DEVELOPMENT OF AN IMPROVED SYSTEM FOR CONTRACT TIME DETERMINATION

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CONTRACT TIME DETERMINATION

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PREFACE

Contract time, is the maximum time allowed for completion of all work described in contract documents. The determination of contract time affects not only the actual duration of the construction project, but also such aspects of construction such as costs, resource planning, selection of contractors and traffic problems. An accurate estimation of contract time reduces the impact of a delayed project on the local economy and provides justification to contractors during construction claims.

This research performed an extensive literature review on various contract time determination procedures and systems developed and used by various state agencies to estimate contract time for their highway projects. This study surveyed 24 DOTs in the United States to determine the prevalent contract time procedures and determined their advantages and disadvantages.

The Oklahoma Contract Time Determination System (Ok-CTDS) is a contract time estimating system for Tier-II type highway projects of ODOT which are categorized into eight types of road projects. The manual CTD system consists of nine templates, one general template for Tier I type category and eight templates for Tier II type category. The CTDS user supplies the system with actual work quantities for established controlling activities for a project and by applying average or project specific production rates, durations for each controlling activity can be calculated. A standalone computer software was developed using VB.Net linked with Microsoft Access database and Microsoft Project for estimating contract time in working days. This software is recommended to be used in ODOT for effectively running the contract time determination system.

The major benefit of this system to ODOT is that its continuous use would provide a structured approach towards contract time estimation. This system will expedite the contract time estimation process, provide documentation for a stronger defense in contract time disputes and allow less experienced schedulers to gain confidence as they learn how to estimate reasonable and realistic contract times.

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CHAPTER I

INTRODUCTION

1.1 Overview:

Contract time is the maximum time allowed for completion of all work described in the contract documents (Herbsman & Ellis, 1995). An accurate forecast of contract time is crucial to contract administration because the predicted duration and associated cost form a basis for budgeting, planning, monitoring and even litigation purposes. Determining an appropriate contract time is important to all parties: DOT, contractors and the driving public. Excessive contract time is costly, extends the construction crew's exposure to traffic, increases risks for the contractor and the owner, prolongs the inconvenience to the public, and subjects motorists to less than desirable safety conditions. Insufficient contract time results in higher bids, overrun of contract time, increased claims, substandard performance, and safety issues.

1.2 Problem Statement:

The current practice of highway construction projects in Oklahoma Department of Transportation (ODOT) usually takes more time to complete than estimated. A recent survey conducted by ODOT reported that 74% of the projects required more time than stipulated in the original contract. The current system adopted by ODOT for majority of its roadway projects is based on an outdated inaccurate chart that is based on the dollar amount versus project type. As each construction project is unique, this “one size fits all” chart is unreliable and produces contract time that is either excessive or insufficient for a particular project as it fails to account for many complexities involved in a roadway project. For certain projects, CPM is being manually produced by highly experienced personnel leading to reasonable contract time estimation since this solely depends on the experience of the senior staff. But when inexperienced personnel try estimating construction contract time, it is a hit or miss proposition. Recognizing these shortcomings of the current procedures for determining contract time and the increased importance of user costs and quality of highway projects, a system is required in ODOT to automate and enhance the process of determining or estimating a reasonable contract time from the owner’s perspective.

1.3 Research Objectives:

The main objective of this research is to develop a structured approach for ODOT in accurately estimating contract time. Based on the problem statement, the following are the listed research objectives:

1. Literature Review, Survey and Interview with ODOT Personnel: To investigate the various methodologies and techniques currently being used by various states and research agencies to determine contract times for highway projects. Investigate other Departments of Transportation (DOT’s) systems of determining contract time for their highway construction projects through questionnaire survey. The focal point in this stage is to identify the advantages, drawbacks and areas to be improved in the current system under review. The current ODOT

system is also analyzed. Meetings with various DOT personnel are held to identify their concerns.

2. Development of a Manual Contract Time Determination System: To develop a contract time determination system that uses standardized templates, experienced engineer's opinion and computer programs. To identify project controlling activities for the templates, along with a range of production rates (min, avg and max). Finally to develop activity logics to define relationships between controlling activities. The templates with their controlling activities, the productions rates and the activity logics, all working in sync, is the manual contract time determination system.

3. Development of Automated Software for Contract Time Determination System: To develop a standalone computer application that automates the manual process of contract time determination to allow ODOT schedulers to expedite the process without sacrificing or hurting the accuracy and quality of the estimate.

4. Validation of the Developed System: To validate the contract time determination system for reliability with projects that has been completed or with those that are currently in progress and nearing completion. This will ensure the accuracy of the contract time.

1.4 Research Scope:

The scope of this study is limited to ODOT classified Tier-II projects. Details that are required to determine the contract time such as contract methods, scheduling techniques are not considered in this study. Also, cost aspects related to highway projects are beyond the scope of this study.

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1.5 Organization of the Report:

In the chapter 2, literature on relevant topics are reviewed and discussed to gather relevant information on the various methodologies and innovative techniques used in the field of contract time estimation. Various factors such as weather and seasonal effects, traffic conditions, project size, type and location, utility relocations, etc that affect contract time is also studied. Chapter 3 details the methodology followed to achieve the objectives of this study. Chapter 4 presents the DOT survey analysis and recommendations. Chapter 5 presents the Oklahoma contract time determination system in detail. This chapter will discuss the project classifications, the concept of templates, the selection of controlling activities, development of production rate ranges (min, avg and max), defining activity logic relationships and the manual system of contract time determination. Chapter 6 describes the Ok-CTD standalone software application with the system architecture, dataflow process and a software run using a sample project as an example. Chapter 7 concludes the research and provides some recommendations for future research.

CHAPTER II

REVIEW OF LITERATURE

Contract time determination is a research area that has its roots strongly concentrated within construction science and management branches. The research history in this area has always strived to improve the accuracy, efficiency and also investigate innovative techniques for contract time determination. This chapter reviews the current methodologies used by various DOT's on contract time determination. Prior research in this domain is examined and investigated for possible adoption of existing methodologies for the development of an improved system for contract time determination for the Oklahoma Department of Transportation. The chapter also reviews the various factors that affect the production rates based on project characteristics, thus directly affecting contract time estimation.

2.1 Overview Of Current Practices In DOT'S:

Herbsman & Ellis (1995) surveyed and found that most of the DOT's use a common process in determining the contract time for their highway projects. The process flow is as shown in Fig 2.1. Usually the responsibility for determining contract time is designated to a scheduler who gathers all data required for estimating contract time referring the design drawings, specifications, bill of quantities and all other relevant data.

After browsing through all the data, the scheduler prepares a list of controlling activities that represent the major tasks of the project. Some DOT's have created such lists for several project types to assist the scheduler. The scheduler then starts calculating the duration for each controlling activity in the list using production rates and estimated work quantities.

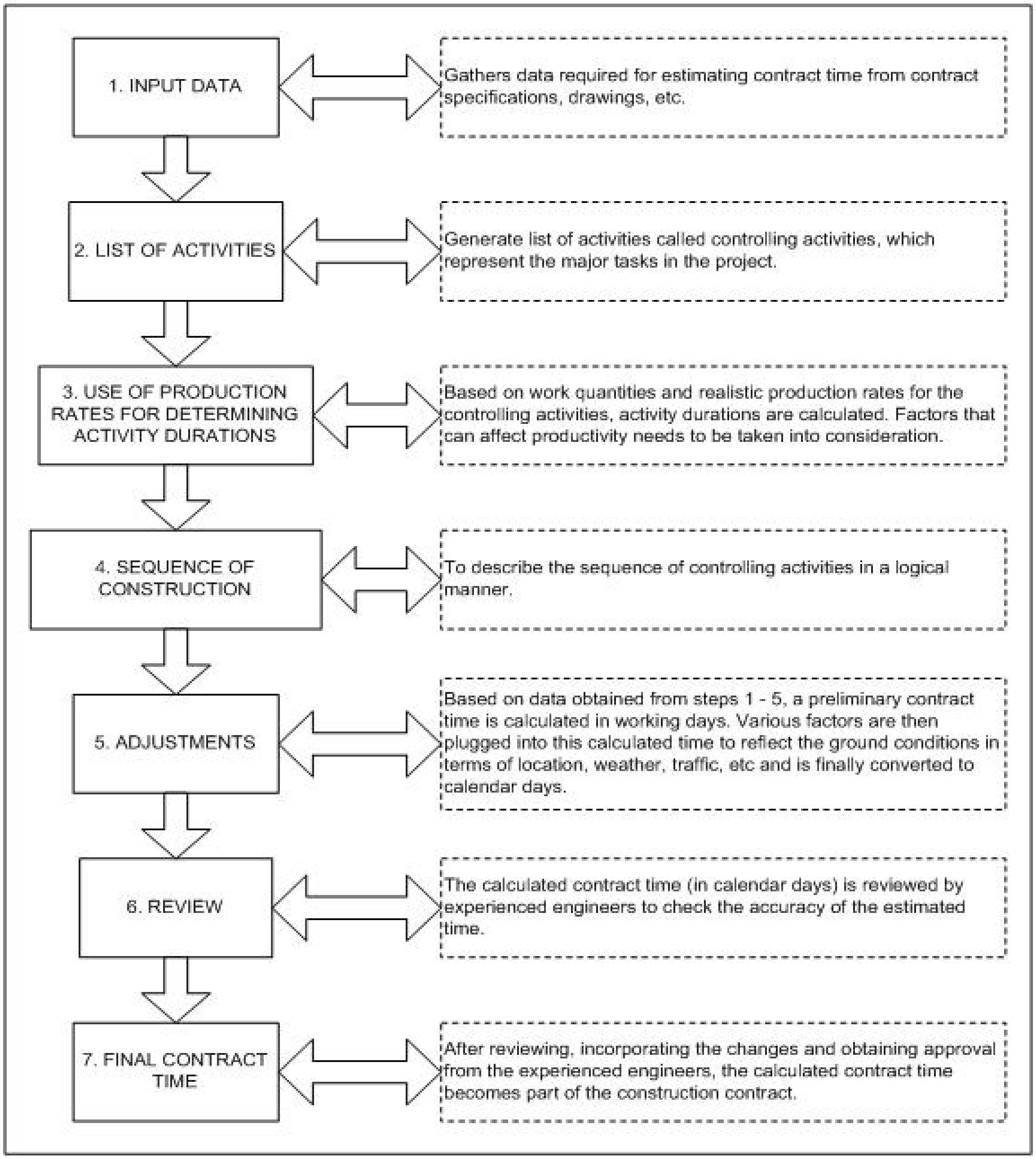


Fig 2.1: Contract Time Determination Process (Herbsman & Ellis, 1995)

Most DOT's use a published list of production rates for contract time estimation (Herbsman & Ellis, 1995). These are developed either by observing the current projects under construction and/or maintaining records from earlier projects. These rates take into account various factors such as weather, topography, project size, crew size, etc. The more realistic the production rates, the more accurate the contract time. It is finally the responsibility of the scheduler to use his experience and understanding of the project to determine whether to use the standard published rates or modify them.

Once the durations are calculated, the scheduler tries to logically sequence the activities and shows the interdependency or independency between the various activities. The sequence is generally prepared either using bar charts (Gantt chart) or critical path method (CPM) to finally derive a preliminary project completion time. This process is done by hand or by using various scheduling software packages such as Microsoft Project, Primavera, etc.. The scheduler then uses experienced engineers and project manager's opinion to identify site specific conditions that are likely to affect the project and have an impact on the contract duration and incorporate them in the calculated preliminary contract time. This adjusted contract time in work days is then converted to calendar days or completion days as used in respective DOT's. After reviewing this adjusted contract time by experienced personnel and obtaining the final approval, the final contract time is incorporated in the bid documents and becomes part of the contract between the contractor and the owner.

On certain simple highway projects, historical data analysis is another method used to determine contract time wherein statistical regression analysis of historical data is used to estimate relationships between construction time and parameters indicating project scale or magnitude (Herbsman & Ellis, 1995). Although it is very simple to use, its results are not accurate as most people argue that one cannot correlate project scale parameters to construction time and its use is being slowly phased out of all the DOT's.

2.2 Research Studies Conducted on Contract Time Estimation:

This section reviews prior studies in the area of contract time determination by various researchers and DOTs in the process of modifying and upgrading their system to help establish realistic contract times.

2.2.1 NCHRP Studies:

The National Cooperative Highway Research Program (NCHRP) in their document called Synthesis of Highway Practice 79: Contract Time Determination (Transportation Research Board, 1981) stressed the need to develop production rates based on historical data for estimating contract time. Rather than using thumb rules for calculating contract time, the report stressed on setting up a method by individual agencies to actually calculate contract time before letting out projects for bidding.

The report recommended DOTs should modify and upgrade their system. Herbsman & Ellis (1995) analyzed and examined the state of practice with respect to various procedures used by DOT's in United States and other countries in estimating contract time for their highway projects (Fig 2.2).

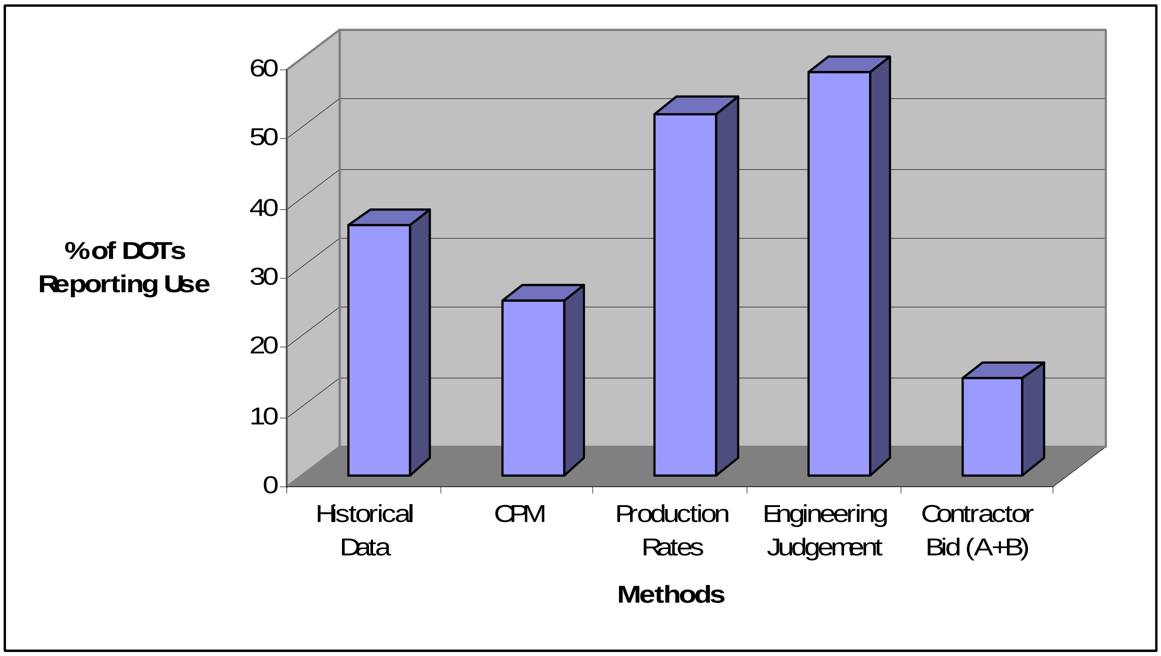


Fig 2.2: Methods used by DOT's for Contract Time Estimation on Incentive/Disincentive Contracts (Herbsman & Ellis, 1995)

The survey indicated that some DOT's had have incorporated new variations such as incentive/ disincentive, bidding on cost and time A+B, Lane Rental, Flex time, etc., to their existing contracting methods to help reduce contract times on highway projects. The study identified the major factors widely recognized to influence contract time such as weather and seasonal effects, location and type of project, traffic impacts, utility relocation, letting time, environmental factors, night/weekend work, permits, legal aspects, material delivery time, etc and suggested that its quantitative impact be estimated based on judgement. The report maintained the need for knowledge based system for project scheduling and time estimation which could be used to assist agencies in determining contract time.

2.2.2 Texas DOT's Research:

Hancher et al (1992) developed a rational procedure for determining a feasible contract time using a conceptual scheduling system for the Texas DOT in the form of a Contract Time Determination System (CTDS) which included both a manual method and a computerized system utilizing software packages of Lotus 123, Flash-Up and SuperProject. Dr.Hancher, through his survey analysis (Fig 2.3) identified that bar charts and experienced engineer's judgement were the most prevalent methods used by various DOT's in contract time estimation.

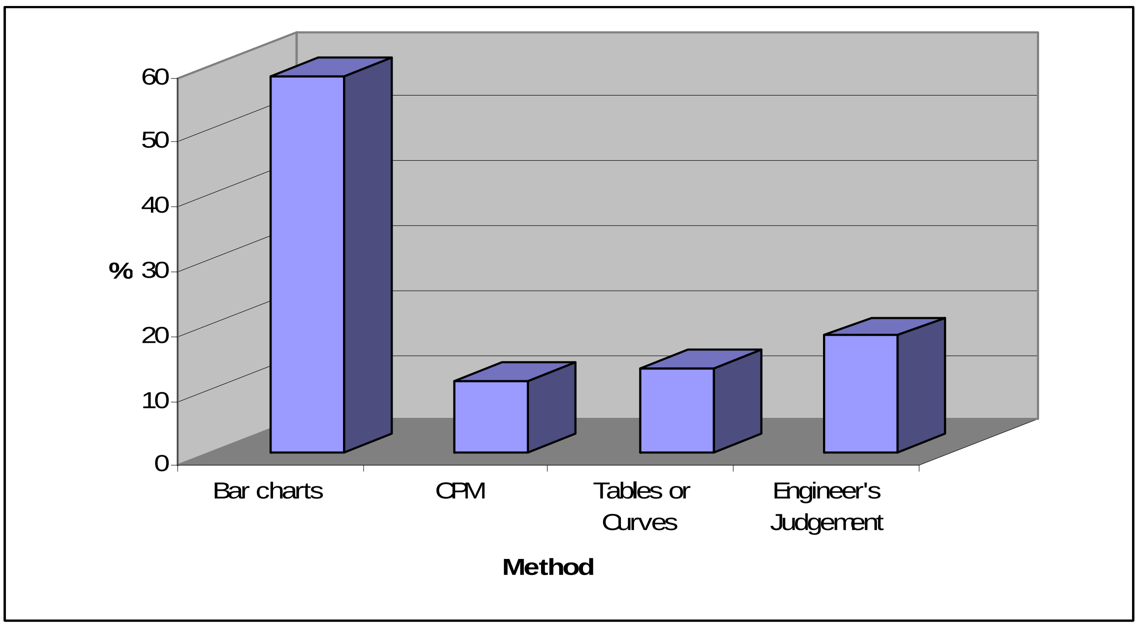


Figure 2.3: Methods used by DOT's to Establish Contract Time Duration (Hancher et al. 1992)

The system developed was based on Texas DOT's project classification system which consisted of thirteen different classes of projects thus generating thirteen different templates (Table 2.1) and a fourteenth was also added to take into account any project that would not fit in one of the thirteen.

TABLE 2.1: Texas DOT Project Templates

Template 1	SC	Seal Coat
Template 2	OV	Overlay
Template 3	RER	Rehabilitate Existing Road
Template 4	CNF	Convert Non-Freeway to Freeway
Template 5	WF	Widen Freeway
Template 6	WNF	Widen Non-Freeway
Template 7	NLF	New Location Freeway
Template 8	NNF	New Location Non-Freeway
Template 9	INC	Interchange
Template 10	BWR	Bridge Widening/Rehabilitation
Template 11	BR	Bridge Replacement/ New Bridge
Template 12	UPG	Upgrade Freeway to Standards
Template 13	UGN	Upgrade Non-Freeway to Standards.
Template 14	MSC	Miscellaneous Construction

It used a bar chart approach to schedule because of the wide familiarity of the bar charts and its ease with which their personnel could be trained. The standard work items developed for each project had pre-established successor and predecessor relationships. The contract time determination system was set up with default values for the production rates along with already established low and high production rates for each controlling item. To enable the user to incorporate project specific features in the production rates, they had defined five adjustment factors. They are location, traffic conditions, project complexity, soil conditions and quantity of work. Using these correction factors the system default values could be modified by the user to accurately estimate production rates for controlling activities for differing project characteristics. Since most of these factors were correlated and not independent, it was recommended that only two correction factors maximum was to be selected for each work item. If the user disagreed with the production rate values generated after using correction factors, the user could use their own values that they think would be suitable for those activities.

The limitations of this study are that the thirteen project templates and the production rates were specific to TxDOT projects and could not be directly implemented in other states. The production rates were based on engineer's judgement and/or historical data and that itself is a limitation as it doesn't have any mechanism to reflect site conditions for every new project. The activity relationships in each schedule had certain overlappings in terms of leads and lags and had various finish to start relationships. Such complex relationships needed to be always kept in mind when the schedule logic is being modified to suit a specific project. Rather than using production rates based on experienced engineer's opinion, a more in-depth study is required to determine realistic production rates. Also it is difficult to modify the activities on the template in case new project characteristics need to be incorporated into the template.

2.2.3 Kentucky DOT Research:

Hancher and Werkmeister (2000) developed a contract time estimation system for the Kentucky Transportation Cabinet. This system was built upon the Texas DOT concept and was called the Kentucky Contract Time Determination System (KyCTDS).

The new system utilized six project templates based on the classification of projects by the Kentucky Transportation Cabinet (Table 2.2).

TABLE 2.2: Kentucky Department of Highway Project Templates (Hancher and Werkmeister, 2000)

Project Template	Project Description
Reconstruction Limited Access	This is a project that utilizes the existing alignment but may revise the profile grade for an overlay.
Reconstruction Open Access	This is a project where a road is being rebuilt that has either “Access by Permit” or “Partial Control” while utilizing the existing right-of-way.
New Route	This is a project being built from point “A” to point “B”
Relocation	This is a project that a section of road is being rebuilt on new alignment and grade.
Bridge Rehabilitation	This is a project that a lane on a bridge would be closed for reconstruction or widening the deck part width.
Bridge Replacement	This project’s main focus would be to build a new bridge.

Each project template displayed logically sequenced major controlling activities (approximately 40 controlling activities in each template) with their default production rates. A range of production rates was also developed. The production rates were generated based on the working committee’s experience and were tested on various projects for validation. Once the rates were validated, each activity in the template had a default production rate which would ultimately need adjustment to reflect project conditions. The user always has an option to override the default production rates or could directly override the activity durations. Any modifications to the production rates or durations were recorded in a comment section for documentation purposes.

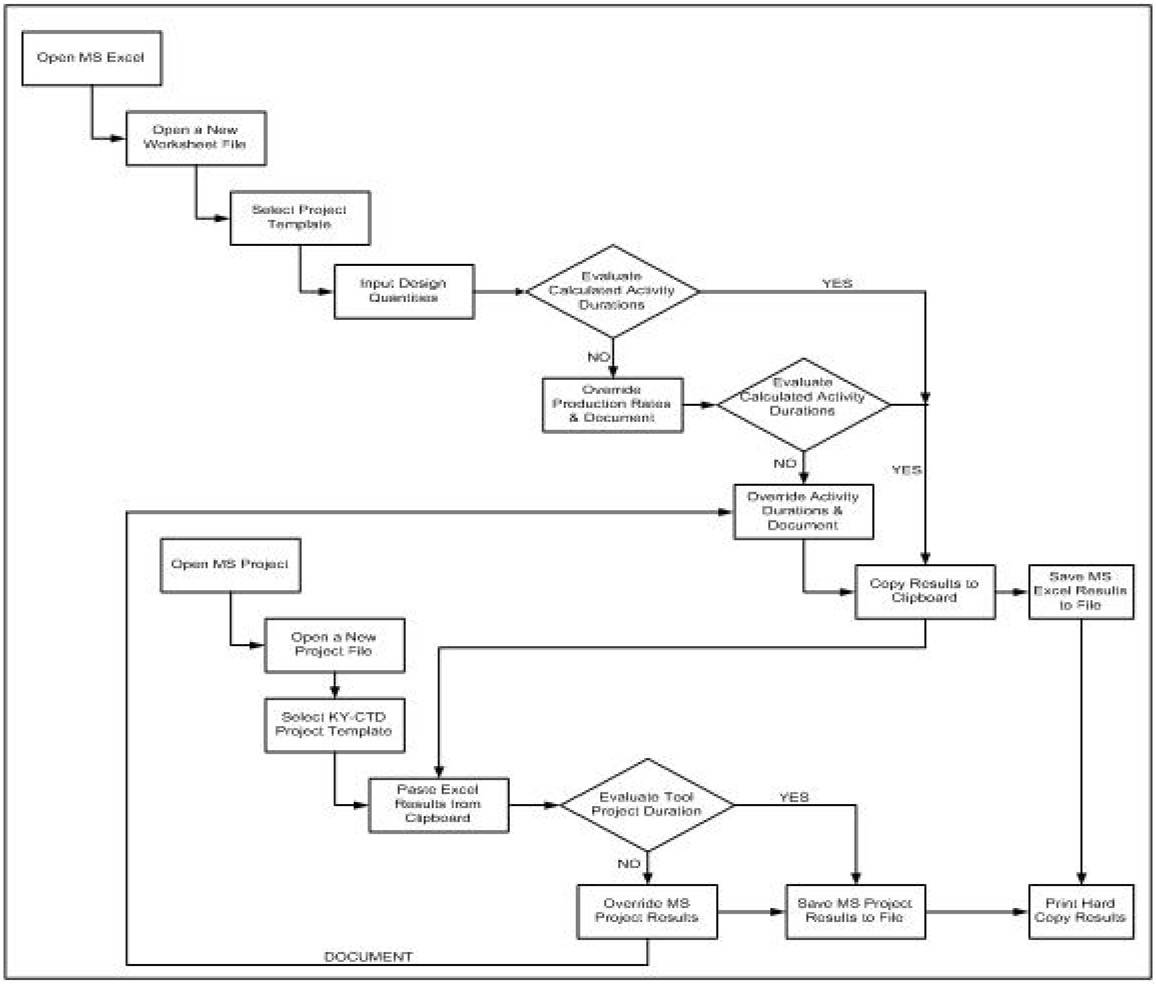


Fig 2.4: Kentucky – Contract Time Determination System Process Flowchart (Hancher & Werkmeister, 2000)

The computer system was developed using Microsoft Excel (that calculates durations) and Microsoft Project (that generates the schedule). Unlike the Texas CTD System, no general template was provided that would be used for a project that wouldn't fall into the six categories. Fig 2.4 shows the logical flow of the computerized system for contract time determination of KyTC.

The limitations in this study are the fact that the six templates with their controlling activities and production rates are specific to projects undertaken by the Kentucky Transportation Center and cannot be adapted to suit projects in different states. The study indicated that there is a need to develop a method to find realistic production rates that incorporate various factors into production rate calculations. Another limitation is the presence of complex successor and predecessor relationships. There should be room to modify the logic to suit project conditions and constraints. Any change in the logic for an activity, causes a ripple effect through the template changing the logic for all the other dependent activities. Since the logic is complex, it causes difficulty to trace and modify the changes on other relevant activities.

2.2.4 Florida, Indiana and Louisiana DOT's Research:

Florida had developed a preformatted form for estimating contract time (manual method) that can be completed by hand. An experienced engineer would fill out the form by identifying the controlling activities and the production rates of these activities. A bar chart diagram would be drawn to calculate the project duration and a conversion factor, which converts workdays to calendar days, would be finally applied to obtain contract time (Herbsman & Ellis, 1995).

Indiana also uses a step-by-step process in which hand-written form is used to establish contract times using an experienced project engineer.

The Louisiana DoT developed a computer program that is similar to the earlier system developed in Texas. They reported that using a personal computer based system that used both templates for production rate analysis and a computer package for development of a bar-chart schedule yields more consistent and accurate contract times (McCrary et al. 1995).

2.2.5 Recent Research Work:

The Contract Time Determination System developed by Dr.Hancher for Texas DOT in 1992, had certain prominent limitations. In spite of the developed system, the time estimation still heavily depended on engineer's judgement and best guesses, with little formal or objective analysis. It was found that there was a high variance in the production rates as various factors such as weather, project type, and site conditions worked towards affecting the contract time estimation. In order to attain a higher reliability, accurate production rates and to improvise on the recommendations chalked out in the Texas Contract Time Determination System (Hancher et al, 1992) another research was conducted by the Texas DOT (O'Connor et al, 2004). The research investigated 26 controlling activities in their highway projects and the driving factors that affected production rates for the controlling activities were studied in detail.

Projects were identified for data collection and the characteristics observed were documented into three distinct parts: project level, work zone level and work item level. Project Level data factors consisted of: (1) project type, (2). location, (3) traffic flow, (4) traffic count, (5) weather (rain and winter length), (6) percentage of project completion, (7) contract amount, (8) technical complexity, (9) contract day, (10) accelerated construction provision, (11) liquidated damages, (12) soil types, (13) clay content of soil, (14) land slope, (15) depth of water table, (16) scheduling technique used, (17) work schedule (hours/day and days/week), (18) contract administration system, and (19) contractor's management system. Work zone level part required the work zone description and to document its characteristics such as accessibility, congestion, and drainage effectiveness. And finally the work item sheet was used to specify the scope of each work item.

Descriptive statistics were used to summarize the data for mean, sum, count and frequency of variables. Box plots were used to present the data in terms of mean, median, quartile, outliers, and extreme values in a graphical format. Two types of driver analysis were performed on the production rate data and based on the results the drivers that affected each production rate were identified. First, for those with continuous numerical data, regression analysis were conducted to identify drivers of production rates and to quantify their effects and second, for those with discrete numerical or categorical data, analysis of variance (ANOVA) was used to test the difference in mean production rate for subsets in each candidate driver. Regression analysis and correlation analysis were also performed on the data.

The study analyzed and compared the differences between their observed data and with the Contract Time Determination System (CTDS) in three ways. First, the differences between the units adopted in both the studies were compared. Second, differences between the work scopes for the selected items were compared. And finally, the differences in production rates (observed and tabulated ones versus historically generated ones) were also compared. It concluded that five work items had similar production rates in both the CTDS, six items had much lower rates, three had lower rates, six had higher rates and three had much higher rates. The observed rates were thus considered to be reliable enough to be used to develop production rate models for the twenty-six work items,

The research also analyzed the driving factors that affect the production rates of work items. Using statistical tools and techniques, formulas and ranges for these production rates were developed so that all these factors could be taken into consideration during the initial time estimation process. The following table (Table 2.3) suggests the various drivers that need consideration and also compares it to the factors that were considered in the CTDS research.

