 days	Wed 1/18/12	Wed 1/18/12	10,11
14	Box Culverts	0 days	Wed 1/18/12	Wed 1/18/12	10,11
15	Inlets and Manholes	0 days	Wed 1/18/12	Wed 1/18/12	13
16	Erect Temp. bridge	0 days	Mon 1/16/12	Mon 1/16/12	1
17	Bridge Demo	0 days	Mon 1/16/12	Mon 1/16/12	16
18	Cofferdams	0 days	Tue 1/17/12	Tue 1/17/12	2,17
19	Piling	0 days	Wed 1/18/12	Wed 1/18/12	10,11,18
20	Footings	0 days	Wed 1/18/12	Wed 1/18/12	19
21	Columns, Caps and Bents	0 days	Wed 1/18/12	Wed 1/18/12	20
22	Wingwalls	0 days	Wed 1/18/12	Wed 1/18/12	21
23	Beams	0 days	Wed 1/18/12	Wed 1/18/12	21
24	Bridge Deck	0 days	Wed 1/18/12	Wed 1/18/12	23
25	Bridge Curbs/Walks	0 days	Wed 1/18/12	Wed 1/18/12	24
26	Bridge Handrails	0 days	Wed 1/18/12	Wed 1/18/12	25
27	Remove Temp Bridge	0 days	Wed 1/18/12	Wed 1/18/12	26
28	Retaining Walls	0 days	Wed 1/18/12	Wed 1/18/12	10,12
29	Lime Stab	0 days	Wed 1/18/12	Wed 1/18/12	10,11,12,13,14
30	Flex. Base Material	0 days	Wed 1/18/12	Wed 1/18/12	29
31	Cement Treated Base Ma	0 days	Wed 1/18/12	Wed 1/18/12	29
32	Curb and Gutter	0 days	Wed 1/18/12	Wed 1/18/12	30,31
33	Hot Mix Asphalt Base	1 day	Thu 1/19/12	Thu 1/19/12	15,32
34	Concrete Paving	1 day	Thu 1/19/12	Thu 1/19/12	15,30,31
35	Hot Mix Asphalt Surface	1 day	Fri 1/20/12	Fri 1/20/12	33
36	Precast Traffic barriers	0 days	Fri 1/20/12	Fri 1/20/12	34,35
37	Permanent Signing and T	0 days	Fri 1/20/12	Fri 1/20/12	34,35
38	Seeding	0 days	Fri 1/20/12	Fri 1/20/12	28,34,36
39	Pavement Markings	1 day	Mon 1/23/12	Mon 1/23/12	34,35,36
40	Finals Clean-Up	10 days	Tue 1/24/12	Mon 2/6/12	27,37,38,39

Figure D-6: Example of KYTC and State X Project Output