Table: 2.3: Summary of Drivers of Contract Time Determination System and Research, (Connor et al. 2004)

Item #	Work Item	Sensitive Factors CTDS Considered	Sensitive Factors the Research Found
110	Excavation	Soil, quantity of work	WAQ*
132	Embankment	Soil, quantity of work	WAQ, WZC[†]
247	Flexible base	Location , quantity of work	WAQ*, lift-length of WA[‡]
260	Lime treated subgrade	Soil, quantity of work	WAQ*, length of WA[‡]
276	Cement treated base	Soil, quantity of work	WAQ*, lift-length of WA[‡]
340, 345	Hot mix asphaltic concrete	Location , quantity of work	WAQ*, course type
360-1	Slip form concrete pavement (CRCP only)	Location , quantity of work	WAQ*, length of WA[‡]
360-2	Conventional form concrete pavement	Location , quantity of work	WAQ*, configuration
409	Prestressed concrete piling	Soil	Total piles in cluster
416	Drilled shaft foundation	Soil	Total shafts in cluster, location conditions of operation
420-1	Footing	Soil	Size, height, excavation depth and number of footings per bent
420-2	Column – rectangle	Complexity, quantity of work	Size, height, number of columns per bent
420-2	Column – round	Complexity, quantity of work	Height, diameter, number of columns per bent
420-3	Cap	Complexity, quantity of work	Size, length, shape
420-4	Abutment (cast in place)	Complexity, quantity of work	---
422-1	Bridge deck – cast in place	Quantity of work	Width of deck, shape, crew size
423	MSE wall	Soil	Size of wall
423-1	MSE wall – copings	----	Length
425	Beam erection	Location	---

450	Bridge Railing	Quantity of work	---
462-1	Precast concrete box culverts	Soil	Length of run, soil types, clay content
462-2	Cast in place concrete box culverts	Soil	Length of run
464-1	RCP 18-42 in	Location, soil	Length of run, WZA**, line orientation
464-2	RCP 48-72 in	Location, soil	
465	Inlets and manholes	Location, soil	Total quantity in run, types
466	Wing wall/head wall	Soil	Wall surface area
529	Concrete curb and gutter	Location , quantity of work	WAQ*
666/628	Pavement markings	Quantity of work	---

*WAQ – work area quantity; **WZA – work zone accessibility, †WZC – work zone congestion, ‡WA – work area.

Thus by categorizing drivers along with the selected work items and generating formulas for estimating realistic production rate ranges, the study has allowed estimators to objectively use production rates in contract time estimation which can further be boosted with their experience and judgement. The study developed a software called HyPRIS (Highway Production Rate Information System) which was based on a Microsoft Visual Basic using Microsoft Excel platform (Fig 2.5). The software uses the developed tools and formulas to assist the estimator to determine realistic production rates once project related information is fed into the system. For example, if a designer plans for an 800 lf culvert in stiff rocky soil, using the multiple regression formula with the combined effects of length of culvert run and soil conditions which the software processes, the production rate calculated is 117.09 lf/crew. It also provides with a range from a low of 107 lf/crew day to a high of 164.51 lf/crew day allowing the estimator to factor in project specific characteristics and constraints to generate a reasonable production rate specific to the project.

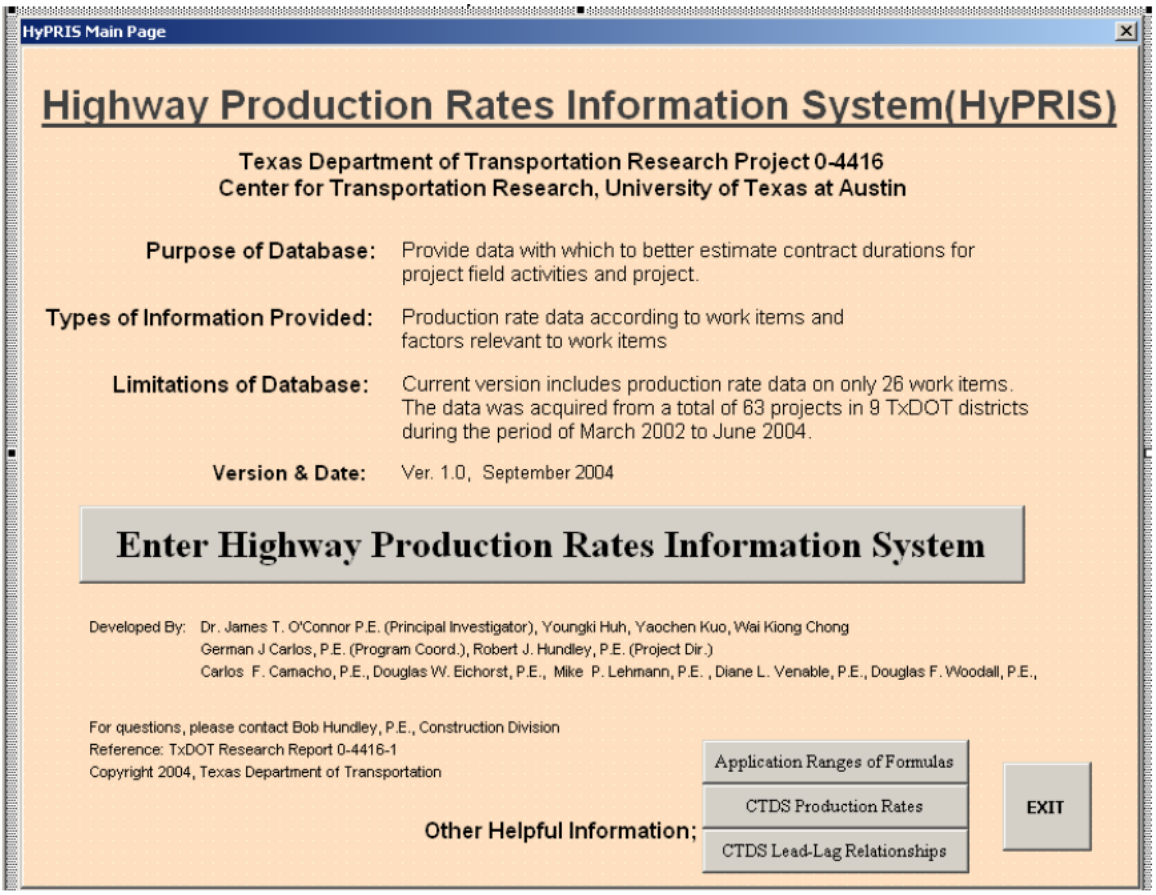


Fig 2.5: HyPRIS Main Frame

2.3 Factors Affecting Contract Time:

A contract time that is estimated using any technique remains inaccurate unless it has been adjusted to take into consideration project specific factors. This is required due to the fact every project is unique in nature.

Hancher et al. (1992) identified five factors that cause an impact on the production rates of the work items. The five factors were location, traffic conditions, project complexity, soil conditions and quantity of work. For each factor, an adjustment value was provided as a multiplier factored in the production rates, so that project characteristics could be easily incorporated in the contract time. Since most of these factors were correlated and not independent, it was recommended that only two correction factors maximum was to be selected for each work item.

Herbsman & Ellis, (1995) investigated in detail a wide range of factors that affect contract time. Through their survey they were able to analyze and compile the factors that their survey respondents considered important based on their experience. Fig 2.6 lists them in order of their importance.

The survey also indicated that no factor could be singled out and isolated and all of the factors overlap each other on more than one occasion. The following paragraphs briefly review these factors.

Weather & Seasonal Effects

Weather and seasonal effects are considered by almost all states (98%) as the major factor affecting contract time and affects almost all highway construction projects to some extent. Weather conditions being a prominent influence in highway construction must be factored into the contract time estimation process by specifying taking into account months that prevent construction work due to adverse weather conditions. During such periods, the construction work is suspended. Time extensions are usually provided to the contractor when such events take place.

Location of the Project

The location of the project has a tendency to affect the contract time estimation (88%). A project located in an urban area is found to take more time than a similar project in a rural area. On other occasions, a rural project might take a longer duration due to long mobilization times and great distances.

Traffic Impacts

There is a marked difference in construction time when work is performed in high-volume traffic areas than that of low-volume traffic areas (86%).

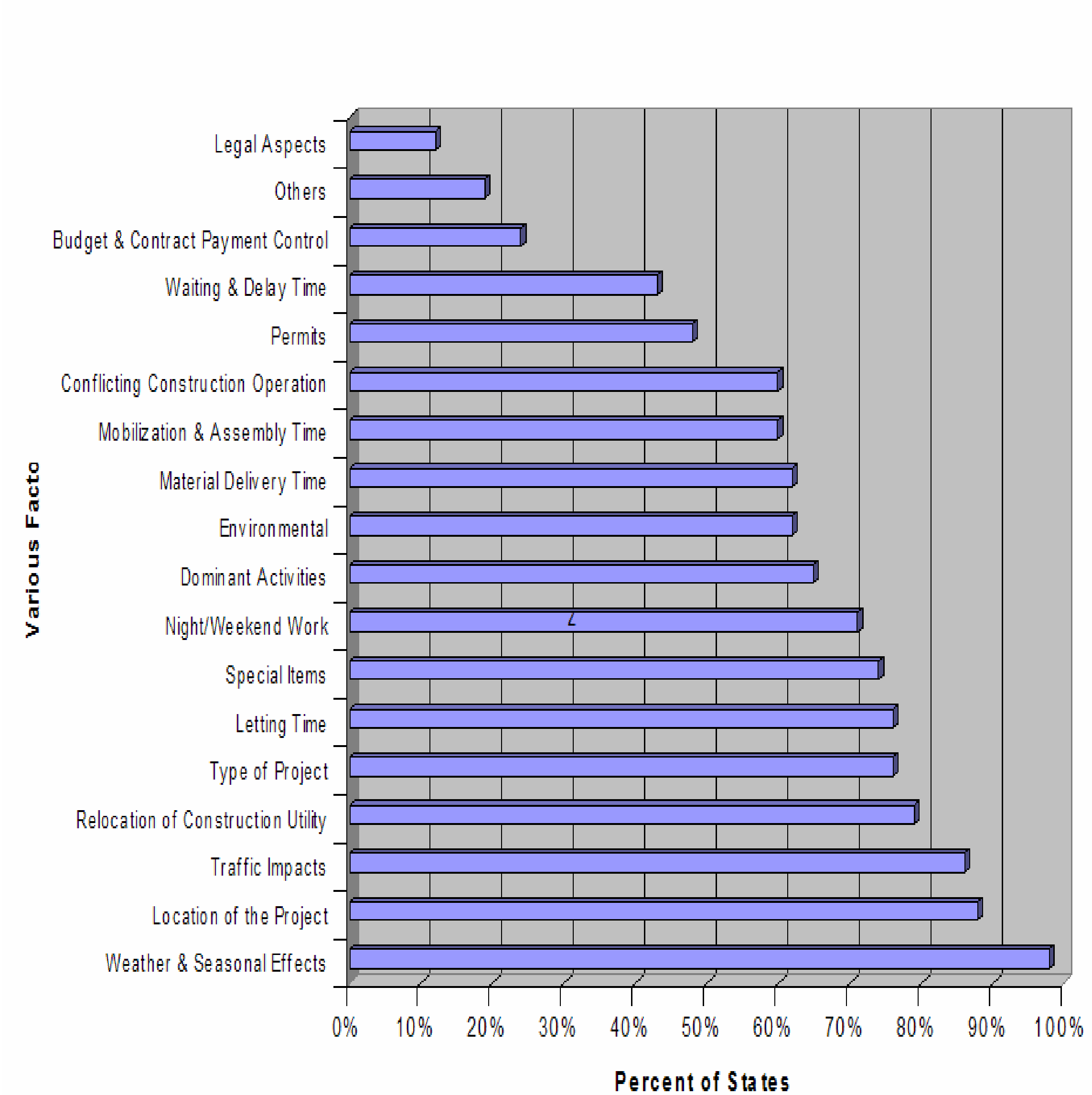


Fig 2.6: Major Factors that affect contract time, adopted from (Herbsman & Ellis, 1995)

Relocation of Construction Utility

79% of respondents believed that the impact of relocation of utilities depends on how the responsibility for relocations has been assigned. If it's included in the contract time, it's one of the several tasks that need to be accomplished during the project, but is a complex process. In some states, utility relocation is the DOT's responsibility and is not included in the contract time. On the other hand, there are other DOT's that relocate utilities 2 to 3 months prior to the commencement of the project and do not include it in the contract time. Finally the states that do not address the issue of relocation in the contract time, allow for time extensions or shut-down time in the contract agreement.

Type of Project

Project type was found to influence estimation of contract time by most of the surveyed participants (76%). Project types that were found to have consistent effect on contract time were urban versus rural projects, flat terrain versus mountain projects, bridge projects, rehabilitation projects, etc.

Letting Time

76% of the respondents felt that if a large number of projects were being contracted at the same time in a region (city, county, district), the contract times need to be extended to account for shortages with respect to labor, materials, equipments, etc.

Special Items

74% accepted that any special item that has a long lead time before it reaches the job site must be factored properly into the contract time. Items such as steel structures, signals and electro-mechanical systems that are usually procured by DOT or the contractor fall under this category.

Night/Weekend Work

Most surveyors (71%) felt that projects involving night or weekend work require longer duration than projects that are completed during normal daytimes since the production rates during these times falls dramatically as the focus shifts more onto safety precautions.

Dominant Activities

Some of the complex construction projects have been found to have one or few dominant activities, phases or controlling operations that influences or controls the total calculated contract time. These operations include roads, bridges, resurfacing, etc and the surveyors rated it as 65%.

Environmental

Whenever a concerned project deals with environment sensitive factors, additional time must be factored into the contract time by the scheduler to mitigate its adverse impacts on the contract time. Many DOT's consider projects that involve hazardous materials to be environmentally sensitive. The surveyed participants rated it at

62% and mentioned that each project needs separate consideration during time estimation.

Material Delivery Time

Timely delivery of certain special items (fabricated steel, signals, signs, etc) has been recognized by the survey respondents (62%) to influence contract time but in other cases, there is no time and/or cost extensions provided on late material procurement and delivery of other general construction materials.

Mobilization & Assembly Time

Mobilization time is usually added into the contract time estimate as a common practice which is acknowledged by the participants and has an influence on the contract time estimation (60%). They range from 3 days to upto 40 days in some DOT's. An ideal mobilization time needs to always be estimated based on other factors such as project size, complexity, and distance of project from other material resources.

Conflicting Construction Operation

Certain activities in a construction project if not properly planned starts to overlap one another causing a conflict not only in the concerned area but also on other following areas (ripple effect). Two or more contractors working on the same limited work front at the same time, slows down the progress of each party thereby causing a conflict. The scheduler needs to properly adjust the schedules to avoid any kind of overlappings by proper phasing before letting the projects and even during the construction process.

Permits

Permits, like relocation of utilities need to be procured prior to commencement of project construction and should be the responsibility of the owner. 48% of the respondents agreed that obtaining environmental permits might be a more complex process and needs proper adjustment in the contract time by the scheduler

Waiting & Delay Time

There are various types of delays that can be forecasted when estimating contract time which may include technical and non-technical bases such as curing of concrete and public hearings in an environmental sensitive project. These need to be factored in the final time estimate.

Budget & Contract Payment Control

Budget also has an influence in contract time estimation, as agreed by the survey participants (24%). When a project is backed by a huge budget, contract time can be reduced to complete the work faster than using normal conditions. Also, budgeting is done for each quarter and accordingly varying amount of money is spent at different quarters. All these have an effect on multi-year projects that are phased.

Legal Aspects

Any project that has to go through environmental agencies, requires special permits, public interest hearings, etc are exceptional cases and may involve legal complications. All these need to be forecasted early in the project depending on the type of project and should be factored into the contract time estimation.

Other Factors

There were other factors listed in the survey but more or less they revisited the above mentioned factors. The other factors mentioned were:

- Commitment by all parties to complete the contract within the deadline.
- Effect of community institutions and events on the project.
- Availability of access roads for emergency situations
- Cash flow of all parties involved.
- Marine and railroad traffic.
- Review time needed for shop drawings, constructability analysis and value engineering.

CHAPTER III

METHODOLOGY

In order to meet the project objectives, the following research methodology was adopted (refer Fig 3.1).

1. Literature review was conducted to identify strengths and weaknesses of prior research in this field for possible adoption into this study.
2. A Study Advisory Committee consisting of ODOT officials and general contractors was set up to guide the research team for the duration of the project.
3. Using the information from the literature review and the inputs provided by the Study Advisory Committee members, a survey questionnaire was developed. The survey intended to help identify current practices being used by other state DOT's in estimating contract time and also to understand the advantages and disadvantages of their system.
4. An analysis of survey responses was performed to identify the best practices of the responded DOT's.
5. ODOT highway projects are classified. Based on the project classification, templates and controlling activities for each type of project are developed.

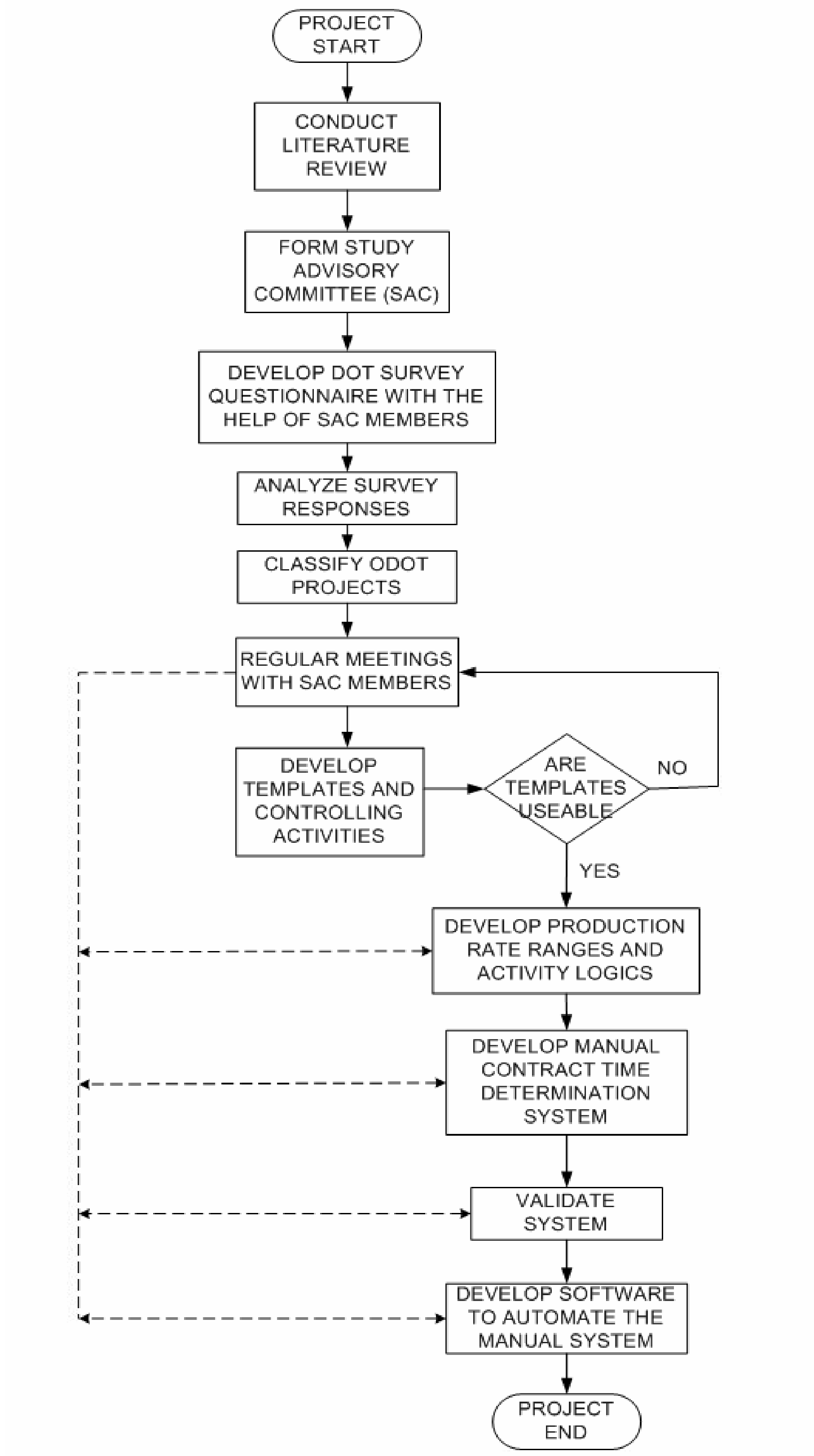


Fig 3.1: Methodology Process Flow Chart

6. Production rate table with ranges (min, avg and max) is generated for each controlling activity identified in the templates. Controlling activity relationships are defined using simple finish to start activity logics.
7. A manual system is developed wherein individual templates are used to calculate duration (working days) for each type of project based on estimated quantities and selected production rates from the table. The template logic along with its durations is then entered into Microsoft Project which schedules the project and also determines the contract time of the project in working days.
8. The manual system is validated against recently completed ODOT projects whose calculated contract time and project completion time were approximately same. The time calculated using the manual system was close to the contract time of the completed projects.
9. A standalone computer program is developed using VB.Net linked with Microsoft Access database and Microsoft Project to automate the process of estimating contract time.

CHAPTER IV

SURVEY ANALYSIS

4.1 Introduction:

A survey was sent to each Department of Transportation (DOT) and the District of Columbia to find out how other state DOT's around the US determine their contract times, and this information would be used to adopt the best practices in determining contract time for Oklahoma's DOT (ODOT). Out of the 51 surveys, there were 24 responses. Furthermore this survey also establishes a contact within each cooperating DOT that will be beneficial for future questions that the research team may seek answers for in each state. This chapter presents and analyses the data collected through the surveys.

4.2 Methodology:

The development of the survey began after initial discussions with ODOT officials and after reviewing Kentucky Transportation Cabinet's and Texas DOT's research work. The main goal of the survey was to identify the current process employed by each state in determining contract time and approaches to increase the accuracy of contract time determination.

The questionnaire starts with how many projects finished late in each DOT and how much were caused due to inaccurate time estimation. The next information sought was to understand the current system of contract time estimation by each DOT and was achieved by asking close-ended specific questions. The questionnaire finally ended with asking open-ended questions pertaining to recommendations and suggestions that the participating DOT might want to share with the research team.

The contacts for each DOT were gathered through telephone calls to each state after initial reviews of each state's website. Each contact is someone currently employed by each state DOT who is involved in planning and estimating the contract time for various highway projects and is well versed with their current procedures. Each participant received the survey and was allowed to complete it in a span of 3 – 4 weeks before the requested return date. Of the states that received the survey (50 total, plus the district of Columbia), twenty three of them responded and the map shown in Fig 3.1 represents those that returned the completed survey. The questionnaire is included in Appendix A.

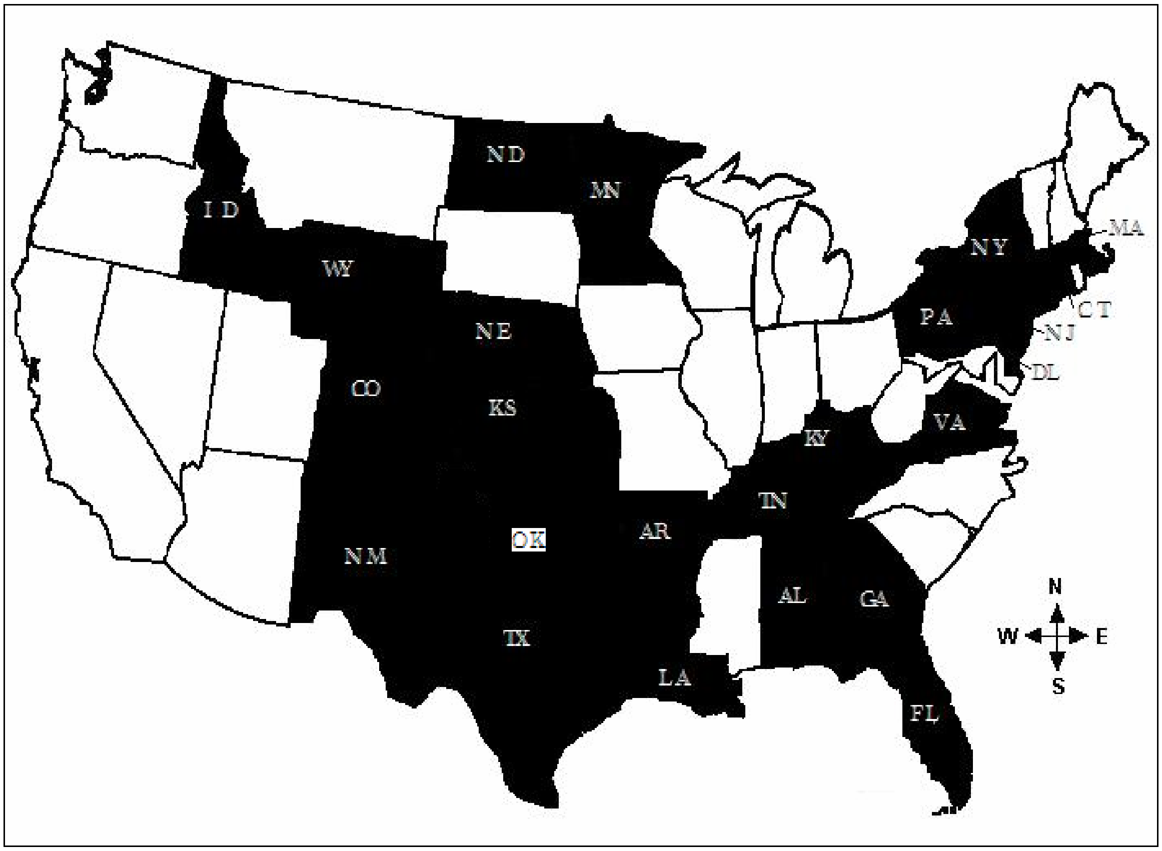


Fig 4.1: Diagram of the states participating in the survey

4.3 Survey Analysis:

The initial questions were the percentage of their construction projects that finish late, and of that percentage what amount could be attributed to inaccurate contract time. Of the 24 states that responded to the questionnaire, the response data to this question is summarized in Table 3.1. Some states were unable to provide us with numbers due to lack of data.

Table 4.1: Summary of state DOTs projects

S.No	States	Percentage of DOT projects finishing late	Percentage of projects attributed to inaccurate contract time
1.	New Mexico	20%	5%
2.	Pennsylvania	5%	0%
3.	Colorado	No data	No data
4.	Kentucky	No data	No data
5.	New York	50%	No data
6.	Louisiana	No data	No data
7.	Kansas	5.2%	0%
8.	North Dakota	No data	No data
9.	Georgia	4%	0%
10.	Florida	15%	0%
11.	Idaho	5%	10%
12.	New Jersey	34%	0%
13.	Tennessee	10%	2%
14.	Delaware	70%	10%
15.	Wyoming	18%	5%
16.	Arkansas	3%	1%
17.	Minnesota	15%	No data
18.	Nebraska	20%	5%
19.	Alabama	15%	0%
20.	Texas	25%	No data
21.	Connecticut	60%	No data
22.	Virginia	18%	No data
23.	Massachusetts	45%	25%

This table shows that majority of the respondents reported that most projects finishing late are attributed to inaccurate contract time. As shown in the table, Massachusetts has reported that 25% of their projects that finish late (45% total) are due to inaccurate contract times. Also some states have reported that they have a significant percentage of projects finishing late for reasons that are not attributed to inaccurate contract time. Delaware reports a maximum of 70% for projects that finish late. Majority of the states that have reported projects finishing late have attributed the following reasons justifying the delay:

1. Extreme weather conditions.
2. Utility relocations.
3. Right of way permits.
4. Environmental permits.
5. Extra work items, etc.

The DOTs have reasoned that on most projects extreme weather conditions have disrupted work to a large extent causing delays. The other major reason was due to delays in relocating various utilities such as power, telephone, cable, gas, water, etc. Extra work that are added to the contract during the course of time, various permits and labor problems are some reasons attributed for project delay. In all such cases contractors have sought for time extension from the DOT for delays not caused by them.

The next question was how the contract time is determined for each particular DOT. The options provided in the survey for establishing contract time were using

a) Experienced engineer's opinion,

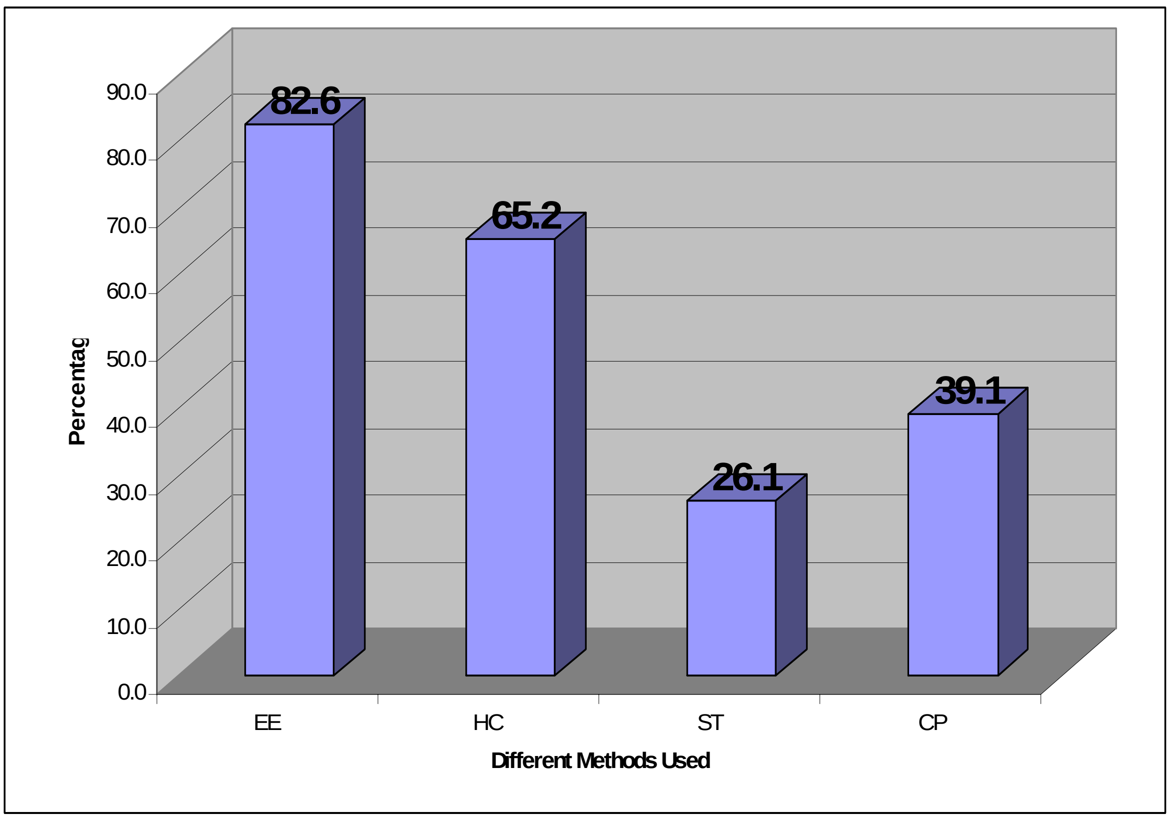
b) Computer program,

c) Handwritten standardized templates

d) Handwritten Calculations, and

e) Other methods.

Figure 3.2 shows how the DOTs answered from the above provided options methods. A majority of the responses (82.6%) showed that an experienced engineer often is in charge of establishing the contract time required for each construction project. This answer agrees with the practice that ODOT is currently following; meetings in the initial research stage indicated that an experienced engineer would be responsible for determining contract time for highway projects.

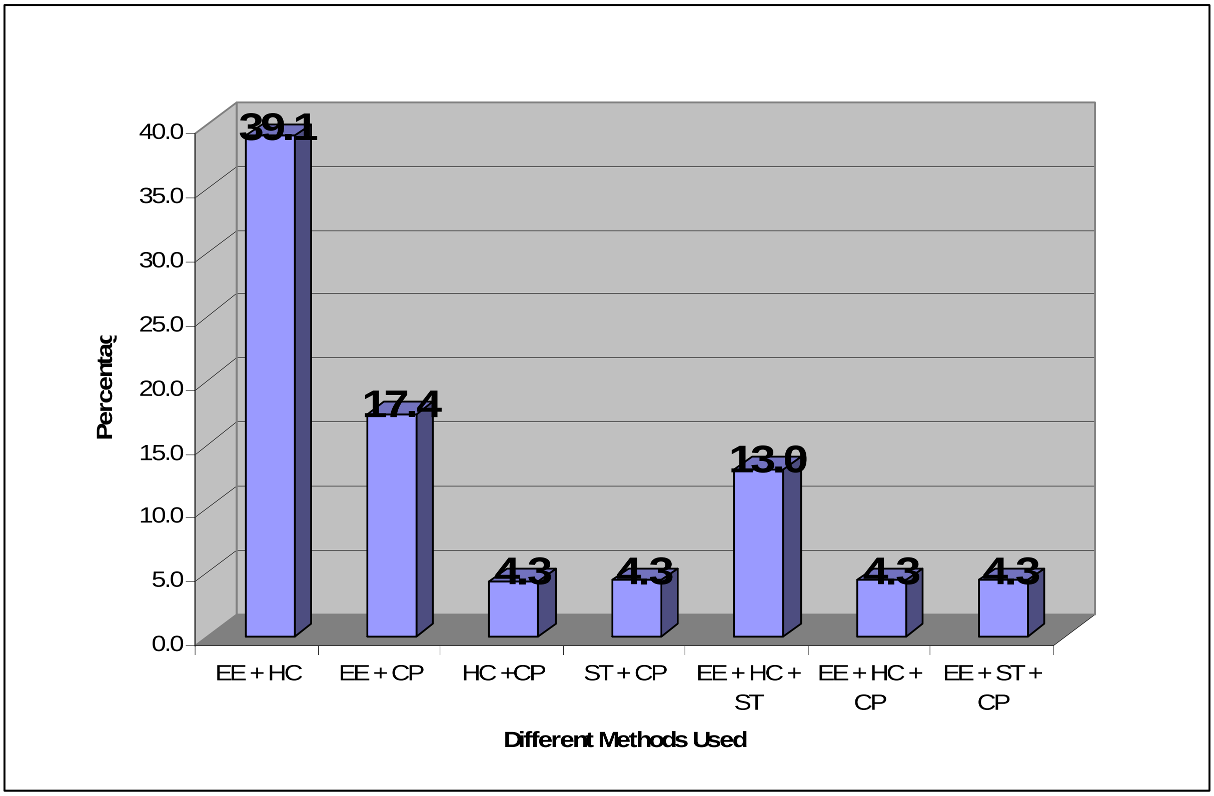


EE – Engineer's Experience ST –Standardized Handwritten Template

HC – Hand Calculations CP – Computer Program

Fig 4.2: DOT Methods Used to Estimate Contract Time

On analyzing the responses further, it was observed that most of the DOT's do not use a single method but instead use a combination of the above methods in establishing contract time. Fig 3.3 summarizes the responses of DOT's using the combination methods.



EE – Engineer's Experience HT –Standardized Handwritten Template

HC – Hand Calculations CP – Computer Program

Fig 4.3: DOT Combination Methods Used to Establish Contract Times

It is observed that around 39.1% use engineer's experience along with hand calculations to estimate contract time. Another popular method was the use of engineer's experience and computer programs (17.4%). A more recent trend among the survey respondents was the use of standardized templates (13%) along with engineer's experience and hand calculations.

When asked if the current contract time determination system in place provided the desired results, all but four responses (83.3%) indicated that they did provide the desired results or close to desired results. Of the four DOT's that reported receiving results that were not desired, Massachusetts reported that their system was fairly unlikely to provide desired results. New York and New Mexico answered neither yes nor no that the system provides desired results. ODOT personnel also do not agree that Oklahoma has a contract time determination system that provides desired results.

The next questions contained in the survey asked the participants about production rates. Of the twenty three participating DOT's, eighteen agencies (78%) replied that they use standard production rates, reporting that they have a range of rates rather than one particular value and these values being either very or moderately accurate to those observed in the field. An important aspect observed here is how often the production rates are updated. Some DOT's responded that they never update their production rates, some mentioned they do it on a regular basis and few others reported it as it being currently done. Fig 3.4 gives more detail on how often the production rates are being updated by various DOT's.

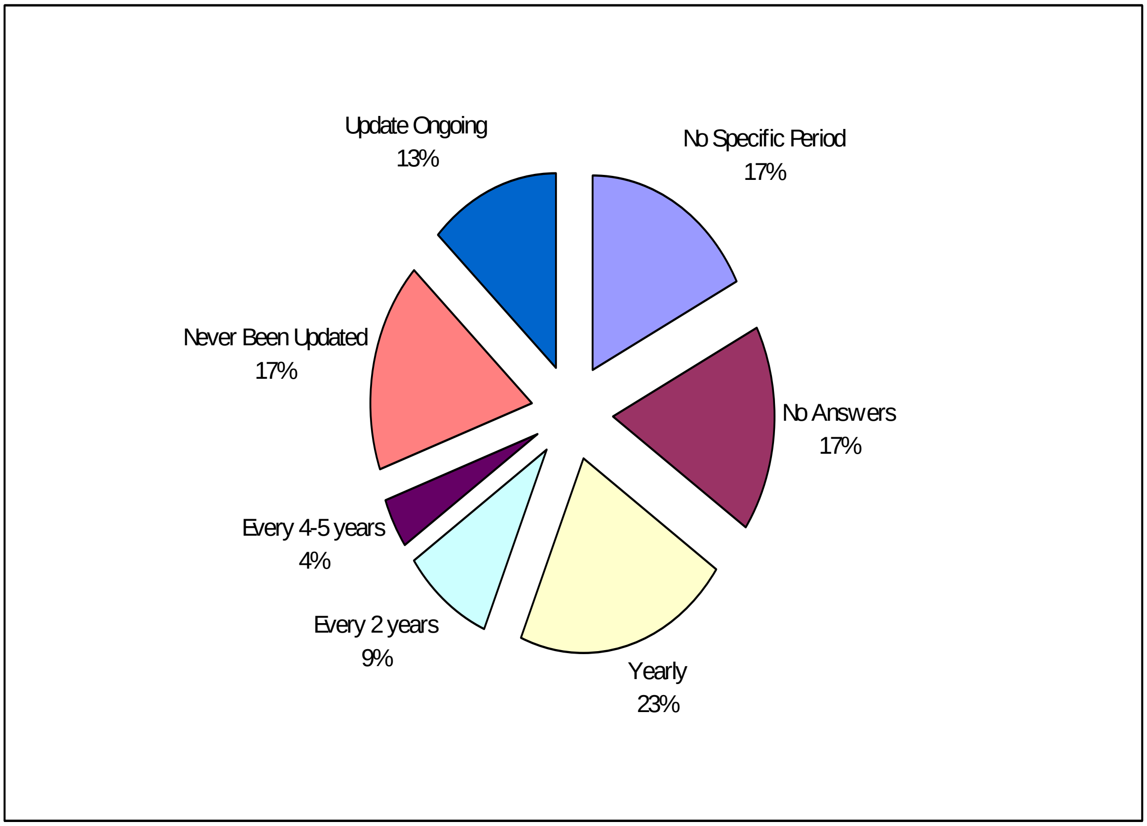


Fig 4.4: Timeframes of production rates being updated

The above figure gives a clear idea that there is a wide range of timeframes for updating the production rates currently in practice by the surveyed DOT's. These responses do not as such specify a set timeframe that requires DOT's to look closer at their production rates and check if they are providing the required results.

On the question pertaining to those DOT's that utilize computer programs in determining contract time, nine states (39.1%) replied that they did take the help of computer programs. The use of computer programs varied from simple scheduling of projects (using Microsoft Project, Primavera, SureTrak, etc) to combination of softwares (using Visual Basic, MS Excel, Microsoft Project, Primavera, SureTrak, etc) that calculated durations based on production rates and quantities entered by the user and also scheduled them. Louisiana uses a custom-written program called CTDS (Contract Time Determination System), which is non-operational presently in their agency. Although their program is not in operation, they have sent the research team their user guide which outlines their procedure of determining the contract time. Also Virginia's DOT reported that they are currently developing a "Time Bank" computer program that will allow their agency to access activity times when needed. Other states such as Florida, Kentucky and New Jersey also report using computer programs to help in establishing contract time.

During the literature review, the method of templates was found to be in use for determining contract time. To understand more about the templates in practice, a question was asked in the survey to find out if any of the participants use templates, and to describe them if they do. Eight state DOT's (35%) answered that they used standardized templates when determining construction project contract times, but only three responses give enough detail to understand their method. Of these three detailed responses, the participants state the templates are broken up by district or by project type. These standardized templates of highway projects have critical controlling work items listed in a sequential order. Estimators use this template to plug in calculated quantities and production rates to obtain total work days for the project, which needs to be approved by an experienced engineer. Once approved this is then converted to get total duration of the project in calendar days. It is notable that two of these three states report that 0% of their projects finish late due to inaccurate contract time (the other state reported an unknown percentage finishing late due to inaccurate contract time).

The final question in this survey asks each participant to offer recommendations and suggestions that will improve their state's contract time determination procedure.

Colorado recommends the use of a database of production rates which needs to be updated periodically so as to reflect realistic values. Kentucky and New Jersey have stressed the need for organized and real time feedback on the calculated estimates so as to help the scheduler/ estimator in estimating future projects. Arkansas has suggested the use of production rates manual that would bring consistency amongst estimators during time calculation. Connecticut has recommended increased communication between the design and construction team to help get realistic time durations. In summary of the findings obtained through this survey, it is apparent that each DOT cannot be evaluated equally. There is no single solution that will lead to a perfect contract time determination procedure, but all of these states display the positives and negatives that may be present in each of their current method.

4.4 Summary:

The survey analysis provides certain options on selecting a specific method for determining contract times. Collectively almost all the states have stressed using experienced engineer's opinion along with hand calculations to determine contract time. Those who use only this method have not only reported having a high percentage (Massachusetts – 45%) of projects that finish late but have also attributed them to inaccurate time estimate (MA -25%).

Four states have reported using computer program with engineer's experience as their method to estimate contract time. But these states have also reported a high percentage of project delays (Delaware - 70%) and they have also attributed around 10% to inaccurate contract time estimation.

Another method that is gaining popularity is the use of standardized templates along with hand calculations and engineer's experience. Three states have reported using them for establishing contract time. Connecticut has reported that 60% of their projects finish late while Colorado and North Dakota reported that they were not able to provide percentages of project delays due to lack of data. However, all of them mentioned satisfaction with their current methods and didn't report any projects that finished late due to inaccurate contract time estimation. The main factors cited for the projects that finished late were extreme weather conditions, utility relocations, right of way, environmental permits, extra work items, etc.

For the case of ODOT, this survey has offered insight into each of the above mentioned options of setting up an improved method to determine contract time. For the case of a better understanding of contract time determination procedures, this survey also offers to the reader how complex this practice may become, and with this survey broader areas may be clarified and refocused with future survey questions. On further discussions with ODOT personnel the following process was chosen, based on the survey findings, to develop an improved system of contract time estimation.

1. A standardized template needs to be prepared based on project classifications in ODOT.
2. The template would consist of critical work modules that govern that specific project.
3. These modules would consist of a given set of activities that would collectively provide duration for the entire module.

4. Each module and its sub activities would have a default production rate along with a range (minimum and maximum) which needs to be adjusted based on project site conditions and schedulers experience. This helps calculate duration for each module which adds up to the total project duration in work days.
5. Once this has been approved it needs to be scheduled using Microsoft Project or Primavera to provide the total project duration in calendar days.

An important recommendation here is the need to monitor the production rates and update them at frequent intervals to reflect the site conditions so as to help the estimator/scheduler in estimating contract time for future projects.

CHAPTER V

DEVELOPMENT OF A MANUAL SYSTEM FOR CONTRACT TIME DETERMINATION

This chapter focuses on the development of a manual system for contract time estimation using templates. The initial sections describe the tier system of highway project classifications of ODOT, the designing of individual templates, generation of production rates, developing of activity relationships, the manual system of the Oklahoma contract time determination system (Ok-CTDS) using the template system and comparison between Texas, Kentucky and Oklahoma CTD systems. The final section validates this system by comparing time estimates for similar projects that were generated by the contractors and ODOT.

5.1 Tier System of Highway Classification:

ODOT manages and classifies highway projects into three different tiers or categories (see Fig 5.1). Tier I projects include highly complicated projects which are subjected to congestion like all A + B projects and most urban or interstate reconstruction projects, so Tier I projects require that contract time be established using critical path methods. Tier III type highway construction projects have their time established using a table that was developed for standard projects using CPM methodology. For instance, many of the local government bridge projects use standard designs and similar construction sequences. Therefore, contract time does not vary between projects and it works well using a standard table to establish contact time. The Tier II type highway projects constitute projects that are in between Tier I and Tier III. These projects are typically constructed on interstates, state highways, and major arterial roads that connect them to state highways and interstates.

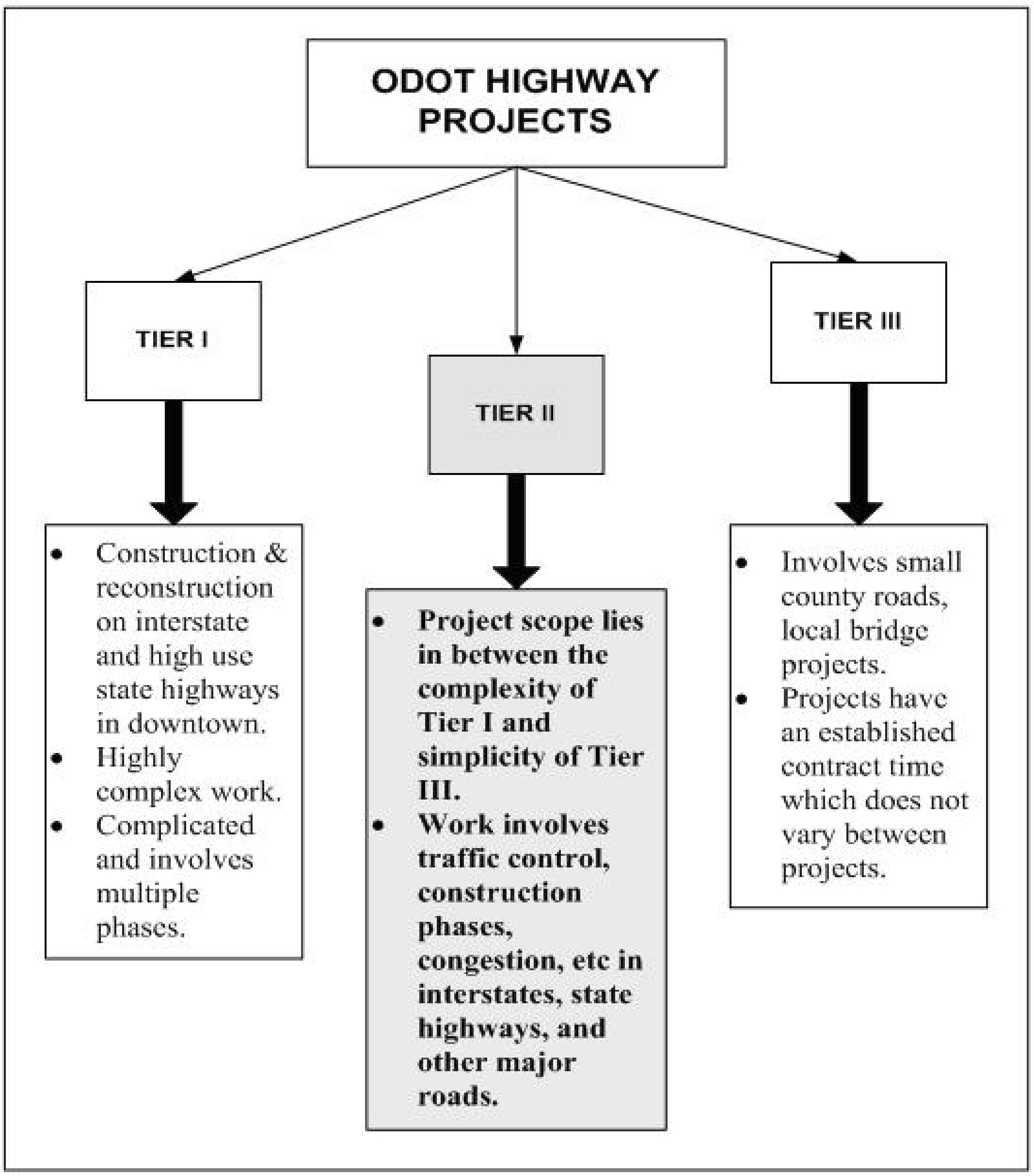


Fig 5.1: ODOT Tier System for Highway Projects

ODOT estimates that around 40% of the highway projects that are let out by ODOT annually, fall within the Tier II classification (7.5% for Tier I type projects and 52.5% for Tier III type highway projects). The earlier system of determining contract time was based on using a “one size fits all”, out-of-date chart which routinely produced unreliable contract times due to its many flaws such as inconsistent interpretation of the project type, lack of consideration for project location (urban versus rural), traffic control methods, etc.

The DOT survey results (Chapter 4) recommended utilizing the tiered classification for calculating contract time and developing contract time establishment procedures for ODOT highway projects. Further based on the DOT survey analysis it was decided to develop a contract time estimation system using standardized templates that would fit individual projects. The characteristics of using standard templates are:

1. Each template falls in one of the identified tiered classifications and consists of pre-determined set of controlling activities that are specific to the type of project under consideration.
2. Each template requires minor adjustments to their production rates and template logic which would factor weather conditions, soil and topography conditions, etc that would be specific to a project, so that the standard template would fit individual projects.

This study focuses on developing time estimation procedures using standardized templates for projects that are performed under Tier II type highway projects. The characteristics of Tier II projects are as follows:

1. They are not as complex as Tier I type highway projects
2. These projects may have characteristics similar to Tier I projects such as congestion, complicated traffic controls and several construction phases.
3. All projects under Tier II category also require time established using CPM.
4. They do not include A + B provisions of Tier I classification.
5. They do not fit the standard table of pre-established contract times that are used for Tier III projects.

Tier II projects in ODOT can be classified as follows:

5.1.1 Reconstruct Existing Alignment/ Rural Interchange

The projects in this category do not typically possess the complexities of Tier I type highway projects but are significant construction projects that involve interstate and state highways. The projects may have reconstruction of two lanes with detours and/or reconstruction of an undivided four lane. The reinforced concrete boxes (RCB's) and drainage structures may have to be extended depending on the scope of the project.

5.1.2 Widen/ Reconstruct Existing Alignment

The highway projects in this category typically have widening a 2-lane highway to a 4-lane highway. It may have extension work on the RCB's and drainage structure and the existing structures may also require widening.

5.1.3 Reconstruct City Street

The projects in this category require widening of existing city streets. Typically old pavements are replaced by new pavements (asphalt or concrete), signals are added at new locations adding signals at new locations and existing signals and lightings are upgraded.

5.1.4 Construct Bridges and Approaches

Projects in this category include replacing existing bridge structures on a rural highway or a county facility. They are also known as Bridge on an Off road "BRO" projects i.e. the bridge project is on an off road and not on the federal highway system, specifically, a county road. The bridges may be single span but can also be multi-span.

5.1.5 Construct Bridge Box and Approaches

The projects in this category usually cover replacement of an existing box bridge structure on a rural highway or a county facility. They are also known as Bridge on an Off road "BRO" projects i.e. the bridge project is on an off road and not on the federal highway system, specifically, a county road. The box bridges may be single or multi-cell as defined by the project scope.

5.1.6 Intersection Modification

These projects are usually constructed inside a municipal city road which involves reconstructing or upgrading an existing intersection. It may also involve changing pavement types, drives, signal systems, lighting systems, etc. One important aspect of this project is that, all construction work is performed keeping the traffic open.

5.1.7 Bridge Rehabilitation/ Repair

The projects in this category are typically to fix an existing bridge structure. The work may involve minor deck repairs for a limited amount of square yard, repairing columns and caps and also painting existing and associated structures.

5.1.8 Roadway Repair/ Overlay

The projects could be on interstates, state highways, city streets or rural roads. The scope of work involves adding new shoulder and adding new overlay over a limited amount of pavement removed.

A ninth template called, General Template, is also developed for Tier I type highway projects that includes all the major controlling activities and can be used as a guideline for estimating time and for generating schedules based on critical path method. The projects in this category (Tier I) involve construction and reconstruction on the interstate and high use arterial roads where the average daily traffic (ADT) exceeds 60,000 a day.

5.2 Concept of Template

Each highway project consists of various construction operations and each operation can be further broken down to a number of activities. Amongst all the activities, many of them can proceed concurrently, for example landscaping and erosion control can be done when pavement construction is being performed. But there are certain activities that are constrained to a given sequence, for example, for casting of concrete, reinforcement and formwork must be in place. One needs to examine each activity and determine necessary sequences or dependencies on other activities to clearly identify project controlling activities for a given project. The basis for identifying such project controlling activities is as follows:

1. The project controlling activities have a huge volume of work to be performed.
2. There may be physical constraints such as project location, soil type, etc, or resource constraints such as lack of materials, equipment and manpower, material delays, etc, that are associated with these controlling activities.
3. There may be certain controlling activities that must be completed within a pre-determined time or date and which is not flexible. Such activities usually drive the project schedule.
4. The timely completion of controlling activities allows the next activities to start on time. But if they get delayed the start of subsequent controlling activities also gets delayed causing a ripple effect in the planned schedule and if left unchecked, delays the completion of the entire project.

The characteristics of controlling activities may seem similar to those for critical activities in a construction project, but there is a main difference between critical activities and project controlling activities. Unlike critical activities, which are always part of the critical path and determine the total project duration, project controlling activities may or may not be part of the critical path in all projects. They are usually activities that drive the project and based on project constraints and scope they may change criticality to become part of the critical path. Thus these activities need to be carefully studied and analyzed while logically sequencing all the activities for the project. All the other activities that can be performed concurrently, that does not have constraints associated with them and whose completion is not mandatory for starting subsequent activities are called the project non-controlling activities.

Dr. Hancher had used this concept for both the Texas CTDS as well as the Kentucky CTDS to generate a conceptual system to determine contract time for the respective DOTs (Hancher et al, 1992 and Hancher and Werkmeister, 2000). Fig 5.2 gives a diagrammatic representation on the concept of controlling activities. The square box includes all the activities of a project. The bigger circle includes all the controlling activities and the smaller circle includes only the critical activities. Based on the project scope and constraints, these project controlling activities may lie on the critical path and hence be part of the critical activities.

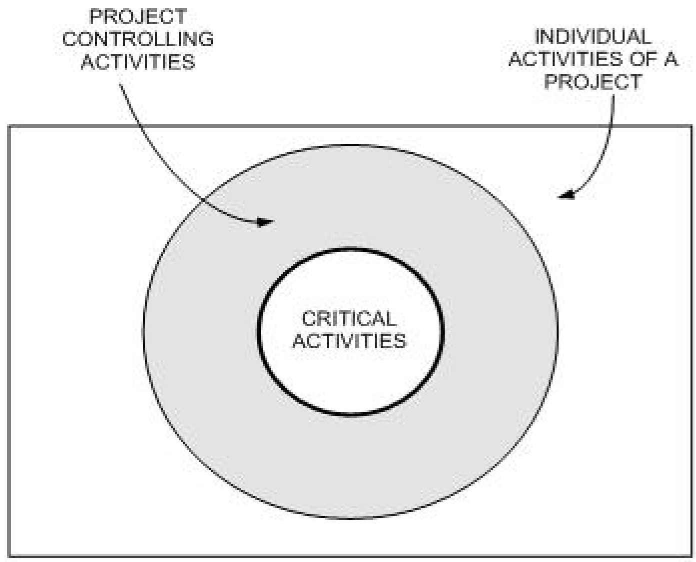


Fig 5.2: Concept of Project Controlling Activities

To explain this concept, consider a simple project of installing sewer and utility lines as shown in Fig 5.3.

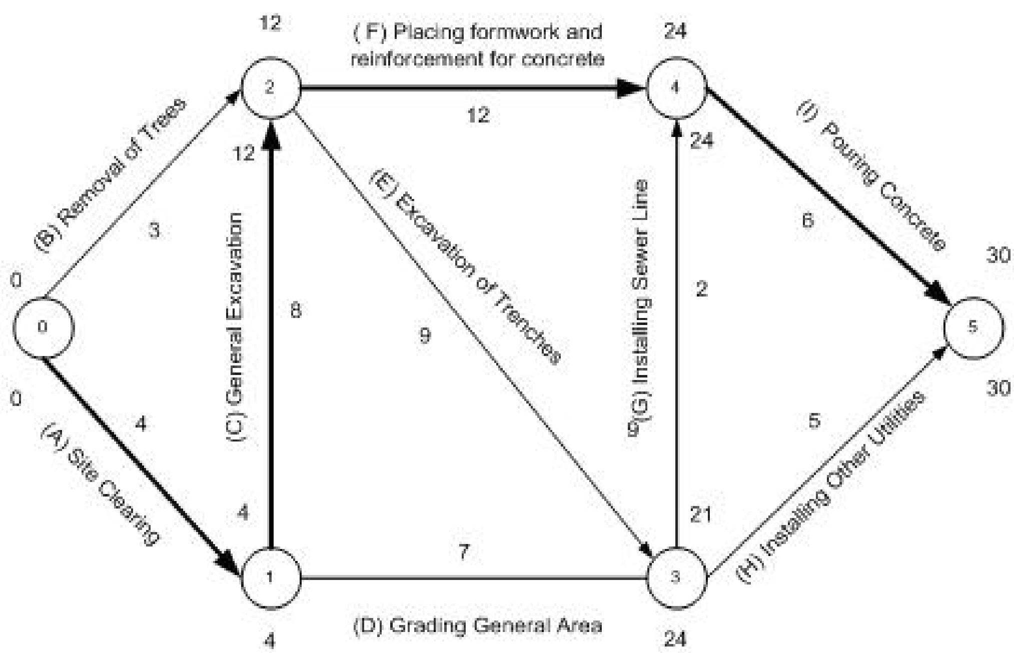


Fig 5.3: Installing Sewer and Utility Lines Project Network Diagram

The project consists of nine specific tasks viz., site clearing (4 days), removal of trees (3 days), general excavation (8 days), grading general area (7 days), excavation of trenches (9 days), placing formwork and reinforcement (12 days), installing sewer line (2 days), installing utilities (5 days) and pouring of concrete (6 days) that totals to a 30 day project and has a critical path of 0-1-2-4-5 (A-C-F-I) .

Apart from the critical activities being the project controlling activities, excavation of trenches, installing sewer line and installing other utilities are also the other project controlling activities (see Table 5.1). Although they are not part of the critical path, they need to be carefully watched during construction due to their near-critical state (as they have very small total float).

Table 5.1: Sewer Project Activities Sorted Based on their Classification

<table>
<tr><td rowspan="2">Controlling Activities</td><td>Critical Activities</td><td>1. Site Clearing
2. General Excavation
3. Placing Formwork & reinforcement for concrete
4. Pouring concrete</td></tr>
<tr><td>Controlling Activities</td><td>1. Excavation of trenches
2. Installing sewer lines
3. Installing other utilities</td></tr>
<tr><td colspan="2">Non-controlling Activities</td><td>1. Grading general area</td></tr>
</table>

If the same project is being constructed in a different location, by changing certain conditions of the project such as volume of work, soil conditions, productivity, etc, there is a possibility that the other controlling activities become critical activities. Thus, all critical activities are part of the project controlling activities, but not all project controlling activities can be part of the critical path.

The grading general area activity is the only non project controlling activity or the non-critical activity in this project. Since this activity has a huge float, is not part of the critical path and the start of other subsequent activities does not depend on it, the activity can be performed concurrently to all other activities and wouldn't typically affect the total project duration.

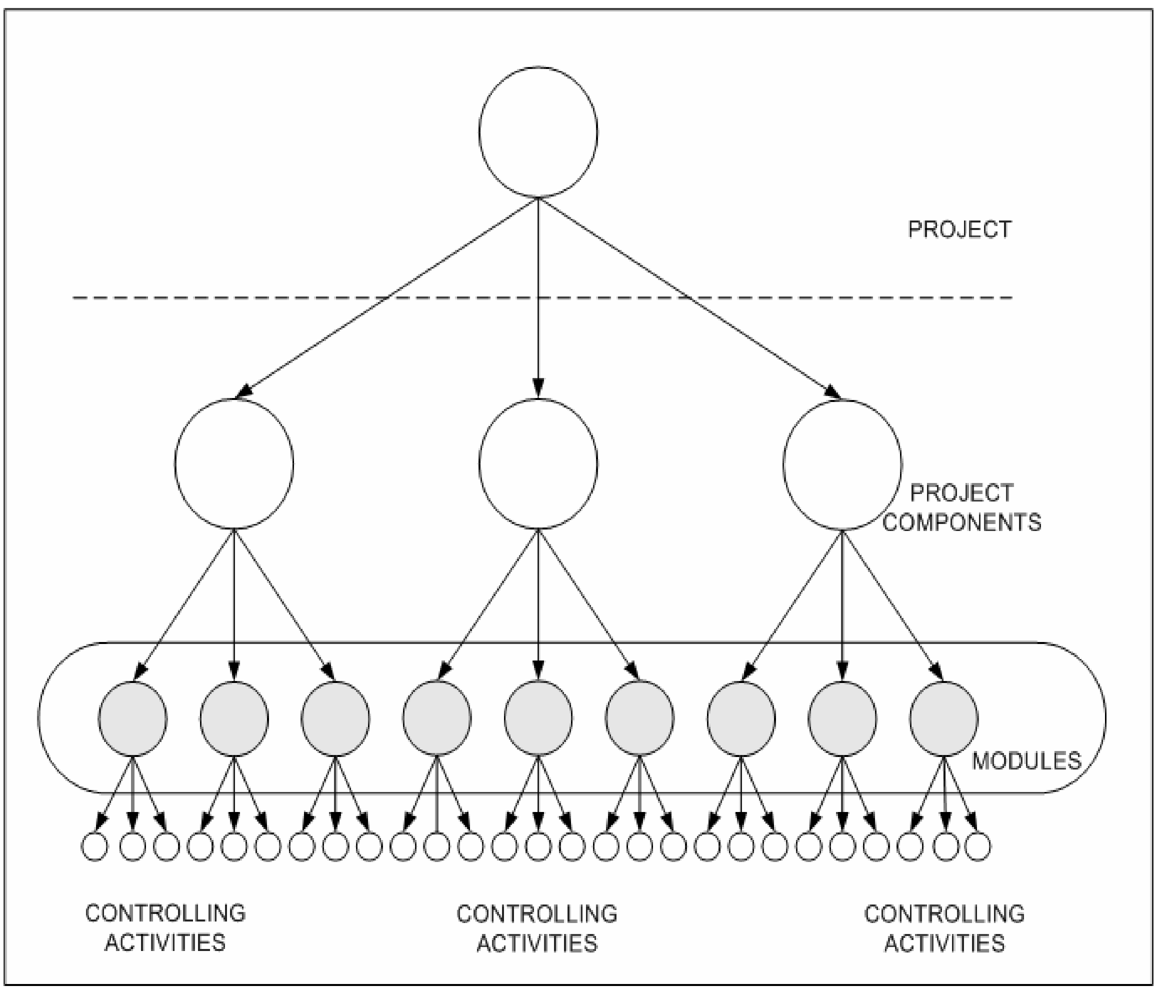


Fig 5.4: Operation Level Breakdown of a Project

Each project is made of various sub projects and each of these sub projects are broken down into project components (see Fig 5.4), of which certain project components have to be performed by a specific period of time sot that the main project doesn't get delayed or affected in any way. These project components consist of numerous activities and the ones that affect the timely completion of the project are the controlling activities. Modules have been used to sort and arrange the controlling activities in a logical sequence. Thus each module consists of one or more controlling activities. For example, a specific road project has been broken down into three main project components, i.e. road reconstruction, signal work and erosion control. Each of these project components will have a given set of modules that have to be completed for successful completion of individual sub project. In signal work, the main modules will be laying of electrical conduits, wiring work and finally signal installation. These individual modules will have a set of controlling activities that typically governs that specific module. The timely completion of a set of controlling activities implies the successful completion of that module. There is no fixed number of controlling activities that have to be part of a module and if required, the number of controlling activities can be increased or decreased.

Once such project controlling activities are identified and their associated quantities of work and production rates are determined, the duration for each controlling activity is calculated.

$$\text{Activity Duration} = \frac{\text{Total estimated quantity of the activity}}{\text{Production rate}} \qquad \ldots \text{ equation 5.1}$$

Sequential arrangement of the controlling activities will produce a schedule for the proposed project. On generating this schedule, the total duration that the project is expected to take can be calculated in working days.

5.3 Selection of Tier II Template Activities:

Based on the concept of template, modules were first identified depending on the various types of highway construction. After identifying the modules, project controlling activities were identified, analyzed and arranged in a sequenced manner for each module. Thus every Tier II template consists of number of modules and each module consists of one or more controlling activity as can be seen in Table 5.2

Table 5.2: Template Controlling Activities for Tier II Projects

Mod No	Controlling Activities
1	**Mobilization**
2	**Traffic Control & Detours**
	Signs
	Striping
	Barrier wall
	Pavements for detours
3	**Clearing and Grubbing**
4	**Removals**
	Removal of existing structures/ Pavements (Asp/Conc)
	Excavate/ Borrow Bridge Structure
5	**Grading - Top soil, excavation & embankment**
	Unclassified Roadway Excavation/ borrow
6	**Sub Grade operations**
	Soil Stabilization works (Lime or Fly Ash)
7	**Drainage Structures**
	Storm Drainage Piping
	Manholes
	RCB's (Extend/ install 4'x2', 3'x3', etc)
8	**Box Construction - Single or Multi Cell**
	Slab (form, rebar, pour concrete)
	Walls/wings (form, rebars, pour concrete strip forms)
	Roof Deck (form, rebar, pour concrete)

	Backfill at box
	Parapets, if required (form, rebar, pour concrete)
	Curing
9	**Bridge Construction - Single or Multi Span**
	Driving Piles
	Abutments (Rebars, Forming, Concrete)
	Drive/ pour Piers (24”, 36”, 48”, 72” pier)
	Form/ Pour Columns and Caps
	Beams (placing)
	Slab Decking (forming, rebars, concrete)
	Parapets (forming, rebars, concrete)
	Approach Slabs
	Curing
10	**Base operations**
	Agg Base 10"
	Asphalt Base/ fabric installation
	Pour Concrete Curb
	Curing
11	**Surfacing Works**
	Asphalt, Type A
	Asphalt, Type B
	9" PC
	10" PC
	Curing
	TBSC
12	**Finish Grading/Shouldering**
13	**Guardrail installation**
14	**Electrical Lighting Works**
15	**Signals Installation**
14	**Permanent Signs/ Striping**
15	**Final Erosion Control**
	Riprap, filter blanket
	Sodding
	Mulching
	Seeding
16	**Cleanup/ Open to Traffic**
17	**Phasing Allowance**

This table details out each module and is composed of all the controlling activities that ODOT considers as major and critical for all Tier II projects. Based on the different Tier II project classifications, few modules may not be part of such templates depending on the scope of work. For example, in a reconstruction of city street project, modules for a bridge or box bridge construction are not included and in a reconstruction existing alignment with rural interchange, modules for traffic signals are excluded, thus reflecting the actual work operation involved in such a highway projects.

5.3.1 Ok-CTDS Tier II Templates:

Based on the project classification for ODOT highway projects, one general template that accounts for projects executed under Tier I project classification and eight templates that account for Tier II project classifications have been developed. Table 5.3 shows a Tier II project category template (Reconstruction Existing Alignment/ Rural Interchange) as an example. The general template and other Tier II templates are included in appendix B.

Table 5.3: Tier II Template for Ok-CTDS

Mod No.	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Duration Override	Comments
1	**Mobilization**	days					
2	**Traffic Control & Detours**						
	Signs	days					
	Striping	lf					
	Barrier wall	lf					
	Pavements for detours	tons					
3	**Clearing and Grubbing**	days					
4	**Removals**						
	Removal of pavements	sy					
	Remove Bridge Structure(s)	sf					
5	**Grading - Top soil, excavation & embankment**						
	Unclassified Roadway Excavation/ borrow	cy					
6	**Sub Grade operations**						
	Soil Stabilization works (Lime/ Fly Ash)	sy					
7	**Drainage Structures**						
	Storm Drainage Piping	lf					
	Manholes	ea					
	RCB's (Extend/install 4'x2', 3'x3', etc)	lf					
8	**Box Construction - Single or Multi Cell**						
	Slab (form, rebar, pour concrete)	sf					
	Walls/wings (form, rebars, pour concrete, strip forms)	sf					

	Roof Deck (form, rebar, pour concrete)	sf					
	Backfill at box	cy					
	Parapets, if required (form, rebar, pour concrete)	lf					
	Curing	days					
9	**Bridge Construction - Single or Multi Span**						
	Driving Piles	lf					
	Abutments (Rebars, Forming, Concrete)	cy					
	Drill/ Pour Piers						
	Form/ Pour Columns and Caps	cy					
	Beams (placing)	lf					
	Slab Decking (forming, rebars, concrete)	sf					
	Parapets (forming, rebars, concrete)	lf					
	Approach Slabs	sy					
	Curing	days					
10	**Base operations**						
	Agg base 10"	cy					
	Asphalt base/ fabric installation	Tons					
11	**Surfacing Works**						
	Asphalt Type A	tons					
	Asphalt Type B	tons					
	9" PC	sy					
	10" PC	sy					
	Curing	days					
	TBSC	tons					
12	**Finish Grading/Shouldering**	sy					
13	**Guardrail installation**	lf					
14	**Permanent Signs/ Striping**	lf					
15	**Final Erosion Control**						
	Riprap, filter blanket	tons					
	Sodding	sy					
	Mulching	acres					
	Seeding	acres					
16	**Cleanup/ Open to Traffic**	days					
17	**Phasing Allowance**	days					

5.4 Production Rates:

Production rate is a quantity of production accomplished over a specific period of time and realistic production rates are the key in determining reasonable contract times (Herbsman and Ellis, 1995). Actual production rates in the field depend on many factors such as weather, topography, project size, soil conditions, crew size etc. For most of the time, the actual impact of these factors on the production rates is very difficult to be accurately forecasted. The Texas and the Kentucky CTDS have used a range of production rates for each of their controlling activities and have certain procedures to follow to account for variances caused due to project uniqueness.

Texas CTDS was setup with default values for the production rates along with already established low and high production rates for each controlling item. To enable the user to incorporate project specific features in the production rates, they had defined five adjustment factors. They are location, traffic conditions, project complexity, soil conditions and quantity of work. Using these correction factors the system default values could be modified by the user to accurately estimate production rates for controlling activities for differing project characteristics. Based on TxDOT's research, they had developed an adjustment factor table (see Table 5.4) that helped the user in estimating production rates.

Table 5.4: Default values for CTDS Job Correction Factors (Hancher et al, 1992)

FACTORS	**ADJUSTMENTS FOR NOTED CONDITIONS**		
LOCATION	RURAL 1.00	SMALL CITY 0.85	BIG CITY 0.75
TRAFFIC CONDITIONS	LIGHT 1.00	MODERATE 0.85	HIGH 0.75
COMPLEXITY	LOW 1.00	MEDIUM 0.85	HIGH 0.75
SOIL CONDITIONS	GOOD 1.00	FAIR 0.85	POOR 0.75
QUANTITY OF WORK	LARGE 1.00	MEDIUM 0.85	SMALL 0.75

Since most of these factors were correlated and not independent, it was recommended that only two correction factors maximum was to be selected for each work item. If the user disagreed with the production rate values generated after using correction factors, the user could use their own values that they think would be suitable for those activities. For example, the production rate for the embankment work, with soil (fair condition) and quantity (medium) as sensitivity factors would be calculated as follows:

Embankment daily production = Embankment PR x soil factor x quantity factor

= 4200 x 0.85 x 0.88

= 3142 cubic yards

Kentucky CTDS, rather than using specific sensitivity factors, generated average production rates and ranges (lower limit, average rate and upper limit) for each controlling activity, to reflect the working and site conditions and which the user had to adjust to suit the local district conditions. The production rates developed were based on historical data and engineer’s experience, which were validated by testing on previously completed projects.

For example, roadway excavation has the following three ranges; lower limit is 1,000, average is 5,000 and upper limit is 10,000. Now, if the soil condition at the project location is going to be a mixture loose soil, sand and clay, a production rate of 7,000 or 8,000 can be used, but in case the soil condition is rocky in nature, a production rate of 3,000 or 4,000 may be selected because the productivity is low in rocky conditions as compared to loose soil conditions.

This study has adopted the concept used in the Kentucky Contract Time Determination System (Hancher et al, 2000; TRB Research Record No.1712, Construction 2000) to develop DOT specific production rates for the selected controlling activities. Each controlling activity was studied and its productivity was analyzed using recently completed highway projects. Experienced engineers as well the project scheduling coordinator's assisted in determining the default average production rates as well as the ranges for all the selected controlling activities. The ranges developed were compared with the values generated using the RS Means Cost guide data and contractors estimated values to ascertain if the ranges selected were in par with the industry standards. All the controlling activities have a range of production rates that has a minimum value, an average value and a maximum value. In all the templates, each controlling activity is represented using the average production rate which the user needs to adjust to incorporate actual site characteristics and constraints. Table 5.5 displays the entire list of controlling activities with their range of production rates.

Table 5.5: Production Rates chart for all controlling activities

Mod No.	Controlling Activities	Unit	Min Rate	Avg Rate	Max Rate
1	**Mobilization**	days	2	4	5
2	**Traffic Control & Detours**		-	-	-
	Signs	days	20	30	40
	Striping	lf	5000	10000	18000
	Barrier wall	lf	625	1045	1336
	Pavements for detours	tons	400	862	1600
3	**Clearing and Grubbing**	days	1.5	4	6.2
4	**Removals**		-	-	-
	Pavements (Asp/Conc)	sy	1200	1900	2600
	Excavate/ Borrow Bridge Structure	sy	80	620	1600
	Cold Mill pavement	day	-	-	1
5	**Grading - Top soil, excavation & embankment**		-	-	-
	Unclassified Roadway Excavation/ borrow	cy	1800	2825	7000

6	**Sub Grade operations**		-	-	-
	Soil Stabilization works (Lime or Fly Ash)	sy	1900	2500	4600
7	**Drainage Structures**		-	-	-
	Storm Drainage Piping	lf	50	110	190
	Manholes	EA	-	1	1.5
	RCB's (Extend/ install 4'x2', 3'x3', etc)	lf	25	60	95
8	**Retaining Walls**				
	Excavation & backfill	cy/day	200	350	500
	Rebar	tn/day	2.5	3	4
	Formwork	sfca/day	1700	2200	2400
	Conc pouring + cure	cy/day	75	80	90
9	**Box Construction - Single or Multi Cell**		-	-	-
	Slab (form, rebar, pour concrete)	sf	200	350	570
	Walls/wings (form, rebars, pour concrete, strip forms)	sf	125	290	370
	Roof Deck (form, rebar, pour concrete)	sf	125	290	370
	Backfill at box	cy	300	410	520
	Parapets, if required (form, rebar, pour concrete)	lf	20	110	175
	Curing	days	3	7	10
10	**Bridge Construction - Single or Multi Span**		-	-	-
	Driving Piles	lf	90	257	700
	Abutments (Rebars, Forming, Concrete)	cy	2.9	3.75	5.6
	Drill/ Pour Piers				
	24" pier	lf	120	175	200
	36" pier	lf	75	125	155
	48" pier	lf	70	100	130
	72" pier	lf	60	80	115
	Form/ Pour Columns and Caps	cy	1.75	2.5	3.3
	Beams (placing)	lf	400	575	800
	Slab Decking (forming, rebars, concrete)	sf	600	730	900
	Parapets (forming, rebars, concrete)	lf	20	110	175
	Approach Slabs	sy	65	220	490
	Curing	days	3	7	10
11	**Base operations**		-	-	-
	Agg Base 10"	cy/day	160	310	775
	Asphalt Base/ fabric installation	tn/day	270	1000	1700
	Pour Concrete Curb + cure time	lf	500	800	1400
	Curing	days	3	7	10
12	**Surfacing Works**		-	-	-
	Asphalt, Type A	tn/day	440	900	1600
	Asphalt, Type B	tn/day	400	825	1560
	9" PC	sy/days	600	1640	2400
	10" PC	sy/days	700	1560	2275
	TBSC	tn	425	600	985
	HES Drives	sy/days	350	500	700
	Curing	days	3	7	10
13	**Finish Grading/Shouldering**	sy	1600	2500	3300
14	**Guardrail installation**	lf	400	1000	1800
15	**Electrical Lighting Works**	poles/days	1	2	3

16	**Signals Installation**	days	2	3	3
17	**Permanent Signs/ Striping**	lf	5000	10000	18000
18	**Final Erosion Control**		-	-	-
	Riprap, filter blanket	tn/day	40	480	800
	Sodding	sy	840	1280	3200
	Mulching	acres	2.6	3.5	5.3
	Seeding	acres	1.6	2.4	3.8
19	**Cleanup/ Open to Traffic**	days	1	3	4
20	**Phasing Allowance**	days	1	2	5

Since contract time relies on the accuracy of generating realistic production rates, there is a generic drawback with the contract time determination systems developed for Texas DOT, Kentucky Transportation Center and Oklahoma DOT. The default rates and the ranges for the controlling activities are still suggested rates and its accuracy depends on how the user appropriately factors project constraints such as size and location of the project, soil conditions and topography, and complexity of the job. Thus the system with all its stated benefits still relies on engineer's judgement.

Understanding this drawback, Texas DOT had conducted a research to assess the various factors that affect production rates within Texas districts for pre-selected 26 controlling activities. Construction projects that were in progress (less than 80% complete and contract duration greater than 120 days) were identified as sample data and detailed analysis was performed on three distinct parts of the project: project level, work zone level and work item level.

The data collected from each of them was subjected to various statistical analyses. Descriptive statistics were used to summarize the data for mean, sum, count and frequency of variables. They were also subjected to box plots to present the data in terms of mean, median, quartile, outliers, and extreme values in a graphical format. Two types of driver analysis were performed on the production rate data and based on the results the drivers that affected each production rate were identified. First, for those with continuous numerical data, regression analysis were conducted to identify drivers of production rates and to quantify their effects and second, for those with discrete numerical or categorical data, analysis of variance (ANOVA) was used to test the difference in mean production rate for subsets in each candidate driver. Regression analysis and correlation analysis were also performed on the data.

The research also analyzed the driving factors that affects the production rates of each of the work items and using statistical tools and techniques developed formulas and ranges for these production rates so that all these factors could be taken into consideration during the initial time estimation process itself. The end result of this research was the development of a construction production rate information system for highway projects called HyPRIS (Highway Production Rate Information System) which was based on a Microsoft Visual Basic using Microsoft Excel platform. The software used the developed tools and formulas to assist the estimator to determine realistic production rates once project related information is fed into the system (O'Connor et al, 2004).

Although this tool provided a quantitative analysis towards generating realistic production rates, there are certain issues which the users faced which are as listed below:

1. The earlier Texas CTDS had around forty two controlling activities and the HyPRIS system allowed the user to generate production rates for only 26 critical activities which restricted the users to a limited number of activities. For controlling activities beyond the twenty six, the engineer's had to still use their best guesses and experience for determining production rates.

2. Engineers were concerned that the formulas used to develop production rates was applicable only state wide (state of Texas) and not applicable locally by district offices since the sample data chosen to develop those formulas were not sufficient to generate accurate values for individual district offices.
3. The users were specifically looking for a system where the user would need to input project site conditions, characteristics and constraints. Based on the entered information the system would help generate a localized production rate using the developed mathematical models and their database of completed projects as a source to come up with reasonable and realistic production rate values thus avoiding engineers to use "best guesses" as a source for data generation.

Due to these reasons, majority of users at TxDoT currently make use of a combination of Tx-CTDS, HyPRIS (for relevant activities), industry published production rates that are modified to local conditions and engineer's experience to estimate contract time for their highway projects. There has been steps taken recently by Texas DOT to try and either modify HyPRIS by enlisting more number of controlling activities to help generate localized production rates or to develop a new system or approach towards generating realistic production rates (Mr.Darrell Owens, 2007).

The production rates generated for ODOT in this research are developed using engineer's experiences and are based for the state of Oklahoma which are further supported by historical data and which carry the above stated drawbacks as well. The users are provided with a default rate and a range of values to choose from and the user needs to factor in the project characteristics and constraints like soil conditions, project location, weather, traffic conditions, availability of work front, etc and modify the default rate to suit the project. After factoring is completed, the production rate would be localized for that specific project. It is highly recommended that the production rate values be reviewed by experienced engineer's and project scheduling coordinators to determine whether the values estimated are reasonable enough or not.

5.4.1 Comparison between ODOTs, Contractors and RS Means Production rates:

A questionnaire was sent to ten general contractors in Oklahoma seeking information on their production rates for selected controlling activities to allow comparison to be made with ODOT's rates. However, due to the sensitivity of the information only two contractors responded with the required information. The purpose was to compare differences between contractor's production rates and ODOT's.

Fig 5.5 shows the comparison of production rates between ODOT's calculated ranges versus contractor's rates and average rates calculated using RS Means Cost Guide 2007. Baring a few activities, where production rates of contractors were well beyond ODOT maximum production rate range, all the rates provided by the contractors and calculated from RS Means Cost Guide were found to be in the range that has been developed for ODOT. This would mean that the production rates calculated by ODOT would be quite reasonable and realistic for competitive contractors to achieve.

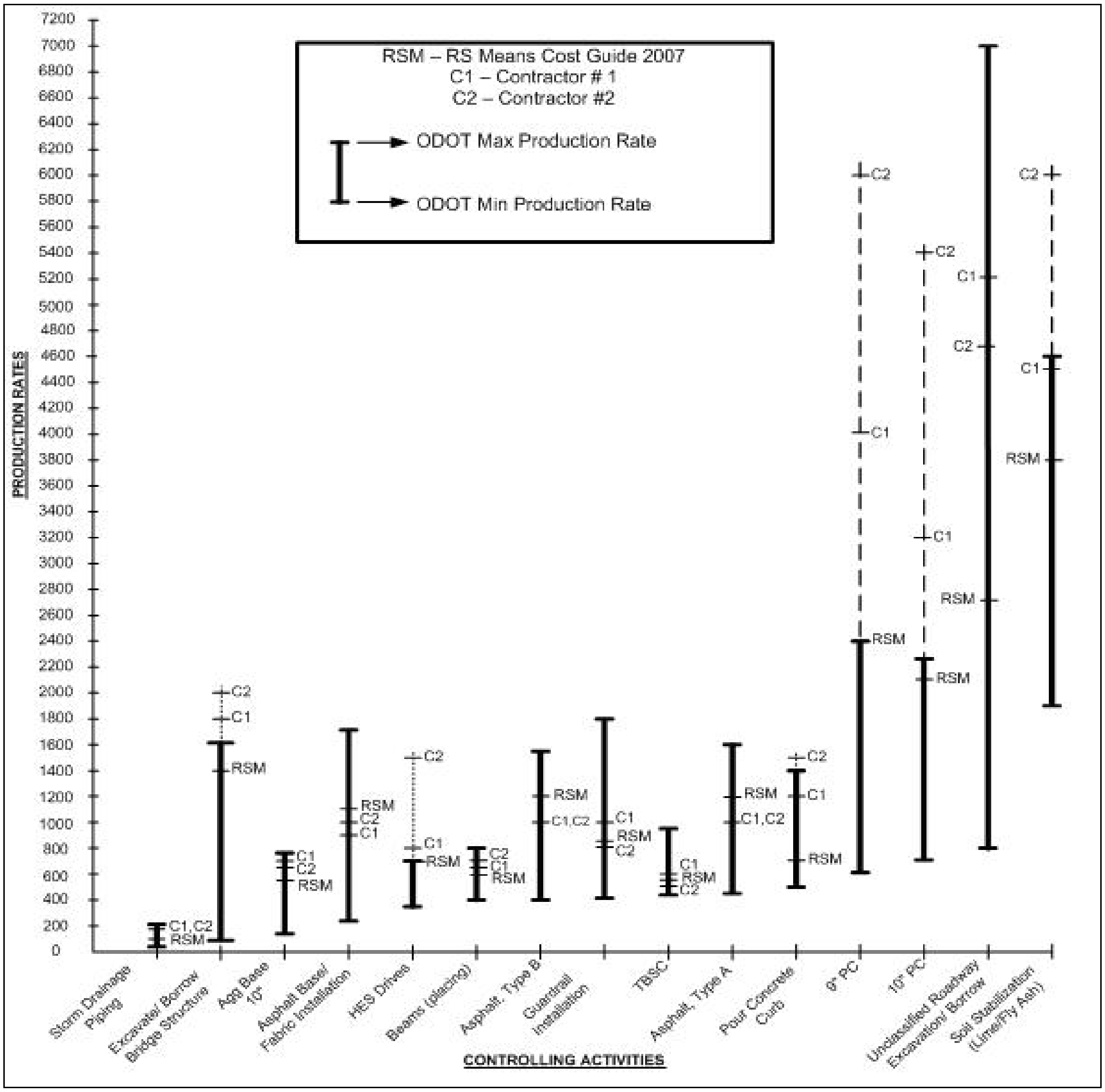


Fig 5.5: Comparison Chart between ODOT's Production Rate Ranges versus Contractor's and RS Means Cost Guide Production Rates

Production rates being the bread and butter for contractors, their approach towards them is totally different than ODOT's. Based on their production rates, contractors can determine the duration of their job and how fast they can move on to another job. Their monthly cash flow and profits all stem from their production rates. Each of their values, apart from some being generated based on experience, are calculated based on the quantity of work, the number of man-hours required for each operation, crew size, job site characteristics and constraints, etc. Thus contractors follow a mathematical and a rational approach towards generating each of their production rates.

The ODOT, on the other hand, does not generate detailed production rates like the contractors, to determine the exact values. The reason is that, ODOT cannot impose a certain value of production rates onto contractors. Since production rates between contractors differ to such a large extent, ODOT's main concern is to use conservative production rates so that it helps in generating contract time that are reasonable for majority of the contractors to work with. Having said that, it must be noted that inspite of ODOT using realistic production rates there are certain contractors who do not have the resources or have their resources locked in multiple projects and who believe to always have less time than required to construct the project. This is what typically distinguishes competitive contractors from the general ones. Thus, ODOT's main concern is to have a reasonable range of production rates for each of their activities so as to cater to different rates used by the contractors.

The flaw discussed earlier between Kentucky and Oklahoma CTDS doesn't lie in the production rate ranges selected for their respective controlling activities but lies in the users who are actually selecting the production rates. When users estimate contract time they need to study the project characteristics and constraints and along with their experience, choose a production rate that would be ideal and reasonable. This process is a drawback because no two users would recommend the same production rate because that decision would be based on their earlier experiences. Hence different users working on the same project would typically use varied production rates to estimate different contract times.

The Texas DOT's research tried to minimize the user effect of best guesses on their production rates by trying to standardize the process of generating realistic ranges of production rates (HyPRIS) for selected controlling activities. This system based on the pre-determined statistical formulas, would generate realistic production rate ranges as soon as the user would enter the project specific characteristics (O'Connor et al, 2004) allowing the user to use a more rational approach while determining production rates.

5.5 Activity Logic for the Templates:

This section discusses the process to determine the sequential relationship between all the controlling activities to be represented as a diagram using CPM diagram. This diagram is a representation of the project which provides the estimated contract time of the project in working days.

The idea here is to develop a pre-established logic for sequencing the controlling activities that would reflect the actual construction process under ideal working conditions. The CPM schedule generated would form a basis for the user to incorporate all the project specific factors and constraints such as project type (urban versus rural), soil conditions and topography, size and location of the project (urban versus rural), and complexity of the job.

5.5.1 Basis for developing template logic:

Texas CTDS as well as Kentucky CTDS (Hancher et al, 1992; Hancher and Werkmeister, 2000) have used various lags and leads between each controlling activity to reflect the actual construction sequence and to define the relationship and logic between their controlling activities. All their controlling activities in their CTD system are interlinked with leads, lags and complex logical relationships. Table 5.5 and Table 5.6 shows a template from the Texas and Kentucky CTDS using this approach.

Table 5.5: Texas CTDS Template Logic

S.No	Major Work Items	Preceding Activities & Relationship
1.	Initial traffic control	
2.	Detour	1, 100%
3.	ROW Preparations	2, 100%
	A. Major Structure demolition	
	B. Clear and grub	
	C. Remove old structures (small)	
	D. Remove old pavement	
	E. Remove old curb & gutter	
	F. Remove old sidewalks	
	G. Remove old drainage/ utility structures	
4.	Excavation/ embankment	
	A. Earth excavation	3, 25%
	B. Rock excavation	3, 25%
	C. Embankment	3, 25%
5.	Bridge structures	
	A. Erect temporary bridge	1, 100%
	B. Bridge demolition	5A, 100%
	C. Cofferdams	2, 100%; 5B, 100%
	D. Piling	4A, 10%; 4B, 10%; 5C, 1000%
	E. Footings	5D, 75%
	F. Columns, Caps and Bents	5E, 75%
	G. Wingwalls	5F, 50%
	H. Beams (erection only)	5F, 100%
	I. Bridge deck (total depth)	5G, 100%; 5H, 100%
	J. Bridge curbs/ walks	5I, 100%
	K. Bridge handrails	5J, 100%
	L. Remove temporary bridge	5K, 100%
6.	Retaining walls	4A, 40%; 4C, 40%
7.	Base preparations	
	A. Lime stabilizations	4, 100%

	B. Flexible base material	7A, 100%
	C. Cement treated base material	7A, 100%
8.	New curb and gutter	7B, 100%; 7C, 100%
9.	Hot Mix asphalt base	8, 75%
10	Concrete paving	7B, 100%; 7C, 100%
11.	Hot mix asphalt surface	9, 100%
12.	Precast traffic barriers	10, 100%; 11, 100%
13.	Permanent signing and traffic signals	
	A. Small signs	10, 100%; 11, 100%
	B. Overhead signs	10, 100%; 11, 100%
	C. Major traffic signals	10, 100%; 11, 100%
14.	Seeding and landscape	6, 100%; 10, 50%; 11, 50%
15.	Pavement markings	10, 100%; 11, 100%; 12, 100%
16.	Final clean up	5L, 100%; 13, 100%; 14, 100%; 15, 100%

Table 5.6: Kentucky CTDS Template Logic

Item No	Activity	Predecessors
1	Initial Traffic Control	
2	Clearing & Grubbing	1
3	Diversion (By-Pass Detour)	1
4	Roadway Excavation	3SS+2,2SS+0
5	Embankment in Place	3SS+2,2SS+0
6	Drainage Pipe	4SS+0,5SS+0
7	Box Culverts, Class A Concrete	2SS+0
8	Erect Temporary Bridge	1
9	Remove Existing Structures	3,8
10	Cofferdams	9
11	Structure Excavation	9,10
12	Piling	10,11SS+0
13	Sub-Structure, Class A Concrete	12SS+0
14	Concrete Beams	13
15	Steel Beams	13
16	Super-Structure, Class AA Concrete	14,15SS+0
17	Remove Temporary Bridge	16
18	Major Retaining Walls	4,5
19	Sub-grade Stabilization	4,5,6SS+0,7SS+0
20	Stone Base	19
21	Drainage Blanket	19
22	Asphalt Base, Leveling, & Wedging	20,21
23	Curb & Gutter	22SS+0,20
24	Entrance Pavement	22SS+0,20
25	Barrier Walls, Slip Form	22SS+0
26	Asphalt Repair	22SS+0
27	Concrete Repair	20
28	Concrete Paving	20,21,23SS+0,24SS+0,27
29	Asphalt Surface	22SS+0,23SS+0,24SS+0,25,26,27
30	Sheet Signs	28,29

31	Panel Signs	28,29
32	Major Traffic Signals	28,29
33	Lighting, Total Installation Luminaries	28,29
34	Guardrail	28,29
35	Finish Seeding	28,29
36	Pavement Marking	28,29
37	Final Clean-Up	17,18,28,29,30,31,32,33,34,35,36
38	Phasing Allowance	37

These templates with controlling activities have not only complex logic but also various leads and lags associated with them. Each project being unique has certain inherent characteristics and constraints for example, following a different construction methodology due to job complexity, or changing the proposed sequence of construction, etc., which requires to be factored into the template logic as well for scheduling the project thereby establishing a reasonable contract time. With such complex network logics if there is a necessity to adjust one or more controlling activity logic to suit project characteristics and constraints, the change would cause a ripple effect through all the other controlling activities that have dependencies on them. The user making such a change must have a very sound understanding of activity logics and would need to update and modify all the relevant activities which have been affected to maintain the template logic. This being a problem, typically the users either won't have the authority to make any changes to the activity logic or else would refrain from carrying out such changes to reflect actual site constraints and characteristics.

If no modifications are going to be made to the pre-established logic, the users would typically follow the logic to schedule all the controlling activities with the calculated durations that would finally provide an estimated contract time in working days for the highway project under consideration.

This study, on the other hand, has defined a template logic which is valid for construction under ideal working conditions and which can be standardized for any project to suit specific project conditions (see fig 5.6). This template logic excludes the complex relationships such as start-finish, finish-start, start-start, and finish-finish containing only logical relations that allow activities to be performed concurrently without the complex leads and lags. With this standardized logic, the user develops and generates an initial project schedule that provides an estimated total duration for that project in working days. Once the schedule is developed, experienced engineers and project schedulers need to study the schedule to ascertain whether project characteristics and constraints have been specifically taken into consideration.

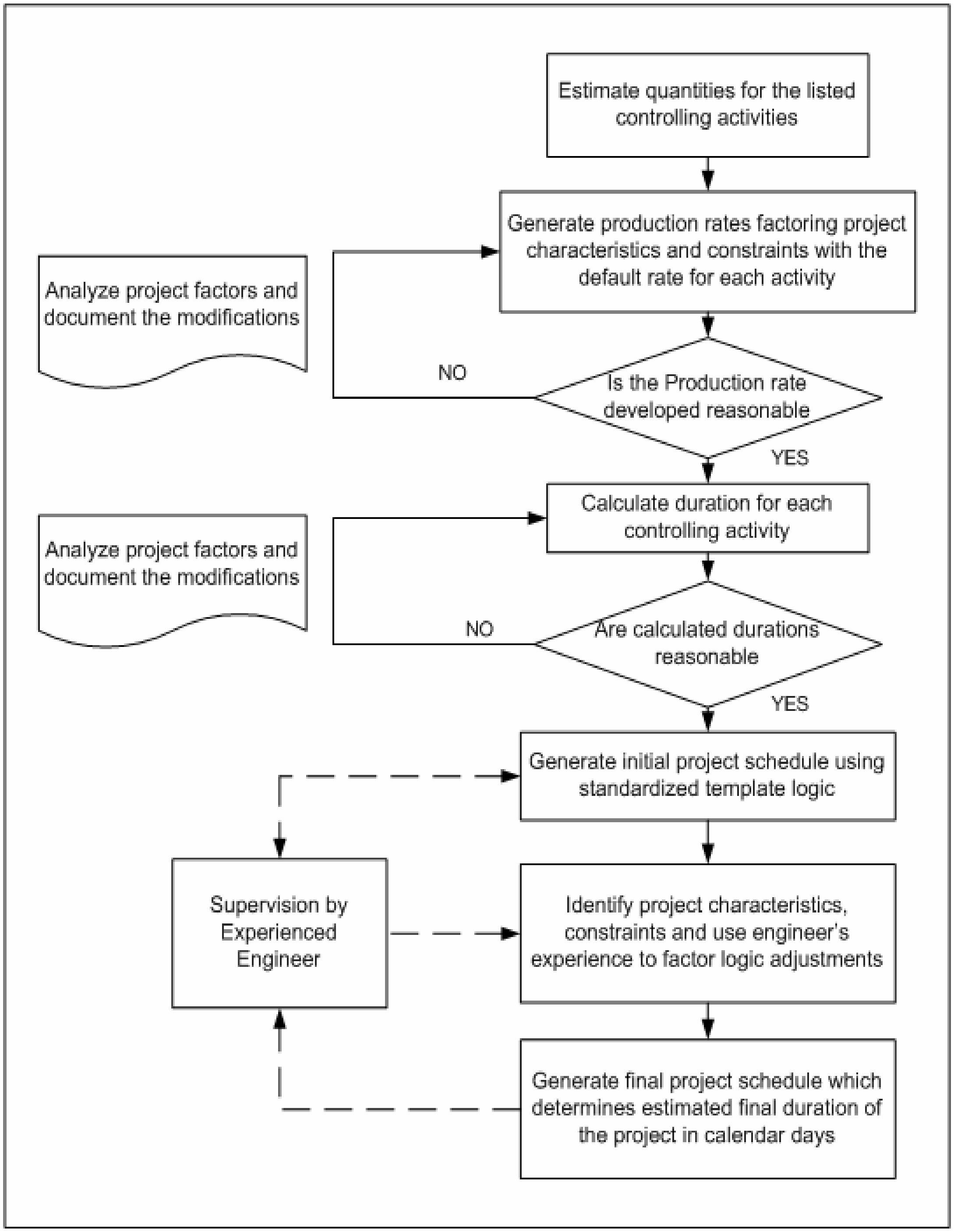


Fig 5.6: Process Flow in Ok-CTDS

5.5.2 Developed template logic for controlling activities:

In order to explain the template logic developed for the ODOT contract time system, a Tier II sample project titled Reconstruct Existing Alignment/ Rural Interchange template has been used (see Fig 5.7). The logic defined for individual Tier II templates can be found in the appendix C.

The template logic developed for this system is typically an arranged flow of all the modules that are logically sequenced and arranged in a manner that reflects the sequence of construction from an owner's perspective for bidding purposes and is not to be confused with the detailed logic diagram that the contractor's usually prepare for construction purposes. Simple finish-start logics are used to define the activity relationships is to obtain an estimated duration which is reasonable and realistic for contractors to achieve.

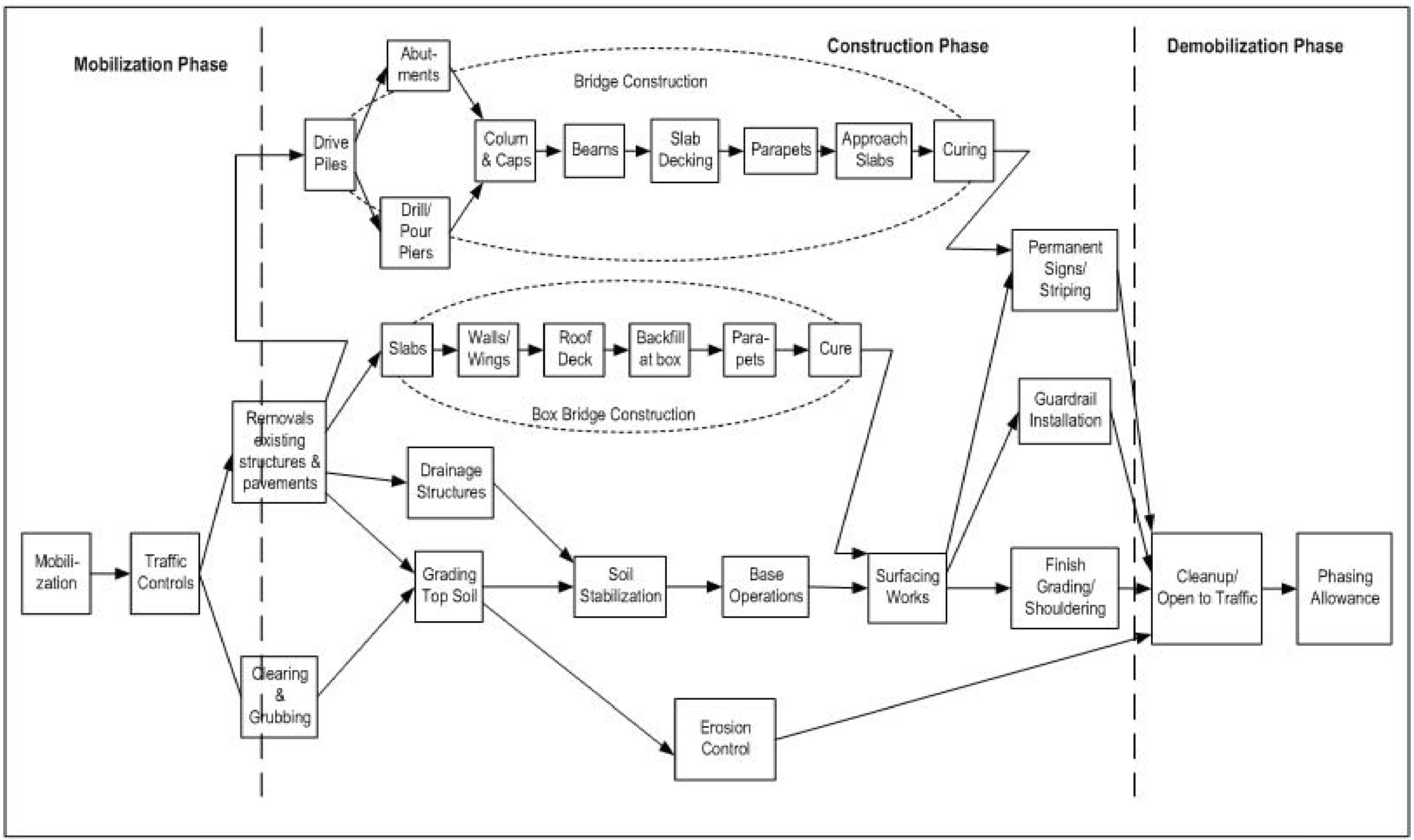


Fig 5.7: Activity Logic for Tier II – 2a Reconstruct Existing Alignment/ Rural Interchange Template

As can be seen from Fig 5.6, the project is broken down into three distinct phases viz., mobilization phase, construction phase and demobilization phase. The mobilization phase starts the project with the initial activity modules of mobilization and traffic controls with controlling activities of signs, striping, barrier walls and constructing pavements for detours. Once they are achieved, removal of existing structures and pavements as well as clearing and grubbing works are performed concurrently.

On completing the removals, the construction phase begins which comprises of a number of modules. Timely completion of each module represents successful completion of the construction phase. Based on the project scope and its requirements, work commences simultaneously on the modules titled as bridge construction, box bridge construction and drainage structures. Each of these modules comprises of a set of controlling activities which are also logically sequenced. For example the bridge construction and the box bridge construction process consist of a number of controlling activities which maybe sequenced concurrently as shown in Fig 5.8 and Fig 5.9. The drainage structure module comprises of constructing and laying storm drainage piping, manholes and reinforced concrete boxes. The grading of top soil is also performed concurrently.

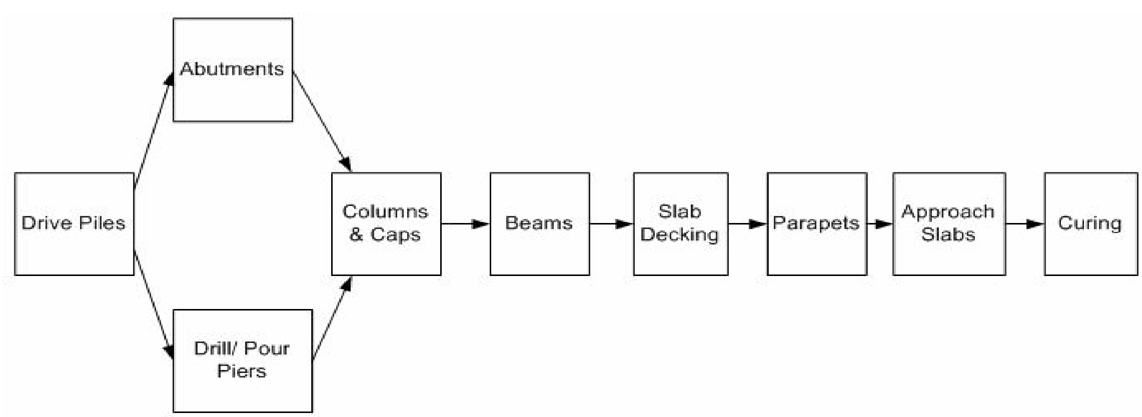


Fig 5.8: Logic for Bridge Construction Activities

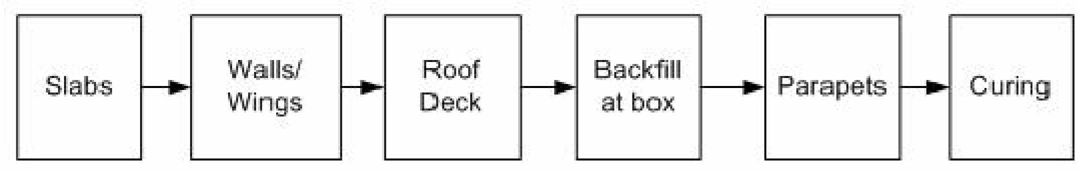


Fig 5.9: Logic for Box Bridge Construction Activities

After the completion of grading of top soil and construction of drainage structures, soil stabilization work using lime or fly ash begins. Concurrently erosion control module also commences. After soil stabilization module has been completed, base operations module which comprises of aggregate base, asphalt base or fabric installations, concrete curbs, etc begins and once they are completed, surfacing with asphalt or P.C concrete or traffic bound surface course (TBSC) begins. On successfully completing the surfacing works modules which represents the finishing works for the highway project begins. Grading and shouldering, guardrail installation, permanent signs and striping and signals installation all go on concurrently. Finally the project enters the demobilization phase, wherein the highway construction site is cleared off any debris and is opened to the general public and traffic.

The Kentucky CTDS used a unique approach to incorporate project phasing into the contract time estimation system as it plays a very significant role. Highway construction projects comprises of different phases such as mobilization phase, construction phase and demobilization phase. It takes a given period of time when moving from one phase to another which remains unaccounted during time estimation. To take care of this, their approach was to provide a phasing allowance to the total project duration (Hancher & Werkmeister, 2000). Thus the user would need to estimate the number of required phases for a project and then estimate the time in days required per phase. This similar approach was incorporated for all the templates in the Ok-CTD system which helps in speeding and simplifying the planning considerations with respect to phasing, without sacrificing accuracy.

5.5.3 Owner's and Contractor's Perspective:

Based on considerable inputs and cooperation from local contractors, there were varied perceptions towards standardizing the template logic. Contractor's perspective of constructing projects and estimating time and cost is totally different from an owner's perspective. Following is the comparison (see Table 5.8) of the typical characteristics between a contractor's and owner's perspective.

Table 5.8: Comparison between Contractor's and Owner's Perspective

S. No	Comparison	Contractor's Perspective	Owner's Perspective
1.	Initial Approach	Contractors study each project in detail.	Owners always have the bigger picture in mind.
2.	Optimization	Every phase analyzed to optimize construction.	No detailed planning performed to optimize construction operations.
3.	Analysis of resources	Analysis of resources performed.	Analysis of resources not performed.
4.	Analysis of equipment	Analysis of equipment deployment performed.	Analysis of equipment deployment not performed.
5.	Risks Assessment	Buffer zones are provided as cushion from risks and uncertainty.	No risk assessment done. All risks transferred to contractors.
6.	Detailed Planning	Detailed schedules prepared.	Detailed schedules not prepared.
7.	Bonus and Liquidated damages	If job is completed on or before time, contractors collect bonus, else they have to pay liquidated damages.	On early completion, to provide bonus else enforce liquidated damages on contractors.
8.	Value Engineering	Contractors provide value engineering to owners.	Owners are open to ideas of value engineering from contractors to optimize construction.

1. Initial Approach:

In the initial stages of the project, contractors study each operation minutely using the drawings, specifications and contract documented to understand and visualize the different phases of the job which helps determine the complexity of a job. In the initial stages of a project, owners always have the big picture in mind. They try to identify the job characteristics based on size and location, try to identify the number of phases required for the job, etc., but do not get into the complexities associated with building the project.

2. Optimization:

Each and every phase is analyzed to determine the most efficient and optimum way of handling that phase without any issues. Owners do not plan in detail the construction aspect of the project. Instead they develop a conceptual plan which holds good only for estimating time.

3. Analysis of Resources:

Availability and size of crew and other resources are considered for each operation by contractors. However, availability and size of crew and other resources are not considered by the owner during their planning operations

4. Analysis of Equipment:

Deployment of equipment needs to be planned and analyzed as they may be used between different jobs. The contracts and specifications usually specify requirements of certain types of equipments for certain operations. Other than this, no analysis is performed on equipment usage and deployment by the owner

5. Risks Assessment:

Buffer zones in terms of durations are calculated which gives contractors some kind of cushion before deadlines or milestones. For example, if a specific operation needs to be completed by the 60th day as part of the contract, the contractors would plan to get that finished by the 55th day, and keep 5 days as a buffer zone against risks and uncertainty.

The owner's main objective is to provide a reasonable time for the contractors to build the job and at the same time it must be shortest time within which the project can be completed. No detailed estimates are performed to determine how much duration each activity takes while estimating the contract time for a project

6. Detailed Planning:

Contractors develop highly detailed schedule for their construction projects which provides all the information such as start and finish dates for each activity, resources deployed towards each activity, cost associated with each activity, and other such related information. They typically perform various activities concurrently and use lags and leads liberally to get the project done either quickly or within the stipulated time.

Owners do not prepare highly detailed schedules during the planning or the construction phases of a project. A schedule that shows the brief outline of the project in terms of project constraints and milestones, phasing conditions, allotted work fronts, etc are sufficient for the owners. The idea here is that the contractors have agreed to build the project within the owner's estimated contract time and hence it's the contractor's responsibility to develop detailed construction schedules for the project.

7. Bonus and Liquidated Damages:

Once the contractor is awarded with the job, they start the project at the earliest and attempt to finish it as quickly as possible, so as to move on to another job site and/or collect rewards for early completion if there are any bonus clauses associated with the project.

Owners are not concerned on how contractors perceive individual activities to be carried out for successful completion of each operation as long as they meet the deadlines of the operations. The contractors are given the liberty to work in an efficient environment. Their main job is to monitor the progress of the contractor and see to it that the project is completed within the stipulated time, cost and quality and based on the contract conditions, would award the contractor with a bonus for early completion or fine the contractor liquidated damages for delayed projects

8. Value Engineering:

Contractors provide value engineering to owners on projects which help the owners save time or money or sometimes both.

The owner's and contractors have specifications that define how the project needs to be built using what methods. Most of the times, owners are open to ideas of value engineering, wherein contractors propose alternate methods to construct specific aspects of the project that helps save time and/or cost to the owner

5.6 Comparison between Various CTDS:

This section summarizes and compares through Table 5.9, the various characteristics, similarities and differences between the contract time determination systems developed by the Departments of Transportation of Texas, Kentucky, Louisiana, Florida, Indiana and Oklahoma.

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Table 5.9: Comparison Table between Texas, Kentucky and Oklahoma CTDS

S.No	Comparison	Texas CTDS	Kentucky CTDS	Louisiana CTDS	Florida & Indiana CTDS	Oklahoma CTDS
5.6.1	Logical Flow of Activities	Sequenced flow.	Sequenced flow.	Templates are listed with selected activities.	No sequenced flow followed.	Sequenced flow
5.6.2	Sorting of Activities	Sorted and arranged under a main activity.	No sorting and arranging of activities.	No sorting performed.	No order set for arranging the activities.	Controlling activities sorted under main activity called module.
5.6.3	Production Rates	Chart provides default rate and range of values in terms of minimum, average and maximum.	Chart provides default rate and range of values in terms of minimum, average and maximum.	Activities are associated with production rates, similar to Texas CTDS.	Published production rates are used for their activities.	Chart provides default rate and range of values in terms of minimum, average and maximum.
5.6.4	Adjustment factors for Prod Rates	Five sensitivity factors used Only two factors to be used at a time.	No sensitivity factors used to adjust production rates.	They use similar approach as Texas CTDS for production rate analysis.	They use engineer's opinion to factor project conditions.	No sensitivity factors used to adjust production rates.
5.6.5	Relationships between controlling activities.	Complex logic, leads and lags to define the relationships between each controlling activity	Complex logic, leads and lags to define the relationships between each controlling activity	Complex logic, leads and lags to define the relationships between each controlling activity	Logical relationships are defined by engineer at the time of establishing contract time.	Simple finish-to-start relationship used to help standardize the process of scheduling.
5..6.6	Method of scheduling	Projects are scheduled using bar chart system.	Projects are scheduled using critical path method.	Projects are scheduled using bar chart system.	Projects are scheduled using critical path method.	Projects are scheduled using critical path method.
5.6.7	Type of system.	Automated system, using Lotus 1-2-3, Flash-up and SuperProject to generate bar charts.	Automated system, using Microsoft Excel and Microsoft Project to generate CPM schedule.	Computers are used for production rate analysis and softwares are used for developing bar-charts.	Manual system. No softwares are used.	Automated system, which is a stand alone application using VB.Net in front end and MS Access database in back end. Microsoft Project used to generate CPM schedule.

5.6.1 Logical Flow of Activities on the Templates:

The activities listed in the templates of all Texas, Kentucky, Louisiana and Oklahoma CTD systems follow a logical sequence beginning with the mobilization phase, construction phase and completing it with demobilization. Florida and Indiana CTD systems does not mention of logical sequencing their activities.

5.6.2 Sorting of Activities on the Templates:

Activities listed on the Kentucky CTD system are not arranged and sorted in a manner other than the logical flow.

The Texas and Louisiana CTD system sorts and arranges a collection of controlling activities under a main activity. For eg: controlling activities like earth excavation, rock excavation and embankment are all part of a main activity called Excavation/Embankment.

Florida and Indiana CTD systems have no set order for arranging their activities.

The Oklahoma CTD system also sorts and arranges a collection of controlling activities under a main activity called the module. For eg: controlling activities such as storm drainage pipes, manholes and RCBs are all part of the drainage structure module.

5.6.3 Use of Production Rates:

All the four CTD systems of Texas, Kentucky, Louisiana and Oklahoma have developed a production rate chart which not only provide default values for their controlling activities but also provides range of production rate values (minimum and maximum) for each of the controlling activities. The user has the liberty to choose any value other than the default rate as long as they are within their ranges, based on their experience and project characteristics while determining contract time.

Florida and Indiana CTD systems make use of published production rates for establishing contract time and the user chooses an appropriate value based on the project characteristics and his experience.

5.6.4 Adjustment factors for Production Rates:

Texas CTDS uses five sensitivity factors viz., location, soil conditions, quantity of work, traffic conditions and complexity as correction factors for localizing their production rates. These multipliers are used to factor in project specific conditions to dine tune the default production rates. Only two sensitivity factors are to be used on any given activity. Louisiana CTD system uses a similar approach as that of Texas CTDS to adjust their production rates.

The Kentucky, Florida, Indiana and Oklahoma CTD systems don’t use any factors to adjust their default production rates. The user uses his experience and local site conditions to fine tune the production rates.

5.6.5 Logic Relationships between Controlling Activities.

The Texas, Kentucky and Louisiana CTDS uses complex logic, leads and lags to define the relationships between each controlling activity to help schedule the project. All the activities have more than one start-to-start, start-to-finish, finish-to-start and/or finish-to-finish relationships to define themselves. Due to such complex logical relations, users may find it difficult to modify the logic whenever they want to incorporate project conditions for scheduling purpose.

No pre-established logics are set for projects in Florida and Indiana CTDS. The engineer develops the logic at the time of contract time estimation based on the project features and constraints.

The Oklahoma CTDS, on the other hand, have simple finish-to-start relationship to define the logic between various controlling activities in order to standardize the process of scheduling. As the logic are not too complex, the users can easily modify and make changes to the standard logic to incorporate project constraints and characteristics while scheduling.

5.6.6 Method of Scheduling:

The Texas and Louisiana CTDS both use bar charts for scheduling their projects while Kentucky, Florida, Indiana and Oklahoma CTDS uses CPM to schedule their projects

5.6.7 Automated System for Determining Contract Time:

The Texas CTDS has a software system to automate the manual time estimation process. Their software was based on Lotus 123, Flash-up and SuperProject. The projects are scheduled using the bar chart system.

The Kentucky CTDS has a software to automate their time estimation process. Their software was developed using Microsoft Excel and Microsoft Project. The projects are scheduled using critical path network diagrams.

The Indiana CTDS is automated and uses computers to perform production rate analysis and scheduling softwares to schedule their projects.

Florida and Indiana CTDS being a manual system doesn't involve use of any computers.

The Oklahoma CTDS also has a software to automate their manual time estimation process. Their software is a standalone visual basic application using VB.Net in the front end and MS Access database in the back end. The calculated durations are automatically transferred to Microsoft Project to help schedule the project.

5.7 Oklahoma Contract Time Determination System

The following section details the manual system of contract time determination and the process flow is graphically represented in Fig 5.10.

Step 1: Study Project Requirements

The first step in this process is to study and collect all relevant information with respect to the highway project under consideration from the design drawings, specifications, construction site location, soil conditions, weather, period of construction, complexity, etc. All the data collected needs to be properly documented for easy reference.

Step 2: Selection of templates

Based on the type of highway project, the next step is to select the right template from the list of templates. If the project falls under a Tier II type highway classification, a template needs to be selected from the list of eight templates. In case, it's a Tier I type highway project, the general template needs to be selected to obtain a list of controlling activities which can act as a guideline for the contract time estimation process.

Step 3: Perform Quantity Take-offs

Once the initial project information has been collected and template is selected, accurate quantity take-offs need to be performed for the activities as listed in the template for the highway project under consideration. Typically, they are obtained from the project contract document which consists of complete drawing sets and specifications.

Step 4: Identify Production Rates

Each activity in the template has a production rate which ranges from minimum, average to maximum. The user needs to factor all the project features and constraints while selecting an appropriate production rate for the activities included in the template. After factoring various adjustments such as location, complexity, soil conditions, etc into the selection of the production rate, it needs to be documented in the adjacent comments field.

Step 5: Duration Calculation

Based on the quantity take-offs and realistic production rates, durations for each controlling activity needs to be calculated. There may be some activities in the modules that are not included in a specific project and for such activities the user need to set their quantity and duration as zero (0). In some cases, project constraints may require certain activities to be completed in days less than or more than calculated. In such situations, the new duration needs to be entered into the duration override column and the change should be justified in the comments section.

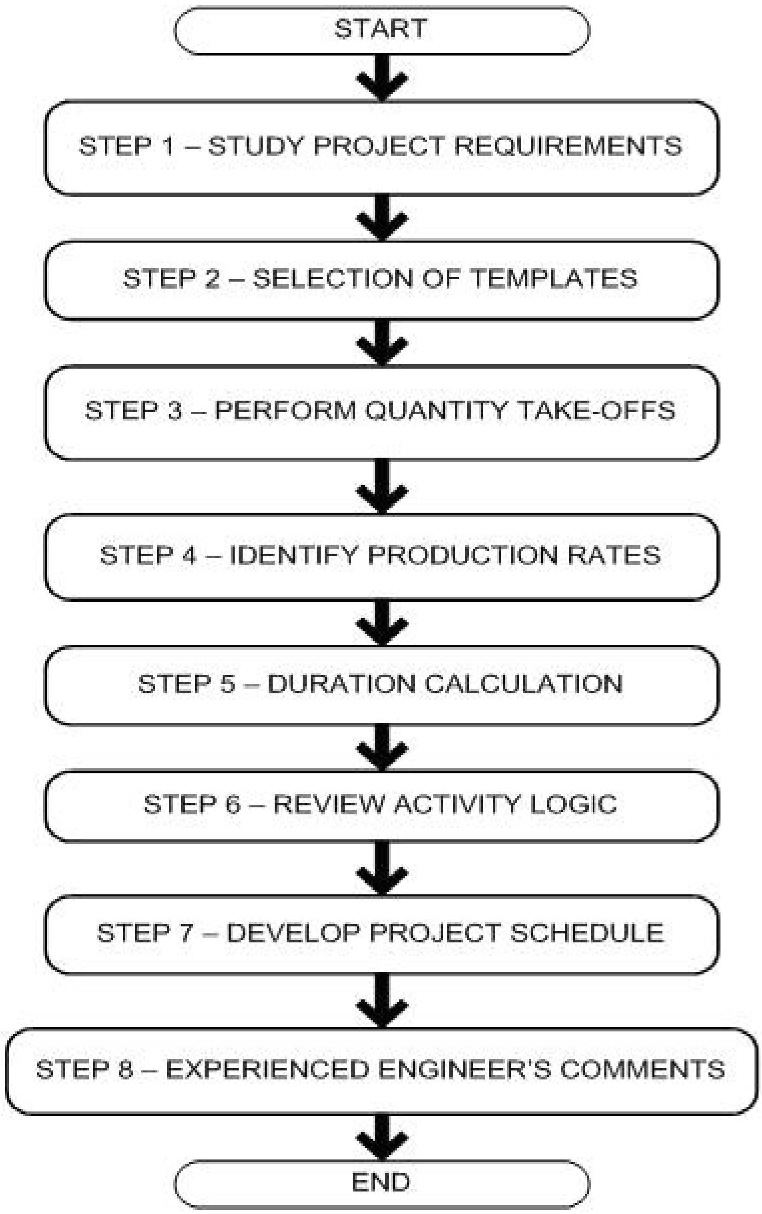

Fig 5.10: Ok-CTDS Manual System Flow Process

Step 6: Review Project Logic

Once the duration for all the controlling activities are estimated, the standard project logic with which all the controlling activities are logically sequenced for the given template needs to be reviewed by the user. As each construction project is unique, the template logic might need to be updated to factor in the project features so as to generate a robust construction schedule for the owner.

Step 7: Develop Project Schedule

Based on the logic used to sequence all the activities, a construction schedule needs to be generated using critical path method by hand or using professional scheduling softwares such as Primavera, Microsoft Project, SureTrak, etc. This generates a working schedule that provides total project duration in working days.

Step 8: Experienced Engineer's Comments:

Once the total project duration is calculated and scheduled, it needs to be reviewed by an experienced engineer. The engineer needs to review the production rates and the logic and based on his experience and necessity of the projects, needs to extend or reduce the contract time to suit the project scope, budget and schedule.

5.8 Template Validation:

ODOT projects which specifically didn't have any major delays during their construction and whose estimated contract time and the project completion time were almost equal were selected. For validating the templates the following procedure was followed. After selecting the projects, they were again estimated for contract time using the templates and checked if the contract time calculated matched the earlier set contract time or the completion time. Also, a few contractors were approached and they were provided with the contract specifications and plans and were requested to estimate the same projects from their prospective. The durations calculated using the templates were then also compared to those estimated by the contractors which helped validate the contract time determination system developed for ODOT.

Two completed projects, one that was constructed in Choctaw County and the other in Roger Mills County, were the projects selected for validation purpose. Choctaw County project falls under Tier II's second project classification of widen & reconstruct of existing alignment whose main scope of works included grading, widening, drainage and resurfacing works and which took around 180 calendar days to reach completion while the Roger Mills County project falls under the Tier II's eight project classification of roadway repair and overlay which took around 30 calendar days to complete.

The project information in terms of their quantities and required production rates were entered into the templates with the help of ODOT personnel and the contract time was calculated for both these projects. The same project plans and information were also provided to two volunteering contractors to estimate project duration. Table 5.10 shows the comparison made for the contract time estimated by ODOT and the contractors for the two projects.

Table 5.10: Time Estimated by ODOT and Contractors

	Actual Time (Calendar days)	ODOT Estimate using Templates (Range in Calendar days)		Contractor Estimate (Range in Calendar days)	
Choctaw County Project	180 days	175 days	180 days	170 days	190 days
Roger Mills County Project	30 days	30 days	40 days	45 days	55 days

Using the templates the ODOT have determined that the contract time for the Choctaw County project should be around 175 - 180 calendar days while the contractors through their estimate, calculated around 170 - 190 calendar days for the same project. For the Roger Mills County project, ODOT estimated around 30 - 40 calendar days while for the same job, the contractors estimated around 45 - 55 calendar days. The graphical representation which compares the above values from Table 5.10 for Choctaw County can be seen in Fig 5.10 and for Roger Mills County can be seen in Fig 5.11.

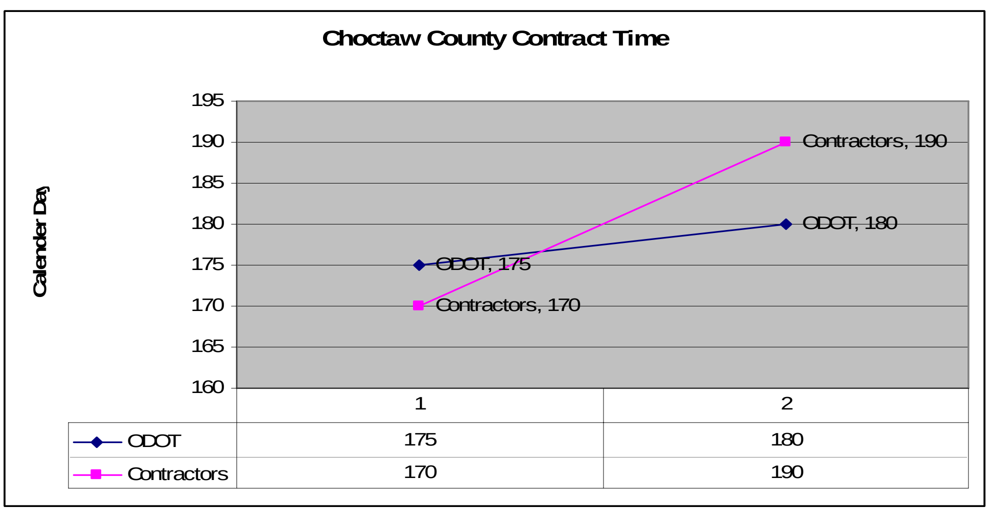

Fig 5.11: Graphical Representation of the Durations Calculated by ODOT and Contractors for Choctaw County

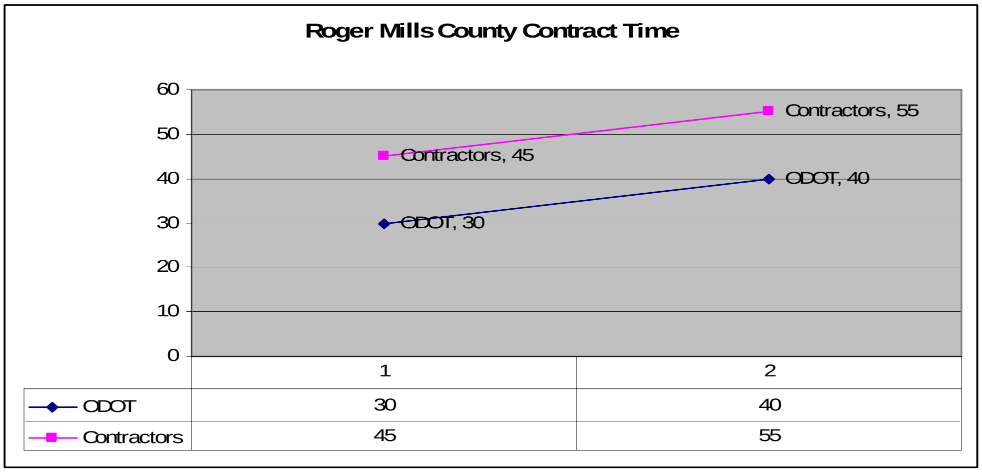

Fig 5.12: Graphical Representation of the Durations Calculated by ODOT and Contractors for Roger Mills County

Through this validation process it can be seen that the time estimated by ODOT using the template system comes close to the time estimated by the contractors.

CHAPTER VI

SOFTWARE DEVELOPMENT FOR OKLAHOMA CONTRACT TIME DETERMINATION SYSTEM

The Oklahoma Contract Time Determination System (Ok-CTDS) is a manual system developed to help ODOT estimate contract time for highway projects. To help make this system more efficient and easy to use, the software is developed that incorporates all the aspects of the manual system and assist the user in automating the entire process. This chapter discusses the system architecture, the process flow and the working of the software by running a sample template project and estimating the contract time.

6.1 System Architecture

System architecture is the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution. The software architecture is the structure which comprises of software elements, the externally visible properties of those elements, and the relationships between them.

The Oklahoma Contract Time Determination System (Ok-CTDS) software is a standalone visual basic application using VB.Net in the front end and MS Access database in the back end.

6.1.1 Front End:

The front end comprises of a Graphical User Interface (GUI) that acts a medium between a user and the program. The Ok-CTDS software has a user friendly GUI that allows a user to select choices and enter proposed project data. Fig 6.1 shows a screenshot of the main input screen.

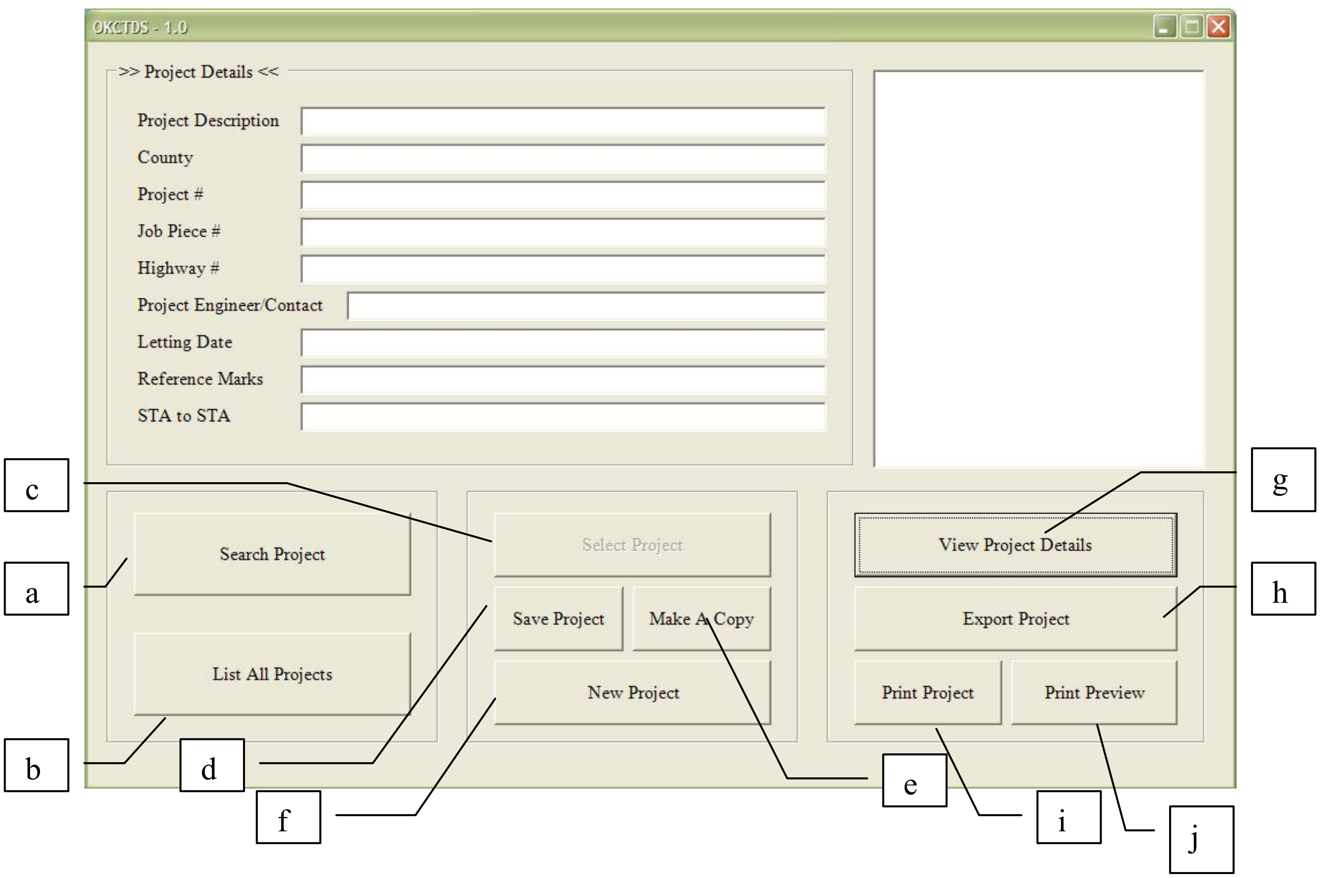

Fig 6.1 Screenshot of Ok-CTDS Application

The various fields on the form are for entering information about project description, county, project #, job piece #, letting date, etc. GUI is a collection of various objects such as textboxes, labels, buttons and list boxes each performing a predefined allocated task. The following list is a brief description of functionality of each item on the form.

a. Search Project: This function searches the database to find existing projects that match any given search criteria such as Job Id, Project Description, County, etc. All the projects that satisfy the search criterion are retrieved and their names are displayed in the list box (see Fig 6.1).
b. List All Projects: When this function is activated, all the existing projects are retrieved and are displayed in the list box (see Fig 6.1).
c. Select Project: The above functions will display projects that satisfy the search criteria and this function opens the selected project from the list box (see Fig 6.1).
d. Save Project: In order to save any modifications made to any old/archived projects this function must be activated to overwrite the previous data in the project and stores this information in the database.
e. Make A Copy: When any modifications are made to any old/archived projects, this function stores the information under a new project name.
f. New Project: Opens a New Project with default values.
g. View Project Details: This opens a new form displaying the finer details of the project such as activity, duration, quantity, additional technical details etc.
h. Export Project: This transfers all the activities, sub activities and their durations into a Microsoft Project file and displays the Gantt bar chart.

i. Print Preview: Creates a report of the project an opens it in the print preview format

j. Print Project: Prints the project.

6.1.2 Back End:

The back end of the application is MS Access database consisting of four tables, namely Project_Data, Project_Header_Data, Template_Name, Project_Template_Data. Tables Project_Data and Project_Header_Data store the project information whereas Template_Name and Project_Template_Data tables store the template information. The information is stored in the tables as record entries. Every table has a primary key that uniquely identifies a record (row). The ODOT database is normalized so as to avoid data redundancy and maintain the data integrity. Normalization is the process of organizing data in a database by establishing relationship between tables so as to efficiently store data. There exists relation between the tables. Each table is connected to another table through a common key (data field). A database schema illustrating the relations between various tables is shown in Fig 6.2.

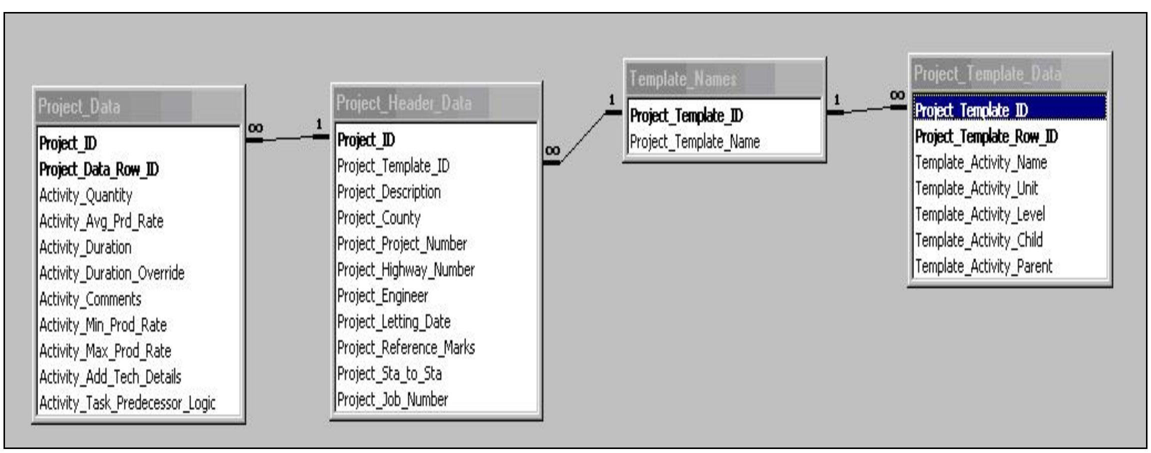

Fig 6.2: Relation between Various Tables in the Database.

The database is so designed that the data is not redundant and repetitive. For example, the template information such as template names, activities, sub activities in a given template, units etc are not required to be copied multiple number of times as they remain the same for all the templates. Template_Data and Template_Header_Data store this information. Whereas all the data items that are repetitive like durations, quantities and additional technical details are stored in the tables Tables Project_Data and Project_Header_data. When a new project is created or an old one is saved with new name, new records are inserted in these tables. This allows for storage and retrieval of multiple projects in en efficient manner.

6.2 Data Flow Diagram:

A data flow diagram is a graphical representation of how the data and information flows within the system. It describes the data storage, external entities, data flows, functional and control transformations. The data flow diagram can be used to provide the end user with a physical idea of where and how the data travels within the system and how it affects the whole system. Fig 6.3 shows the data flow diagram for Ok-CTDS tool.

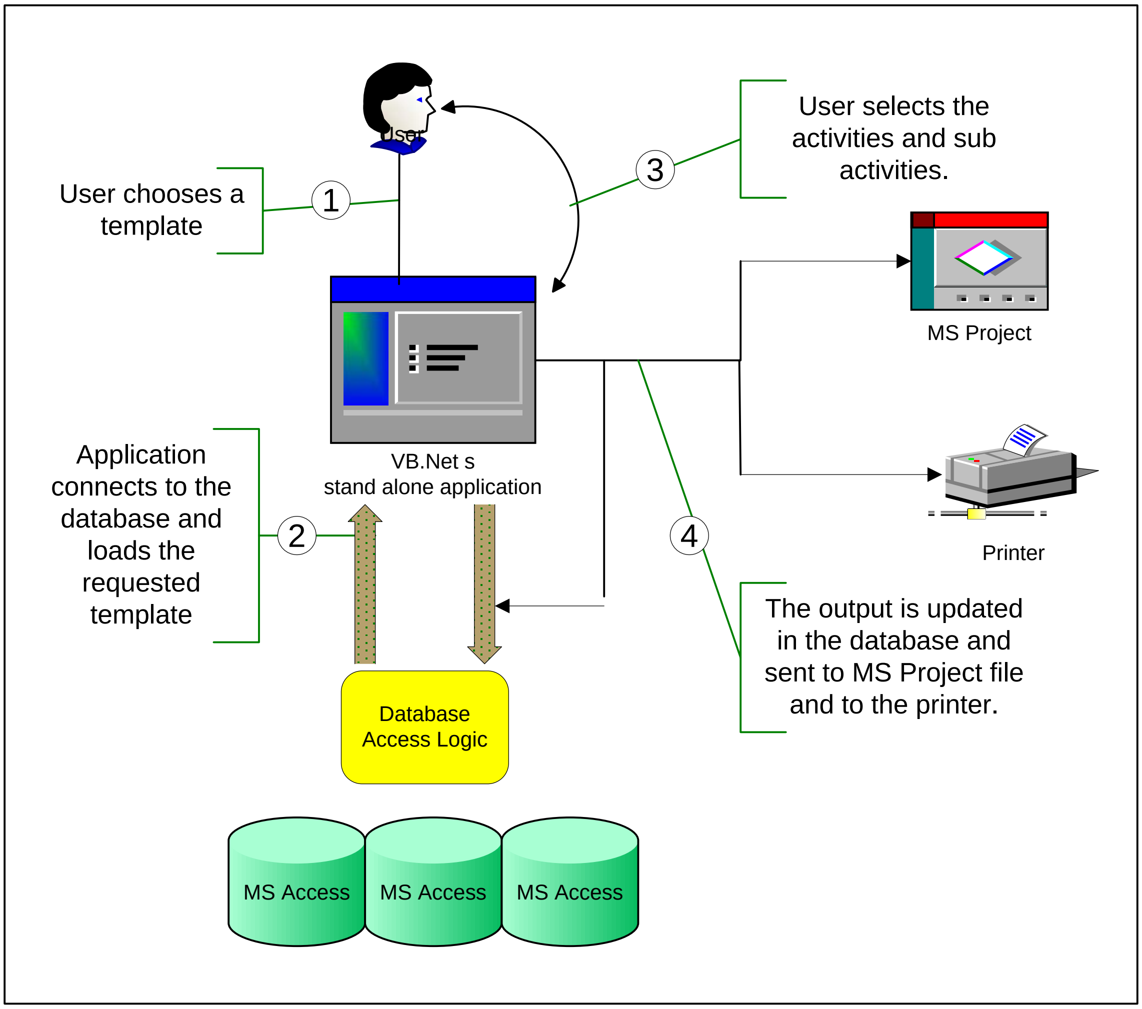

Fig 6.3 Schematic Representation of Process Flow

The whole system can be viewed as number of tiers stacked upon one another. At the lowest level, there is a database that has database access logic. The middle level has a VB.Net application that connects to the database through ADO.Net components. ADO.Net provides an object library for data access and it comes with Microsoft .Net Framework. At the highest level there is a user who communicates with the application using a GUI.

The process starts with a user loading the application and choosing a template to load. The flow of control initially starts out from the front end of the software by an event driven action such as a button click, it then gets transferred to the classes that act as interface between the front end and the back end of the software. VB.Net application connects to the database in order to respond to the user's requests. The classes communicate between the forms and database. The classes also have an important role of handling the transfer and storage of the data in an efficient manner. The classes, depending on the user input or user query, searches the entire database with the query as its search criterion. It then collects the data from the database, sorts it and then processes it. This processed data is then handed back to the form which then visually represents it on the user's screens. After carefully choosing the modules and their controlling activities, the user is able to calculate the duration for each of them. The user then needs to export the project and it is saved as a Microsoft Project file. This allows the user to get a CPM network diagram of the project along with the total project duration. The data is also sent to the printer for printing job.

The application uses the Component Object Model (COM) to create an instance of MS Project. COM defines a standard for component interoperability and is platform independent. COM enabled software can use the underlying services of other COM enabled software. In ODOT project, the .Net application is using the services of MS Project by creating an object of MS Project and instantiating it with the data created by the application.

The entire process is described in detail in the flow chart as shown in Fig 6.4 which gives a schematic representation of the algorithm that a process follows.

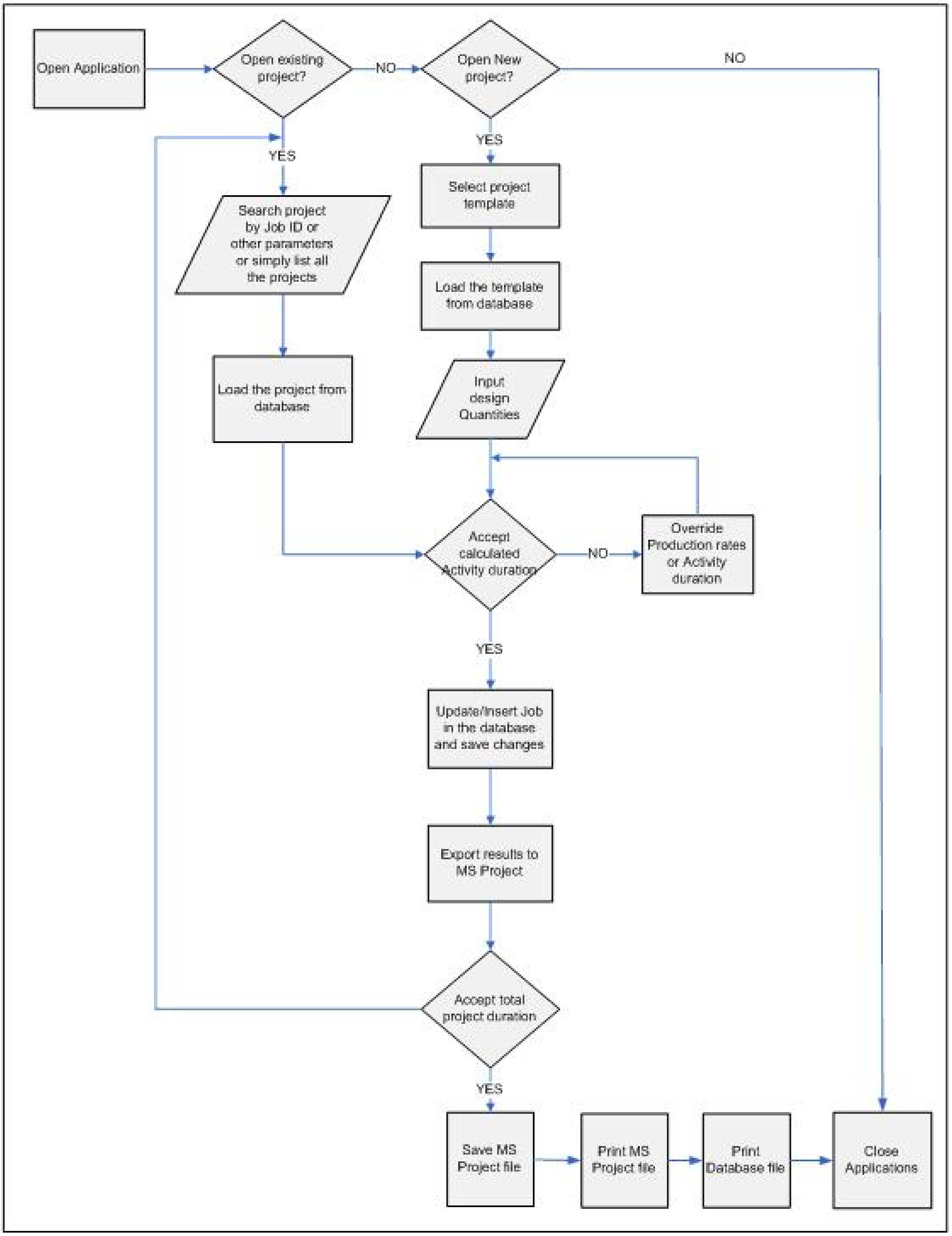

Fig 6.4 Process Control Flowchart of the Software

The software application is launched by clicking on the executable file. A VB.Net form opens up on the screen. The GUI prompts the user to make a selection. A user can create a new project, search and view for an old project for modification or verification purposes, or make a copy of an existing project which allows the user to make changes to it and saves as a different project.

On selecting the new project option, the user is prompted to choose a template that best suits the project. The user then needs to provide relevant project information including such as Project name, Job Id Number, etc. After this, the chosen template is loaded from the database and the default values for that template appear on the screen. The user then needs to input design quantities for each controlling activity listed in the selected template and based on the quantities entered and the production rates selected, duration for each activity is evaluated and any deviations or changes are documented in the comments field. The user has the ability to override the quantities and the production rates by entering directly durations in the duration override field.

After calculating the activity durations, the user then exports the project to Microsoft Project which provides a diagrammatic representation of the entire project with total duration in calendar days. The user can make changes and modify the pre-established logic to derive a different project duration based on the project characteristics and constraints. If unsatisfied with the durations calculated, the user needs to go back into the application, search for the project in consideration and re-evaluate the entered information to recalculate the desired duration. Once satisfied with the calculated project duration as well as the project schedule, the user can then print both these outputs for documentation purposes and finally close the application.

6.3 Software Run:

This section provides a software walk through of the ODOT application. A step-by-step procedure to estimate the contract time is illustrated using an example. The project details and values used in this example are assumed values and are used solely for software demonstration purposes.

ODOT application can be installed by executing the set up files. A set up goes through a series of steps and makes the application ready for use. The minimum system requirements for running this software are:

1. Microsoft Windows 98 (2nd Ed)/2000/NT/XP
2. Microsoft Office 2000 and up
3. Microsoft Project Professional 2000 and up
4. Microsoft .NET Framework SDK (Software Development Kit) 1.1 or higher
5. 128 MB RAM
6. 30 MB Hard Disk Space for installation
7. Minimum display settings: 1024 by 768 pixels
8. Installed printer

6.3.1 Launching the Application:

The user can launch the application by double clicking the Odot_1.0 icon. The set up saves a shortcut to ODOT application on the desktop by default. Another way to launch the application is to click on start menu, go to programs and select Odot_1.0 application. On launching the application, a popup screen appears (see Fig 6.5). The user needs to select the odot_data file and open it.

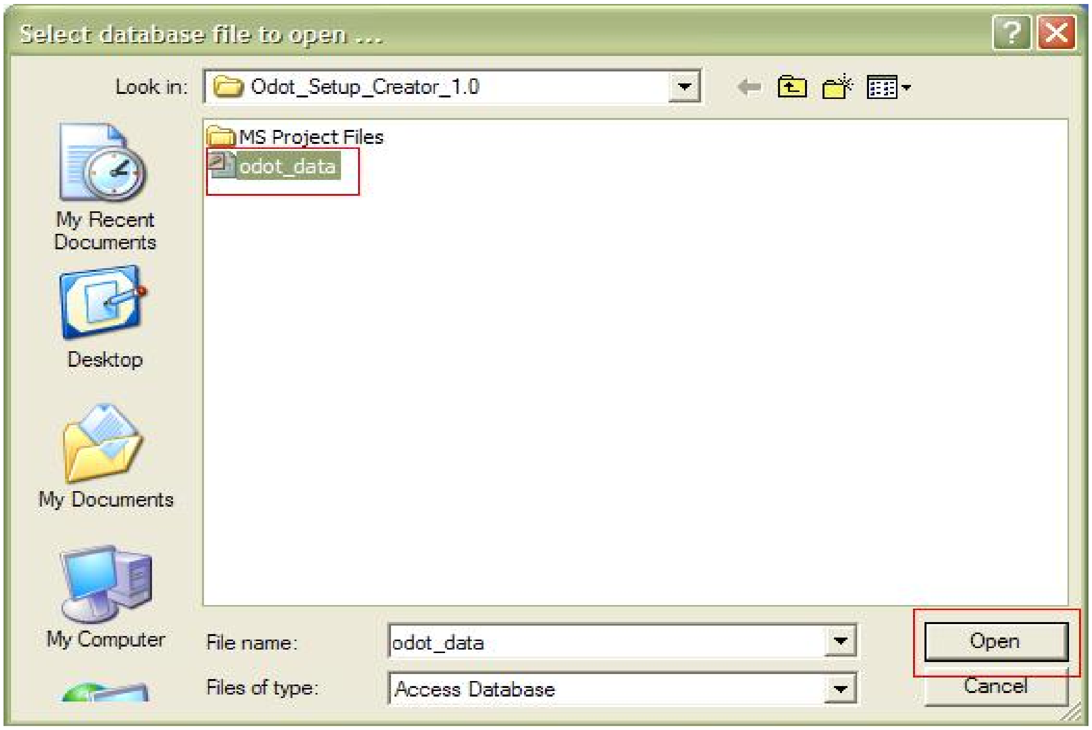

Fig 6.5: Opening Database File

6.3.2 Project Header Screen:

On selecting the ODOT database file, a project header screen opens up as shown in Fig 6.6. This is the main screen of the software and it is from here that the user may either search for past projects or start a new project. Other functions of the software such as print preview, printing and exporting project information to Microsoft Project can also be accessed from this screen. In our sample example, we will create a new project by clicking on the "New Project" button.

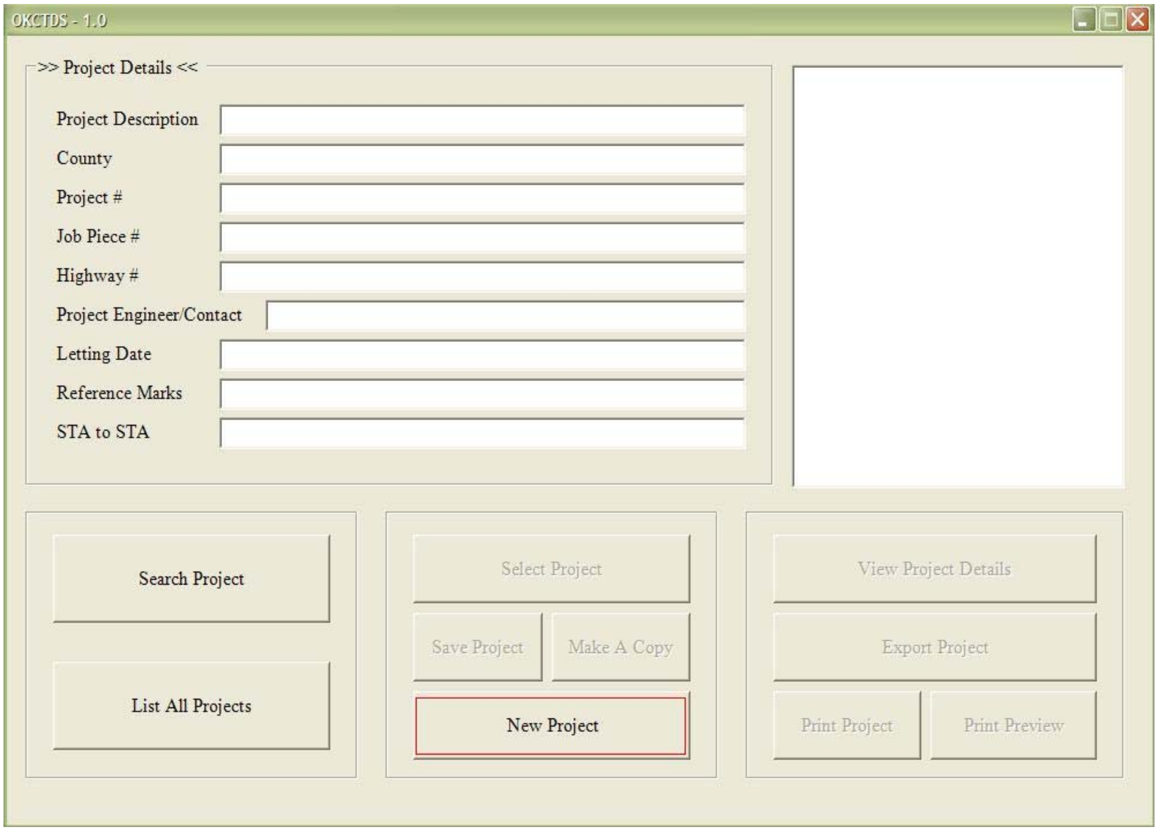

Fig 6.6: Project Header Screen

6.3.3 New Project Selection:

Once the "New Project" button is clicked, a screen pops up, as can be seen in Fig 6.7, which provides the user with a selection of templates available to select. The screen displays all the eight Tier II template classifications and a Tier I general template classification of ODOT highway projects. For this example, let us select Tier II - Template 2h: Roadway_Repair Overlay.

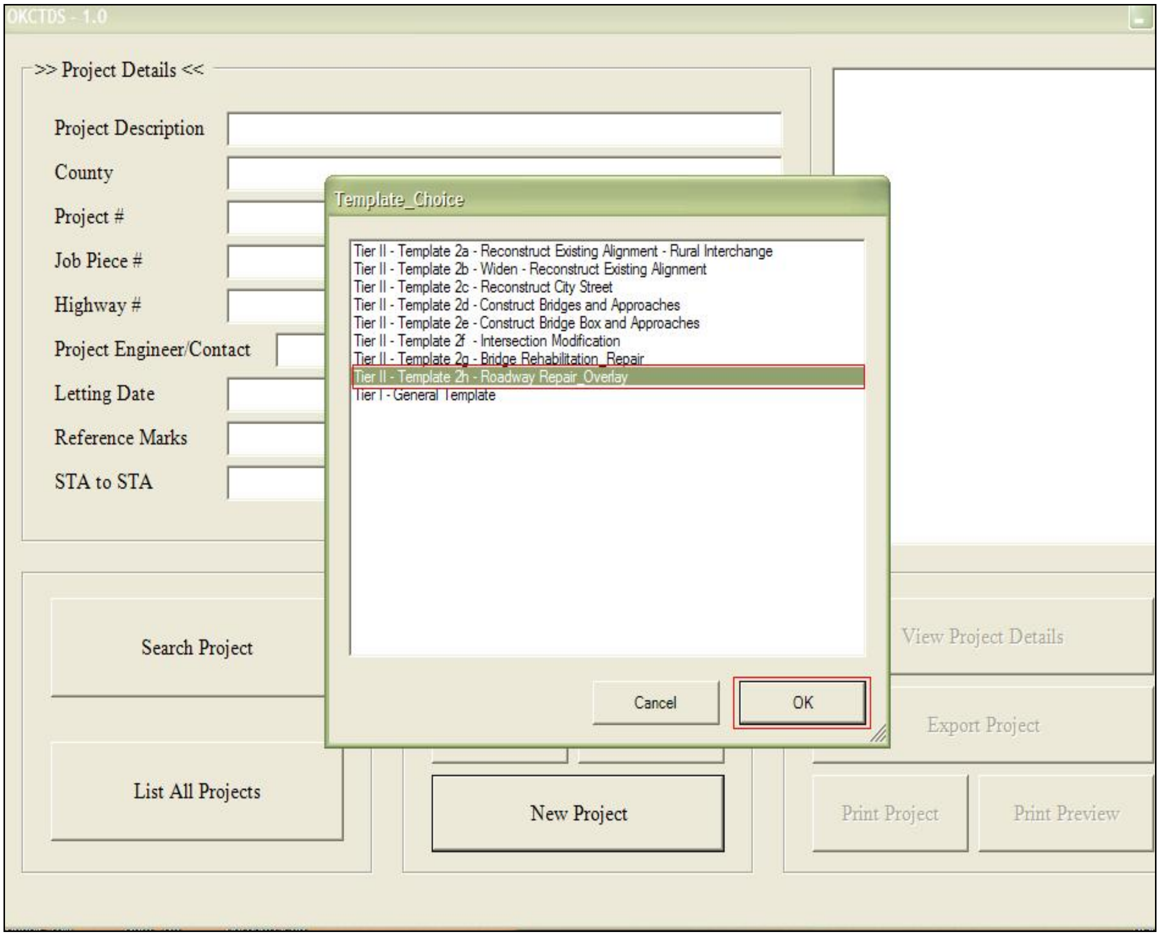

Fig 6.7: New Project Selection Screen

6.3.4 Project Detail Information:

Once the particular template has been selected, the control goes back to the project header screen wherein information related to the project such as Project Description, County, Project and Job Piece Number, etc., need to be entered (as shown in Fig 6.8). After entering all the relevant information, click on "View Project Details" button.

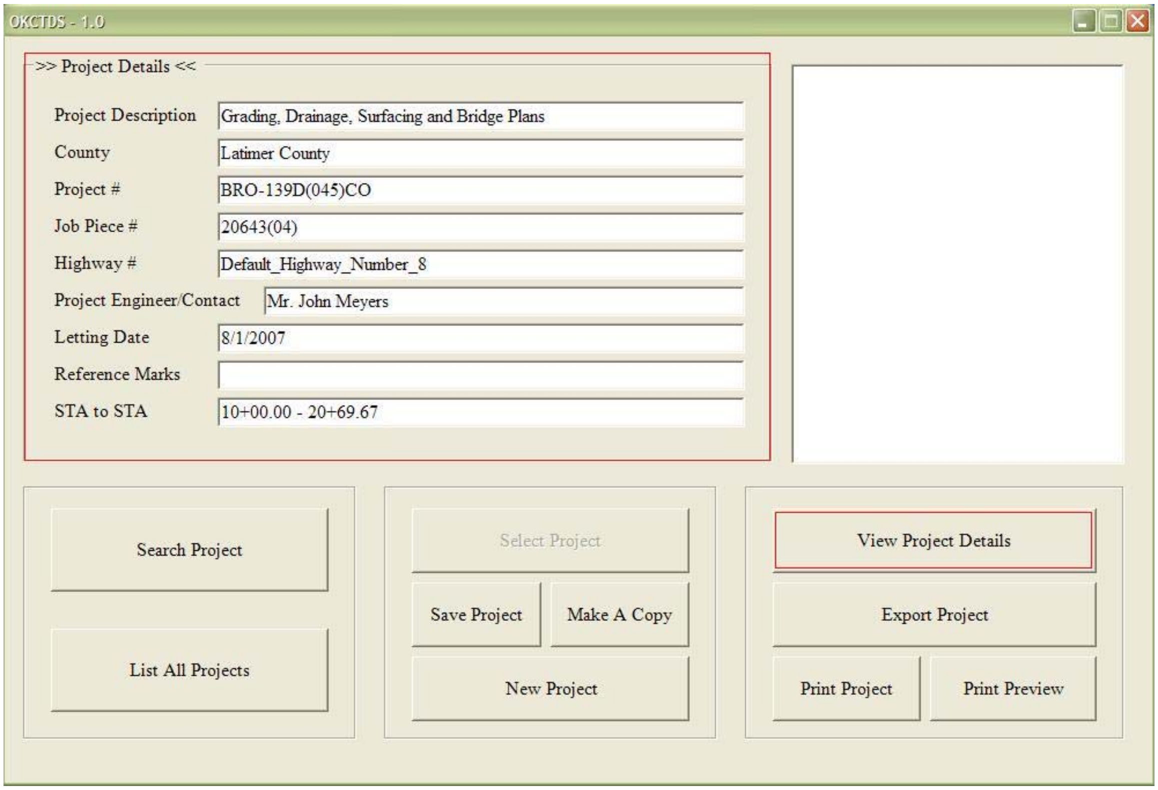

Fig 6.8: Project Information Screen

A new window opens up as can be seen in Fig 6.9. The left hand side of this window displays all the main activities (modules) in the template. The central area of the window displays the various sub-activities that are part of each main activity (module). The top right hand side of the window displays the area where activity details such as quantity, production rates and duration overrides can be entered. The main activities and sub activities section cannot be modified by the user. The only boxes editable by the user are the quantity, average production rates, duration overrides and the comments section. The user enters the different quantities for the different activities and on selecting a realistic production rate, duration is calculated in its respective box. If a different value is used instead of the average production rate and/or if values are entered in the duration override box, the user needs to document such changes in the comment box for easy traceability.

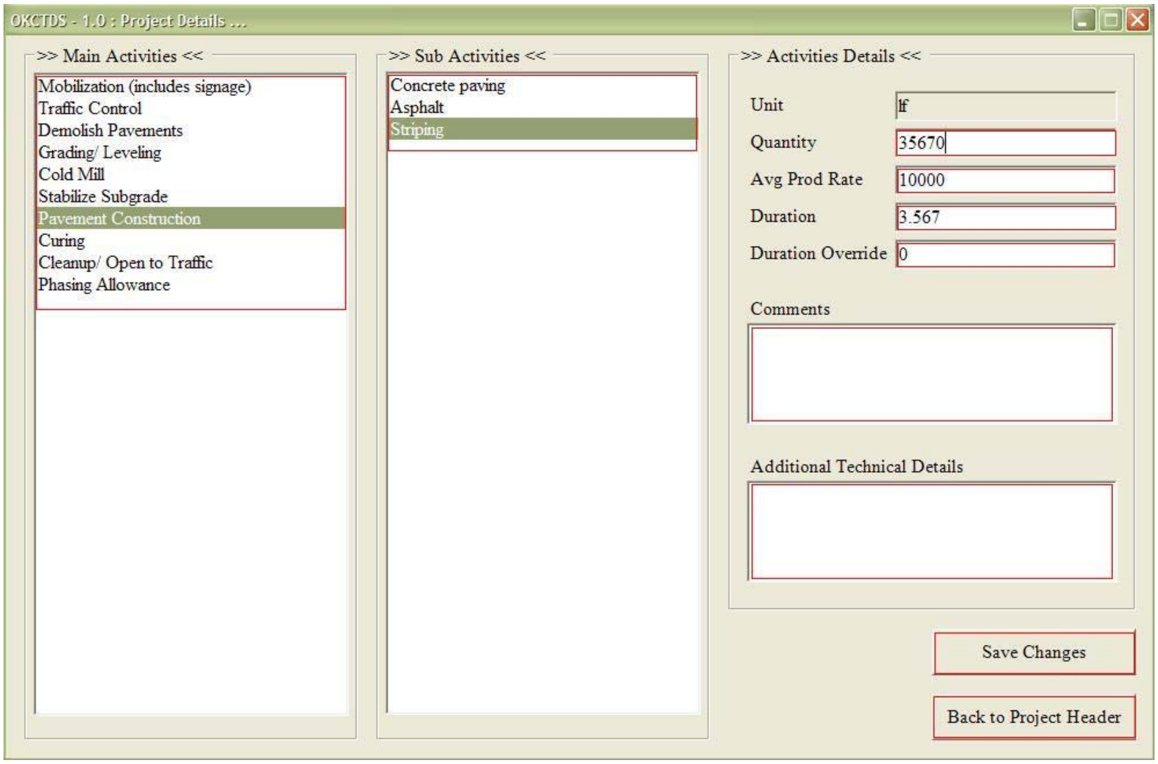

Fig 6.9: Detailed Project Information Screen

If based on the quantity entered and selected production rate for an activity, the calculated duration is not what is expected, the user has the option of either working around the range of production rates available for that activity to get the desired duration. If the activity can be given only a fixed amount of duration to complete, the user can directly enter the number of days in the duration override box and that duration will supersede the calculated duration.

Once all the information has been entered, the user needs to save all the information by clicking the “save changes” button and then selecting the “back to project header” button.

For this example, different assumed quantities and production rates are entered for each activity and sub activity so that the durations can be calculated. On entering all the requisite information, we need to select the “Save Changes” function to save all the information in the database and return back to the main header by selecting “Back to Project Header”.

6.3.5 Ok-CTDS Software – Support Functions:

After entering all the project details and their relevant information, the control goes back to main project header. The user can choose to print preview (as shown in Fig 6.10) to check if all the values entered are reasonable and realistic.

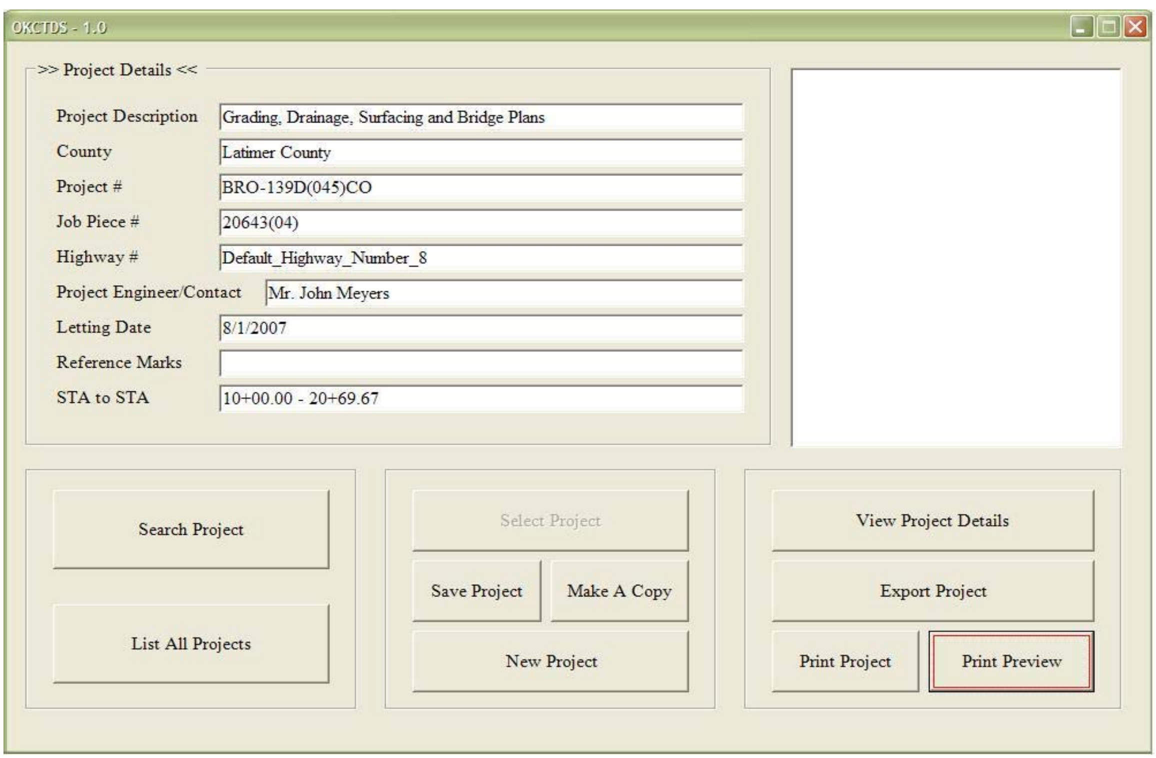

Fig 6.10: Software Command Functions

If any further modifications are necessary, the user needs to close the preview box and go back to view the project details and make those changes. If no modifications are necessary, the user may choose to print the document and return back to the project header. The print preview screen for our sample project is as shown in Fig 6.11.

Project Description : Grading, Drainage, Surfacing and Bridge Plans
County : Latimer County
Job Number : 20643(04)
Project Number : BRO-139D(045)CO
Highway Number : Default_Highway_Number_8
Project Engineer/Contact : Mr. John Meyers
Letting Date : 8/1/2007
Reference Marks :
STA to STA : 10+00.00 - 20+69.67

S.N	Critical Activities	Unit	Quantity	Avg Prod Rate	Duration	Duration Override	Comments
1	**Mobilization (includes signage)**	days	0	3	0	4	
2	**Traffic Control**		0	0	0	0	
	Median Barrier	lf	20000	900	22.22222	23	
3	**Demolish Pavements**	sy	50000	2000	25	0	
4	**Grading/ Leveling**	sta	400	30	13.33333	14	
5	**Cold Mill**	days	0	0	0	1	
6	**Stabilize Subgrade**	sy	50000	2100	23.80952	25	
7	**Pavement Construction**		0	0	0	0	
	Concrete paving	sy	0	1250	0	0	
	Asphalt	tns	5000	1100	4.545455	7	

Fig 6.11: Print Preview Screen

After printing the document, the user needs to then click on the "Export to Project" button. This command exports selected details that has been entered by the user and certain data from the database to Microsoft Project, which helps to diagrammatically represent the project using the critical path method approach as shown in Fig 6.12 and also to calculate the total project duration in calendar days.

Part of the data that is exported from the database involves the pre-established activity logic. Based on the project scope and approach used to construct the project, the user can modify the activity logic in Microsoft Project (the predecessor column) to suit project conditions and get an updated total project duration which is calculated in calendar days.

It should be noted that Microsoft Project has certain default setting options such as calendar, hours per week of work, public holidays, etc. All these options play a role while the software calculates the time required for specific projects. The user needs to keep in mind to also modify these options, if required.

After exporting our sample project to MS Project, we get the following schedule as shown in Fig 6.12.

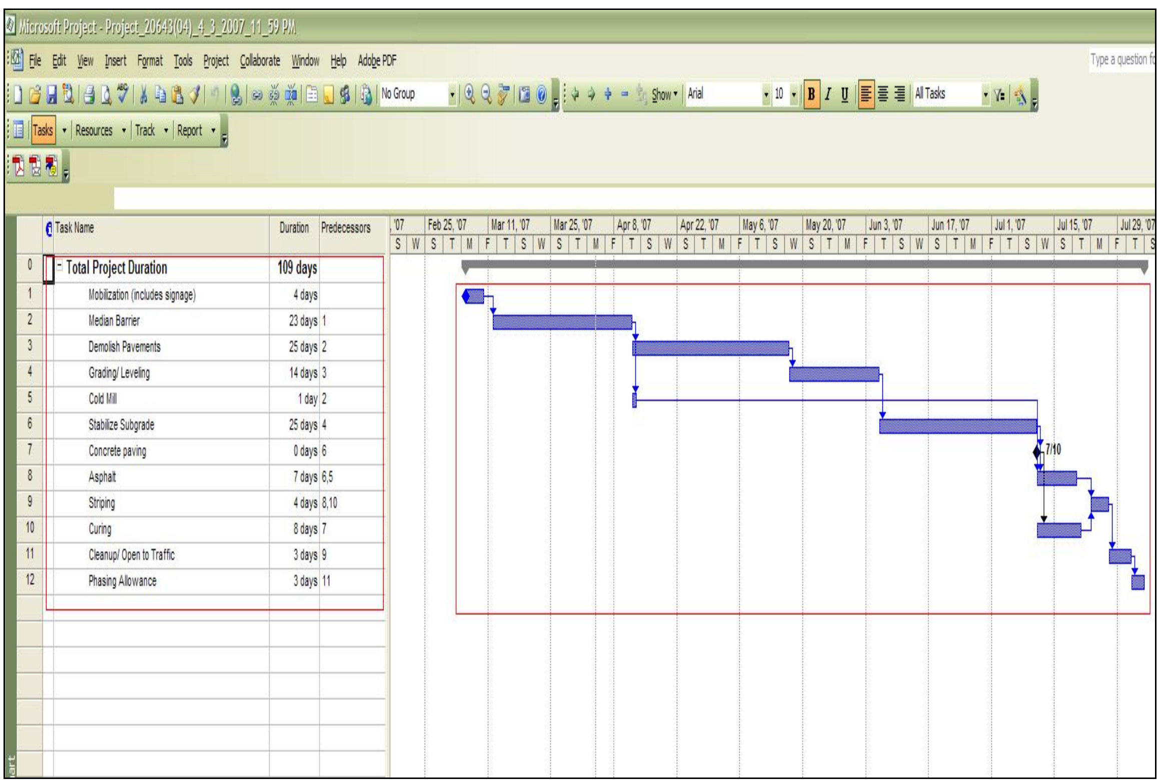

Fig 6.12: Total Project Duration and CPM Network Diagram in Microsoft Project

Based on the assumed values entered for the roadway repair overlay project, total project duration of 109 calendar days has been calculated. This calculated duration may need to be reviewed by an experienced engineer before letting it out for bidding.

6.4 Summary:

The Ok-CTDS software enables the user to calculate and estimate contract time for highway projects in a manner similar to the manual process. Being automated, it has certain benefits of being user friendly, easy to install, faster process than the manual method, easy to modify and incorporate changes, smoothness in developing the deliverables and easy to print out the results.

CHAPTER VII

CONCLUSIONS

7.1 Summary:

The study identified the best practice approaches to contract time estimation, evaluated current methods, and developed a manual system for estimating contract time and a software application that automates the manual process of time estimation. The literature review identified the various methodologies and techniques currently being used by various states and research agencies to determine realistic contract times for highway projects. They include using historical data, CPM/bar charts, production rate charts, engineer's experience and innovative methods such as A+B, incentive/disincentive methods, etc. Various factors were identified which effect the contract time. They include weather and seasonal effects, project location, traffic conditions, utility relocation, soil conditions, letting time, night/weekend work, environmental factors, resource availability, permits and legal factors. These factors need to be taken into consideration while estimating contract time for highway projects.

The DOT survey indicated that the most common method used for time estimation was hand calculations along with experienced engineer's opinion (39.1%). But those who responded using this method also reported a high percentage of projects finishing late (15.4%) and attributed the delay to inaccurate contract time estimation. Four states reported that they used computer programs with experienced engineer's opinion (17.4%) to estimate contract time, but they also have attributed inaccurate contract time for project delays (31%).

The method gaining popularity among many DOT's was found to be using standardized templates along with hand calculations and experienced engineer's opinion (13%). These DOT's also reported that projects that did finish late were not attributed to inaccurate contract time estimation but to reasons such as extreme weather conditions, extra work, utility relocations, etc.

Eight Tier II templates and one Tier I general template were developed as part of the Oklahoma Contract Time Determination System (Ok-CTDS). Each Tier II template consists of a number of controlling activities which are logically sequenced and sorted under various modules. The timely completion of a set of controlling activities implies successful completion of that specific module. Once all project controlling activities were identified and listed, production rates were developed for each of them. Default production rates in ranges (min, avg and max) were generated for each controlling activity using experienced engineer's opinion and historical data. These values proved to be reasonable by comparison with contractors and RS Means Cost Data rates. The users when trying to generate production rates for individual controlling activities would need to factor in project characteristics and constraints such as soil conditions, weather, traffic conditions, project location, etc to modify the default production rates and obtain reasonable and realistic values.

Pre-established logical relationships that defined each controlling activity were then developed based on CPM logic. This schedule forms a basis for the user to again incorporate project specific characteristics and constraints such as project type, size, location, complexity, etc to calculate contract time for highway projects. Activity logics are defined using simple finish-start logic and exclude using complex relationships such as, leads and lags which are used in detailed time estimation. The validation of the manual system was performed by contractors using recently completed projects indicated that the durations calculated using the manual system was within an acceptable range (±6%).

A standalone computer software was developed using VB.Net linked with Microsoft Access database and Microsoft Project for estimating contract time in working days. The database comprises of eight Tier II templates and one Tier I general template. All the controlling activities, their units, their default production rates and their pre-established activity logic were stored in the database. An important aspect of this software is the user friendly feature and the ease with which all controlling activities, their calculated durations and their pre-established logic for a specific template, can be flawlessly transferred to Microsoft Project.

7.2 Conclusions and Contributions:

Considerable research has been performed in the area of contract time determination by various states and research agencies. Different methods, procedures and systems have been developed to enhance the process of estimating time for highway projects. The Ok-CTD system is an advanced and improved system for estimating reasonable contract time for ODOT's Tier II type highway projects.

One area of improvement has been in the use of simple logic for defining relationships between the controlling activities, as compared to the complex logic relationships such as leads and lags used by the Texas and Kentucky contract time determination systems. The use of simple logic allows easy modification when conditions differ from those pre-established in the standardized templates. This would be of great benefit to novice and intermediate users to easily understand the logical flow of the work process and gain experience in the area of scheduling construction projects.

Another major advancement is in the development of the standalone computer application. Unlike the computer programs developed for Texas and Kentucky which are partially automated, the Ok-CTDS is completely an automated application. The application uses VB.Net linked with Microsoft Access database and Microsoft Project for estimating contract time in working days. Once the users provide the estimated quantities and production rates for the controlling activities, the software automatically calculates the durations for each activity, stores them in the database, prints the output for documentation purposes and flawlessly transfers relevant data to Microsoft Project to schedule and determine contract time of the project, all by just selecting appropriate functions in the software. At no point, does the complex process that happens in the back end of the application undermine the user-friendly ability of the software. With these advanced features, the system is also flexible enough accommodate wide range of projects and conditions undertaken by ODOT

The output of this study provides ODOT with a structured approach to determine contract time for Tier II type highway projects. This system will allow ODOT schedulers to expedite the contract time estimation process without sacrificing or hurting the accuracy and the quality of the estimate. This system also forms a basis for better planning and sequencing of activities, provides documentation for a stronger defense in contract time disputes and allows less experienced ODOT personnel to gain confidence as they learn how to consistently estimate reasonable and realistic contract times.

7.3 Recommendations for future work:

There are certain limitations associated with this study which need to be discussed. The process of generating reasonable production rates in this system has some inconsistency because it still relies on experienced engineer's opinion which is largely judgmental and subjective. Due to this, engineers with less experience will not be in a good position to estimate reasonable contract time.

Simple activity logics are used in this study to define the relationships between the controlling activities which allow the user to calculate reasonable contract time and also allow the flexibility to modify and update the logic when required. The developed activity logic may still have certain activities which can be performed concurrently thereby not adding on to the contract time. Such activities and their logic need to be always identified while estimating contract time.

Based on these weaknesses, recommendations are being proposed to improve/ and enhance the contract time determination system.

1. A mechanism needs to be established to collect and analyze the production rate data from construction projects to modify and upgrade the existing production rates. Like the Texas HyPRIS system, ODOT needs to develop a database system that would store production rates for all their controlling activities including factors that affect them under varying site conditions. Based on statistical

analyses, formulas need to be derived which assist the users in using the database system to generate project specific production rates.

2. Various factors that affect production rates need to be studied and analyzed to develop adjustment factors which would assist CTD users to modify their production rates.
3. A CTD system can be developed to assist ODOT in estimating contract time for fast track, highly complex projects (Tier I type). The system would contain an exhaustive database of production rates, detailed procedures to estimate realistic production rates along with adjustment factors that need to be incorporated during estimation, and complex activity logic defining the controlling activities with the flexibility to modify and update them.
4. Research is recommended to establish a system that would allow the CTD user to estimate and predict the total cost of the project along with estimating the contract time.

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APPENDICES

APPENDIX A

QUESTIONNAIRE FOR DETERMINATION OF CONTRACT TIMES BY DOTS

Name: ______________________________ Date: ______________
Address: ____
Phone: __________ Email: ____________________ State: ________

---

1. What percentage of your state's construction projects finish late? ________%

2. Of these projects, what percentage is attributed to inaccurate contract time? ________%

3. How is contract time determined for a construction project in your DOT?

   Experienced engineer's opinion? Yes - ☐ No - ☐
   Computer program? Yes - ☐ No - ☐
   Handwritten standardized template? Yes - ☐ No - ☐
   Handwritten calculations? Yes - ☐ No - ☐
   Other method:
   ____

4. Does your current contract time determination system (or, process) provide desired results?
   Very Likely Yes - ☐ Fairly Likely Yes - ☐ Neither Yes/No - ☐ Fairly Unlikely No - ☐

   Very Unlikely No - ☐

5. Does your state make use of standard *published* production rates for each activity involved in a
   construction project, while determining contract times? Yes - ☐ No - ☐

6. If production rates are used by your state:

   Is there a known source for these production rates? Yes - ☐ No - ☐
   Is there a range of production rates or a single value? Range - ☐ Single - ☐

   How accurate do you feel these production rates are?
   Very Accurate - ☐ Moderately Accurate - ☐ Neither Accurate Nor Inaccurate - ☐
   Moderately Inaccurate - ☐ Very Inaccurate - ☐
   How often are these production rates updated?
   ____

7. If your state currently uses a computer program for determining contract time, which program is being used?

____

In your opinion, is this computer program user-friendly? Yes - □ No - □

8. Does your state utilize templates developed specifically for your state? Yes - □ No - □

If yes, please describe the templates (including number of templates, types of templates, and type of information on the templates):

____
____
____

9. What recommendations/suggestions do you suggest to improve the current contract time determination procedure, for your particular state?

____
____
____

10. May I contact you to learn more about your contract time determination process? Yes - □ No - □

11. What other factors would you attribute towards project that finish late? If possible, provide the percentage break-up for the same.

____
____
____
____

12. Please provide additional comments regarding contract time determination procedures.

APPENDIX B

TIER II TYPE HIGHWAY PROJECT TEMPLATES

Tier II: 2a - Reconstruct Existing Alignment/ Rural Interchange

S.N	Critical Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization**	days				
2	**Traffic Control & Detours**					
	Signs	days				
	Striping	lf				
	Barrier wall	lf				
	Pavements for detours	tons				
3	**Clearing and Grubbing**	days				
4	**Removals**					
	Removal of existing structures	sy				
	Excavate/ borrow Bridge Structure	sy				
5	**Grading - Top soil, excavation & embankment**					
	Unclassified Roadway Excavation/ borrow	cy				
6	**Sub Grade operations**					
	Soil Stabilization works (Lime/ Fly Ash)	sy				
7	**Drainage Structures**					
	Storm Drainage Piping	lf				
	manholes	EA				
	RCB's (Extend/install 4'x2', 3'x3', etc)	lf				
8	**Box Construction - Single or Multi Cell**					
	Slab (form, rebar, pour concrete)	sf				
	Walls/wings (form, rebars, pour concrete, strip forms)	sf				
	Roof Deck (form, rebar, pour concrete)	sf				
	Backfill at box	cy				
	Parapets, if required (form, rebar, pour concrete)	lf				
	Curing	days				
9	**Bridge Construction - Single or Multi Span**					
	Driving Piles	lf				
	Abutments (Rebars, Forming, Concrete)	cy				
	Drill/ Pour Piers					
	24" pier	lf				
	36" pier	lf				
	48" pier	lf				
	72" pier	lf				
	Form/ Pour Columns and Caps	cy				
	Beams (placing)	lf				
	Slab Decking (forming, rebars, concrete)	sf				
	Parapets (forming, rebars, concrete)	lf				

	Approach Slabs	sy				
	Curing	days				
10	**Base operations**					
	Agg base 10"	cy/day				
	Asphalt base/ fabric installation	tn/day				
11	**Surfacing Works**					
	Asphalt Type A	tn/day				
	Asphalt Type B	tn/day				
	9" PC	sy/days				
	10" PC	sy/days				
	Curing	days				
	TBSC	tn/day				
12	**Finish Grading/Shouldering**	sy				
13	**Guardrail installation**	lf				
14	**Permanent Signs/ Striping**	lf				
15	**Final Erosion Control**					
	riprap, filter blanket	tn/day				
	sodding	sy				
	mulching	acres				
	seeding	acres				
16	**Cleanup/ Open to Traffic**	days				
17	**Phasing Allowance**	days				

Tier II: 2b - Widen/ Reconstruct Existing Alignment

S.N	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization**	days				
2	**Traffic Control & Detours**					
	Signs	days				
	Striping	lf				
	Barrier wall	lf				
	Pavements for detours	tons				
3	**Clearing and Grubbing**	days				
4	**Removals**					
	Removal of existing structures	sy				
	Excavate/ borrow bridge structure	sy				
5	**Grading - Top soil, excavation & embankment**					
	Unclassified Roadway excavation/ borrow	cy				
6	**Sub Grade operations**					
	Soil Stabilization works (Lime/Fly Ash)	sy				
7	**Drainage Structures**					
	Storm Drainage Piping	lf				
	Manholes	EA				
	RCB's (Extend/install 4'x2', 3'x3', etc)	lf				
8	**Bridge Construction - Single or Multi Span**					
	Driving Piles	lf				
	Abutments (Rebars, Forming, Concrete)	cy				
	Drill/ Pour Piers					
	24" pier	lf				
	36" pier	lf				
	48" pier	lf				
	72" pier	lf				
	Form/ Pour Columns and Caps	cy				
	Beams (placing)	lf				
	Slab Decking (forming, rebars, concrete)	sf				
	Parapets (forming, rebars, concrete)	lf				
	Approach Slabs	sy				
	Curing	days				
9	**Base operations**					
	Agg Base 10"	cy/day				
	Asphalt Base/ fabric installation	tn/day				
10	**Surfacing Works**					

	Asphalt Type A	tn/day				
	Asphalt Type B	tn/day				
	9" PC	sy/days				
	10" PC	sy/days				
	Curing	days				
	TBSC	tn/day				
11	**Finish Grading/Shouldering**	cy				
12	**Guardrail installation**	lf				
13	**Permanent Stripping, Traffic signs**	lf				
14	**Final Erosion Control**					
	riprap, filter blanket	tn/day				
	sodding	sy				
	mulching	acres				
	seeding	acres				
15	**Cleanup/ Open to Traffic**	days				
16	**Phasing Allowance**	days				

Tier II: 2c - Reconstruct City Street

S.N	Critical Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization**	days				
2	**Traffic Control & Detours**					
	Signs	days				
	Striping	lf				
	Barrier walls	lf				
	Pavements for detours	tons				
3	**Clearing and Grubbing**	days				
4	**Removals**					
	Removal of existing structures	sy				
	Excavate/ Borrow Bridge Structure	sy				
5	**Grading - Top soil, excavation & embankment**					
	Unclassified Roadway Excavation/ borrow	cy				
6	**Sub Grade operations**					
	Soil Stabilization works (Lime/Fly Ash)	sy				
7	**Drainage Structures**					
	Storm Drainage Piping	lf				
	Manholes	EA				
	RCB's (Extend/install 4'x2', 3'x3', etc)	lf				
8	**Base & Curb operations**					
	Agg base 10"	cy/day				
	Asphalt base/fabric installation	tn/day				
	Pour Concrete Curb	lf				
	Curing	days				
9	**Surfacing Works**					
	Asphalt Type A	tn/day				
	Asphalt Type B	tn/day				
	9" PC	sy/days				
	10 " PC	sy/days				
	HES Drives	sy/days				
	Curing	days				
10	**Finish Grading/Shouldering/Sidewalks**	sy				
11	**Permanent Signs/ Striping**	lf				
12	**Electrical Lighting Works**	poles/ day				
13	**Signals Installation**	days				
14	**Final Erosion Control**					
	sodding	sy				

	mulching	acres				
	seeding	acres				
15	**Cleanup/ Open to Traffic**	days				
16	**Phasing Allowance**	days				

Tier II: 2d - Construct Bridges and Approaches

S.N	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization**	days				
2	**Traffic Control & Detours**					
	Signs	days				
	Striping	lf				
	Barrier Walls	lf				
	Pavements for detours	tons				
3	**Clearing and Grubbing**	days				
4	**Removals**					
	Removal of existing structures	sy				
	Excavate/ borrow bridge structure	sy				
5	**Grading - Top soil, excavation & embankment**					
	Unclassified Roadway Excavation/ borrow	cy				
6	**Sub Grade operations**					
	Soil Stabilization works (Lime/ Fly Ash)	sy				
7	**Drainage Structures**					
	Storm Drainage Piping	lf				
	Manholes	EA				
	RCB's (Extend/install 4'x2', 3'x3', etc)	lf				
8	**Bridge Construction - Single or Multi Span**					
	Driving Piles	lf				
	Abutments (Rebars, Forming, Concrete)	cy				
	Drill/ Pour Piers					
	24" pier	lf				
	36" pier	lf				
	48" pier	lf				
	72" pier	lf				
	Form/ Pour Columns and Caps	cy				
	Beams (placing)	lf				
	Slab Decking (forming, rebars, concrete)	sf				
	Parapets (forming, rebars, concrete)	lf				
	Approach Slabs	sy				
	Curing	days				
9	**Base operations**					
	Agg Base 10"	cy/day				
	Asphalt Base/ fabric installation	tn/day				
10	**Surfacing Works**					
	Asphalt Type A	tn/day				

	Asphalt Type B	tn/day				
	9" PC	sy/days				
	10" PC	sy/days				
	Curing	days				
	TBSC	tn/day				
11	**Finish Grading/Shouldering**	sy				
12	**Guardrail installation**	lf				
13	**Permanent Signs/ Striping**	lf				
14	**Final Erosion Control**					
	riprap, filter blanket	tn/day				
	sodding	sy				
	mulching	acres				
	seeding	acres				
15	**Cleanup/ Open to Traffic**	days				
16	**Phasing Allowance**	days				

Tier II: 2e - Construct Bridge Box And Approaches

S.N	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization**	days				
2	**Traffic Control & Detours**					
	Signs	days				
	Striping	lf				
	Barrier Wall	lf				
	Pavements for detours	tons				
3	**Clearing and Grubbing**	days				
4	**Removals**					
	Removal of existing structures	sy				
	Excavate/ borrow bridge structure	sy				
5	**Grading - Top soil, excavation & embankment**					
	Unclassified Roadway Excavation/ borrow	cy				
6	**Sub Grade operations**					
	Soil Stabilization works (Lime/ Fly Ash)	sy				
7	**Drainage Structures**					
	Storm Drainage Piping	lf				
	Manholes	EA				
	RCB's (Extend/ install 4'x2', 3'x3', etc)	lf				
8	**Box Construction - Single or Multi Cell**					
	Slab (form, rebar, pour concrete)	sf				
	Walls/wings (form, rebars, pour concrete, strip forms)	sf				
	Roof Deck (form, rebar, pour concrete)	sf				
	Backfill at box	cy				
	Parapets, if required (form, rebar, pour concrete)	lf				
	Curing	days				
9	**Base Operations**					
	Agg Base 10"	cy/day				
	Asphalt Base/ fabric installation	tn/day				
10	**Surfacing Works**					
	Asphalt Type A	tn/day				
	Asphalt Type B	tn/day				
	9" PC	sy/days				
	10" PC	sy/days				
	Curing	days				
11	TBSC	tn/day				
12	**Guardrail installation**	lf				
13	**Permanent Signs/ Striping**	lf				

14	**Finish Grading/Shouldering**	sy				
15	**Final Erosion Control**					
	riprap, filter blanket	tn/day				
	sodding	sy				
	mulching	acres				
	seeding	acres				
16	**Cleanup/ Open to Traffic**	days				
17	**Phasing Allowance**	days				

Tier II: 2f - Intersection Modification

S.N	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization**	days				
2	**Traffic Control & Detours**					
	Signs	days				
	Striping	lf				
	Barrier Wall	lf				
	Pavements for detours	tons				
3	**Clearing and Grubbing**	days				
4	**Removals**					
	Removal of existing structures	sy				
	Excavate/ borrow bridge structure	sy				
5	**Grading - Top soil, excavation & embankment**					
	Unclassified Roadway Excavation/ borrow	cy				
6	**Sub Grade operations**					
	Soil Stabilization works (Lime, Fly Ash)	sy				
7	**Drainage Structures**					
	Storm Drainage Piping	lf				
	Manholes	EA				
	RCB's (Extend/ install 4'x2', 3'x3', etc)	lf				
8	**Base & Curb operations**					
	Agg base 10"	cy/day				
	Asphalt base/fabric installation	tn/days				
	Concrete Curbs	lf				
	Curing	days				
9	**Surfacing Works**					
	Asphalt Type A	tn/days				
	Asphalt Type B	tn/days				
	9" PC	sy/days				
	10" PC	sy/days				
	HES Drives	sy/days				
	Curing	days				
10	**Finish Grading/Shouldering**	cy				
11	**Permanent Signs/ Striping**	lf				
12	**Electrical/ Lighting Works**	poles/day				
13	**Signals Installation**	days				
14	**Final Erosion Control**					
	sodding	sy				

	mulching	acres				
	seeding	acres				
15	**Cleanup/ Open to Traffic**	days				
16	**Phasing Allowance**	days				

Tier II: 2g - Bridge Rehabilitation/ Repair

S.N	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization**	days				
2	**Traffic Control**					
	Signage, Median Barrier, detour paving	lf/tns				
3	**Demo Bridge Structure**	days				
4	**Clean/ Handle waste**					
	Paint Structure	sf				
5	Repair Replace Beams	lf				
6	**Structural Steel**	lbs				
7	**Rehab Bridge**					
	Clean/ epoxy cracks	lf				
	Form slab, rebar, pour deck	sf				
	Class A, B or C bridge deck repair	sy				
	Pour concrete bridge rails/ parapets	lf				
	Pour approach slabs	sy				
	Set guard rails	lf				
	Curing	days				
8	**Roadway Construction**					
	Asphalt or concrete paving	sy or tons				
	Striping	lf				
	Curing	days				
9	**Cleanup/ Open to Traffic**	days				
10	**Phasing Allowance**	days				

Tier II: 2h - Roadway Repair/ Overlay

S.N	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Duration Override	Comments
1	**Mobilization**	days					
2	**Traffic Control**						
	Signage, Median Barrier	days					
3	**Demolish Pavements**	sy					
4	**Grade/ Leveling**	cy/sta					
5	**Cold Mill**	days					
6	**Stabilize Subgrade**	lbs					
7	**Pavement Construction**						
	Concrete paving	sy					
	Asphalt	tns					
	Striping	lf					
	Curing	days					
7	**Cleanup/ Open to Traffic**	days					
8	**Phasing Allowance**	days					

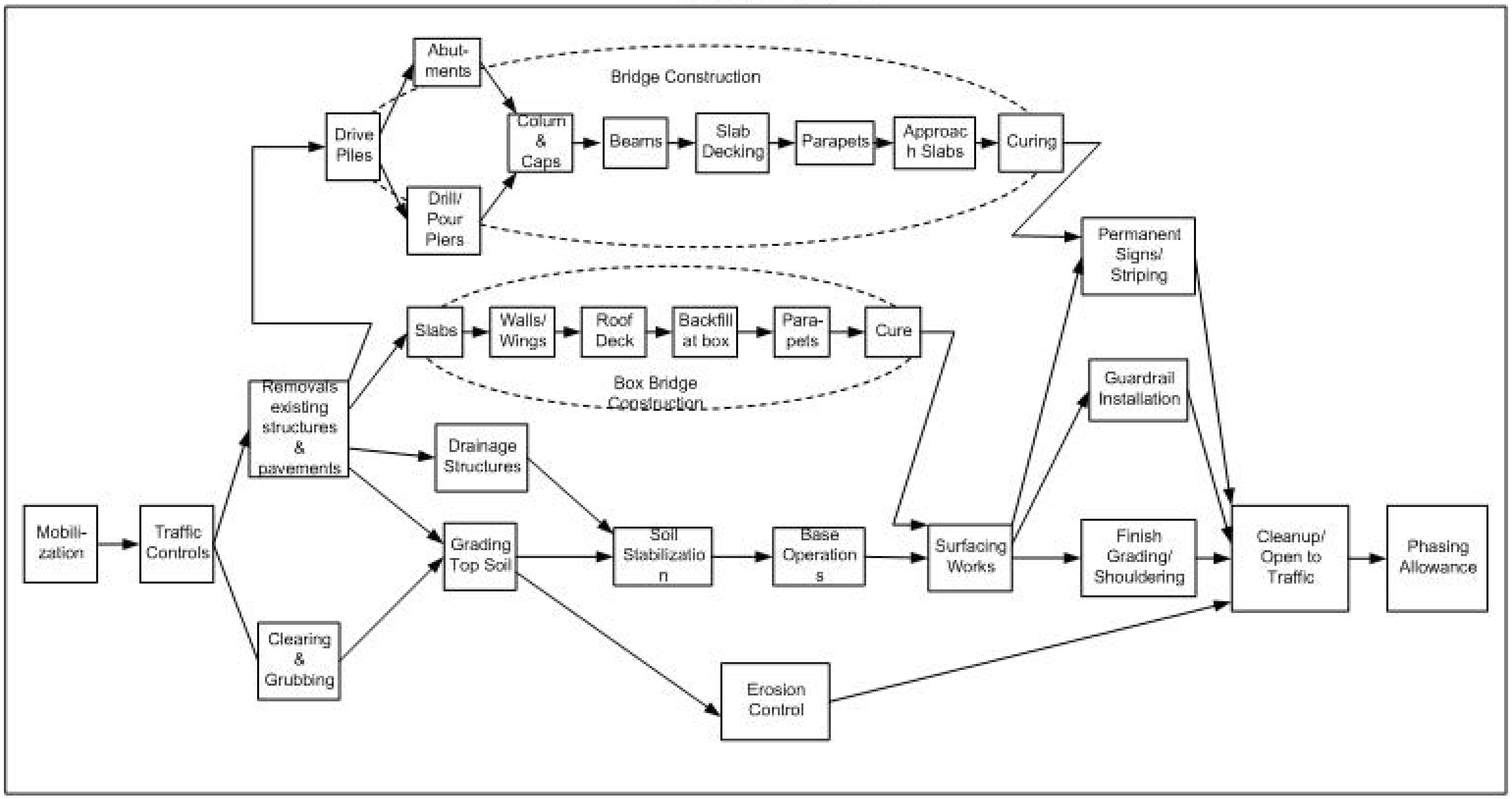
TIER I - GENERAL TEMPLATE

S.N	Critical Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	Mobilization	days				
2	Traffic Control & Detours					
	Signs	days				
	Striping	lf				
	Barrier Wall	lf				
	Pavements for detours	tons				
3	Clearing and Grubbing	days				
4	Removals					
	Removal of existing structures	sy				
	Excavate/ Borrow Bridge Structure	sy				
5	Grading - Top soil, excavation & embankment					
	Unclassified Roadway Excavation/ Borrow	cy				
6	Sub Grade operations (Soil Stabilizations Lime/Fly Ash)	sy				
7	Drainage Structures					
	Storm Drainage Piping	lf				
	Manholes	EA				
	RCB's (Extend/install 4'x2', 3'x3', etc)	lf				
8	Box construction (single or multi-cell)	EA				
9	Bridge construction (Single or Multi-Span)	EA				
10	Retaining Walls					
	Excavation & backfill	cy/day				
	Rebar	tn/day				
	Formwork	sfca/day				
	Conc pouring + cure	cy/day				
11	Base operations (aggregate base/ asphalt base/ fabrics/ Conc Curb)	cy/tn/lf				
12	Permanent Surfacing (Asphalt/ P.C Concrete)	tn/sy				
13	Finish Grading and Shouldering	cy				
14	Guardrail installation	lf				
15	Permanent Stripping, Traffic signs	lf				
16	Electrical/ Lighting works	days				
17	Signals Installation	days				
18	Final Erosion Control (Sodding/Mulching/Seeding)	ac/sy				
19	Cleanup/ Open to Traffic	days				
20	Phasing Allowance	days				

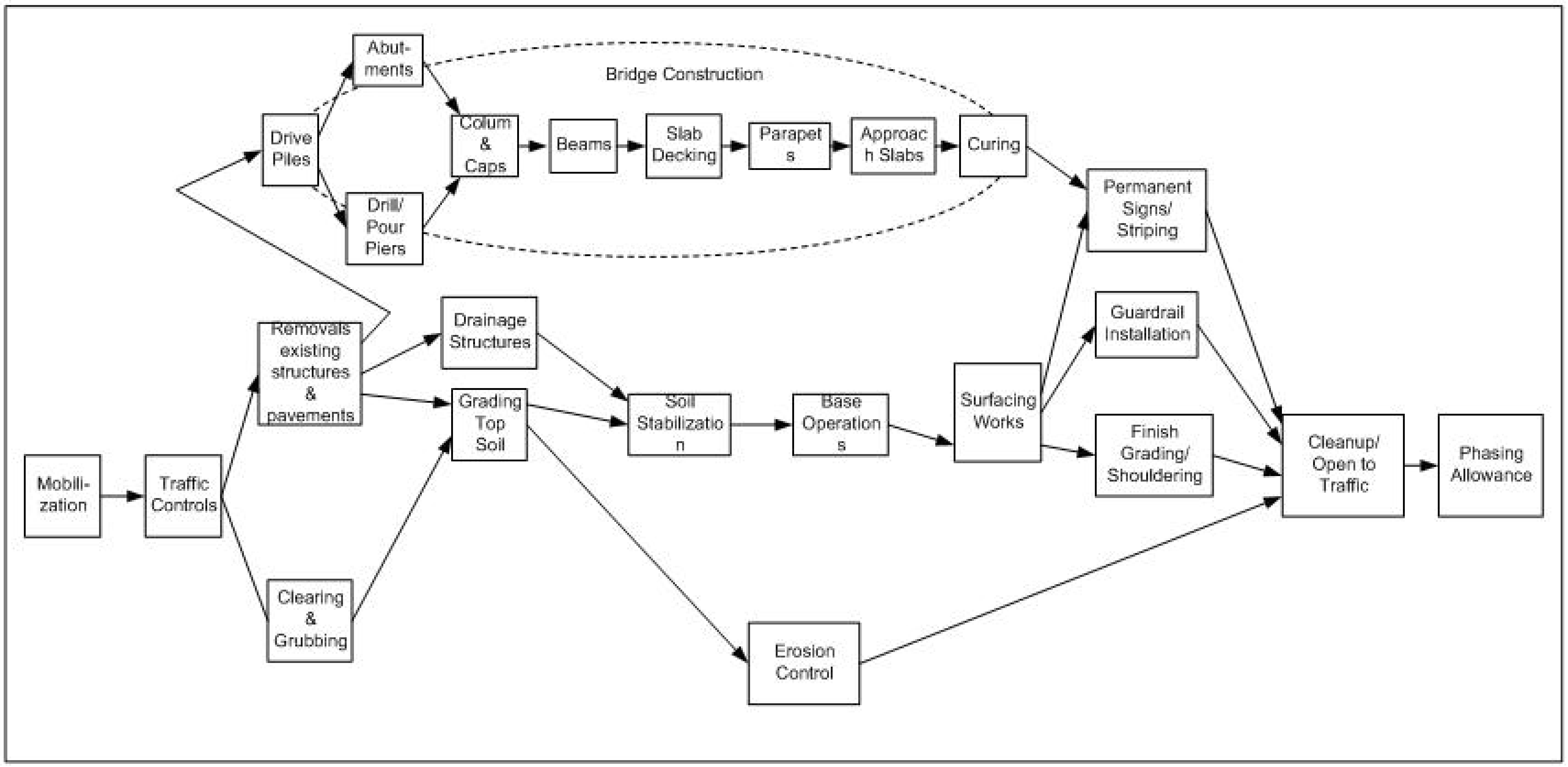
APPENDIX C

ACTIVITY LOGIC FOR TIER II TYPE HIGHWAY PROJECTS

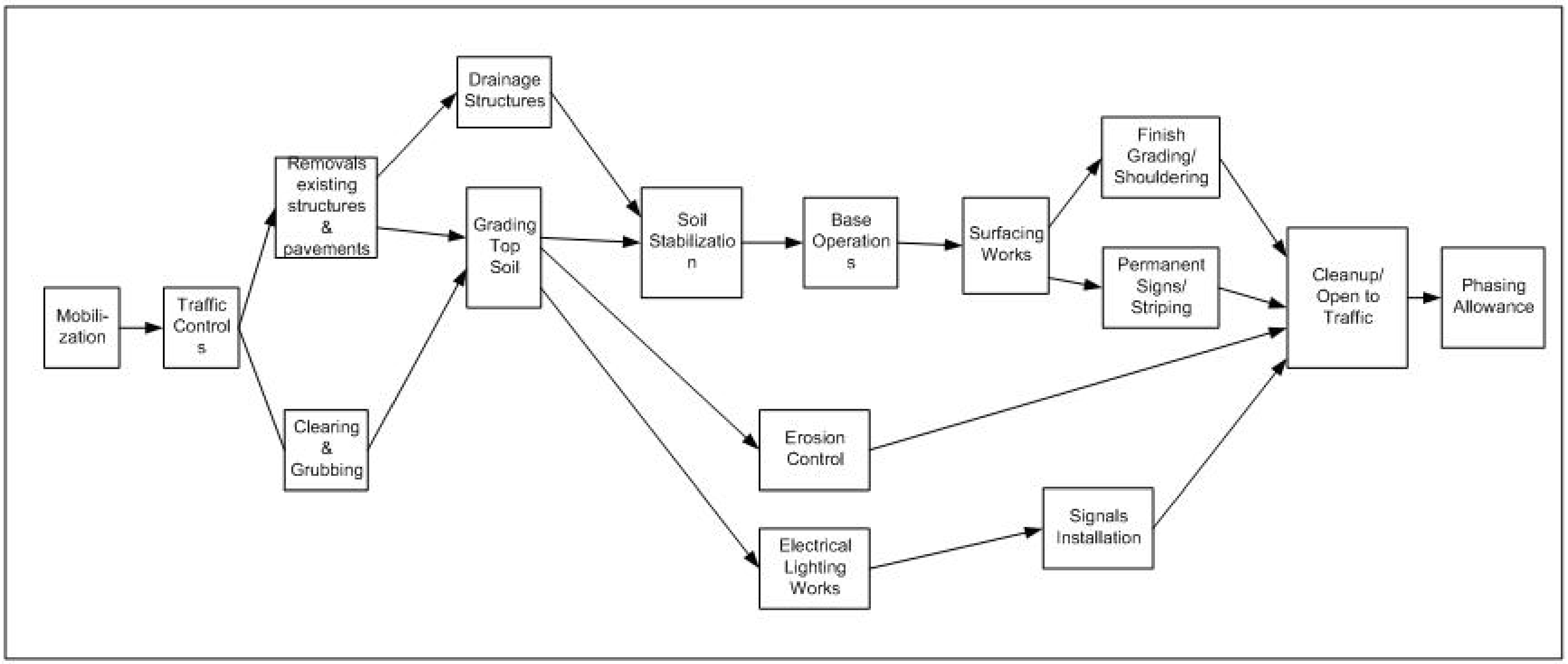
TIER II: 2a – RECONSTRUCT EXISTING ALIGNMENT/ RURAL INTERCHANGE



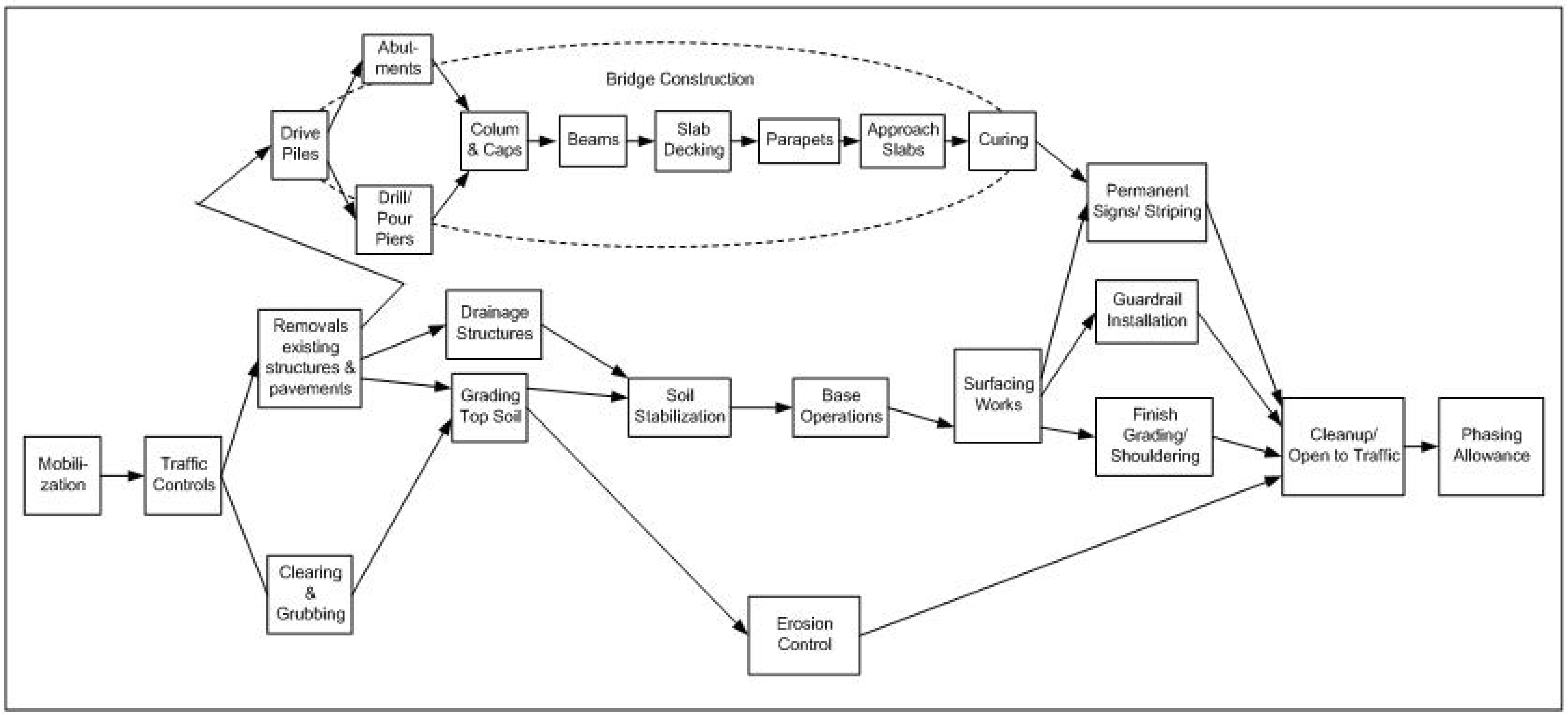
TIER II: 2b – WIDEN/ RECONSTRUCT EXISTING ALIGNMENT



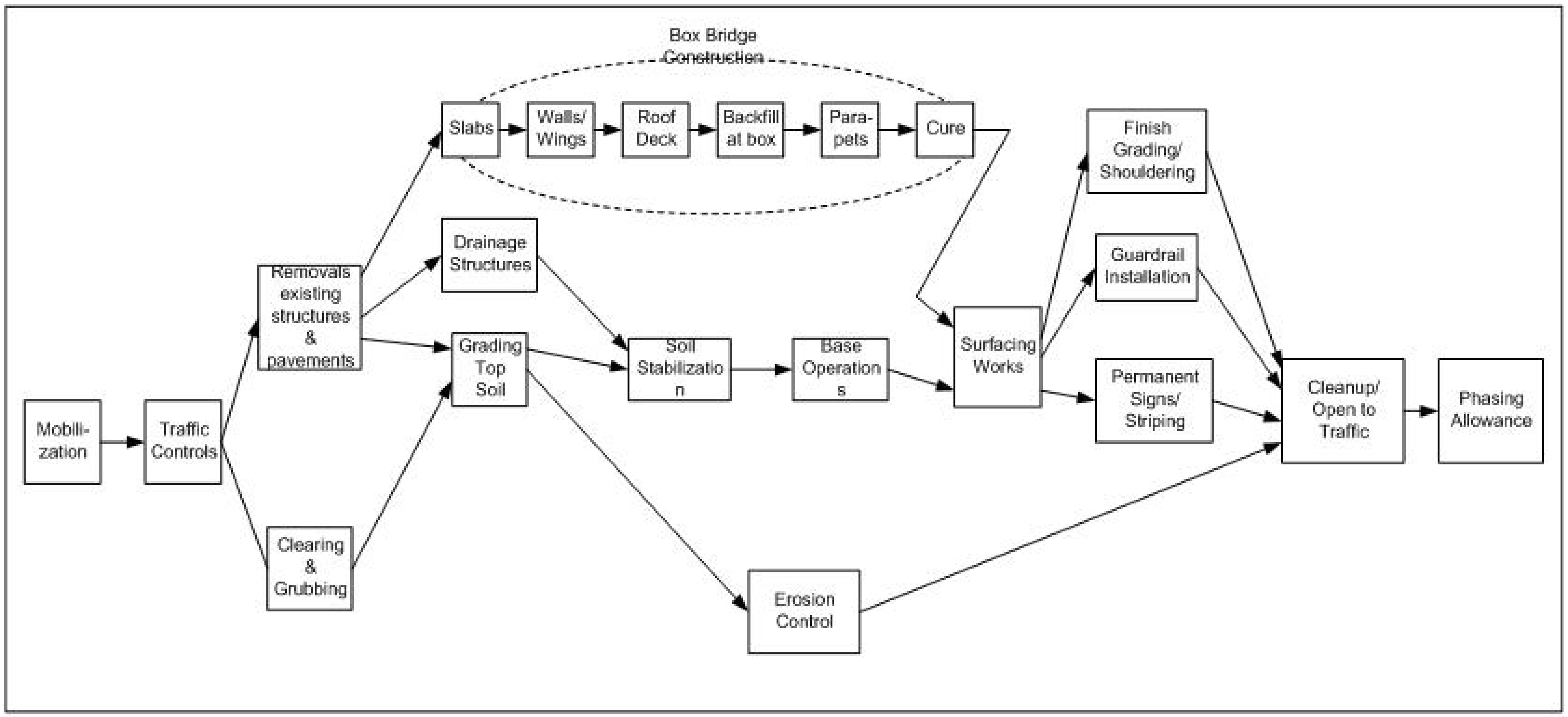
TIER II: 2c – RECONSTRUCT CITY STREET



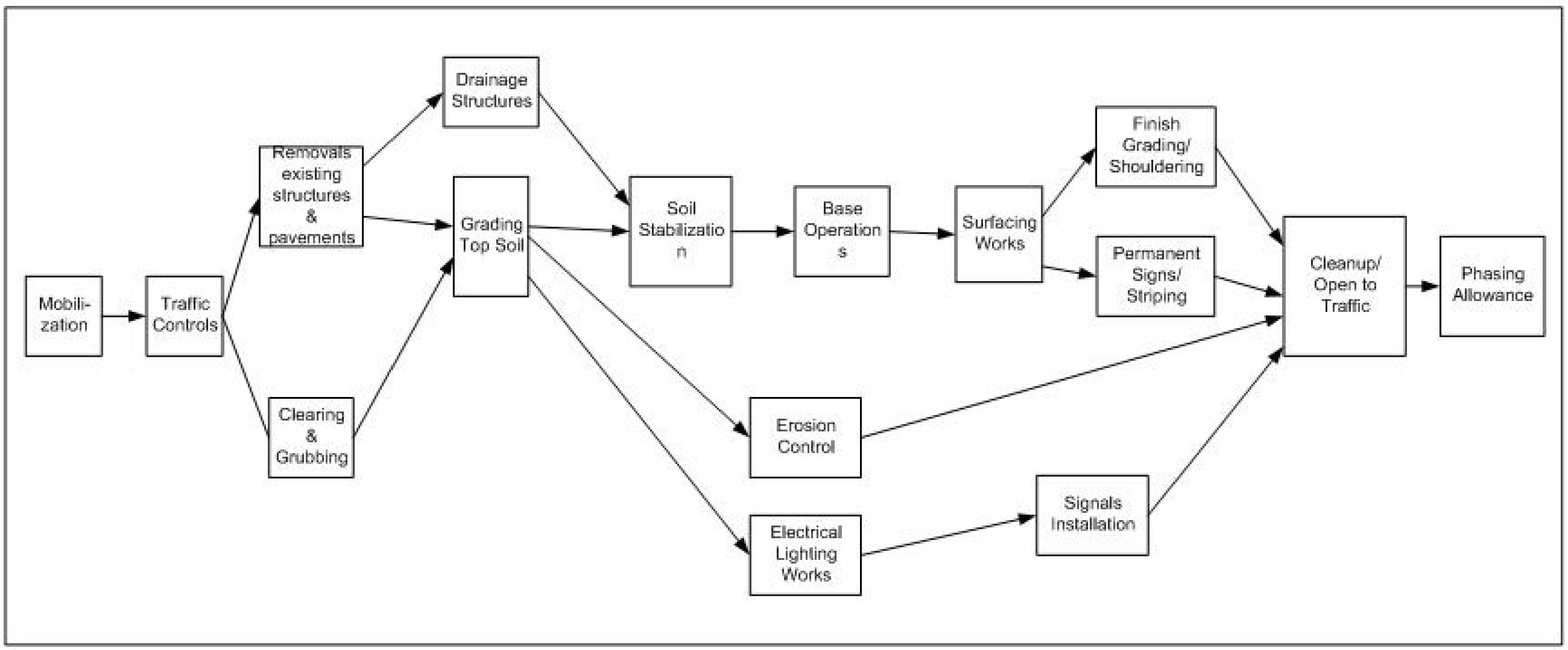
TIER II: 2d – CONSTRUCT BRIDGES AND APPROACHES



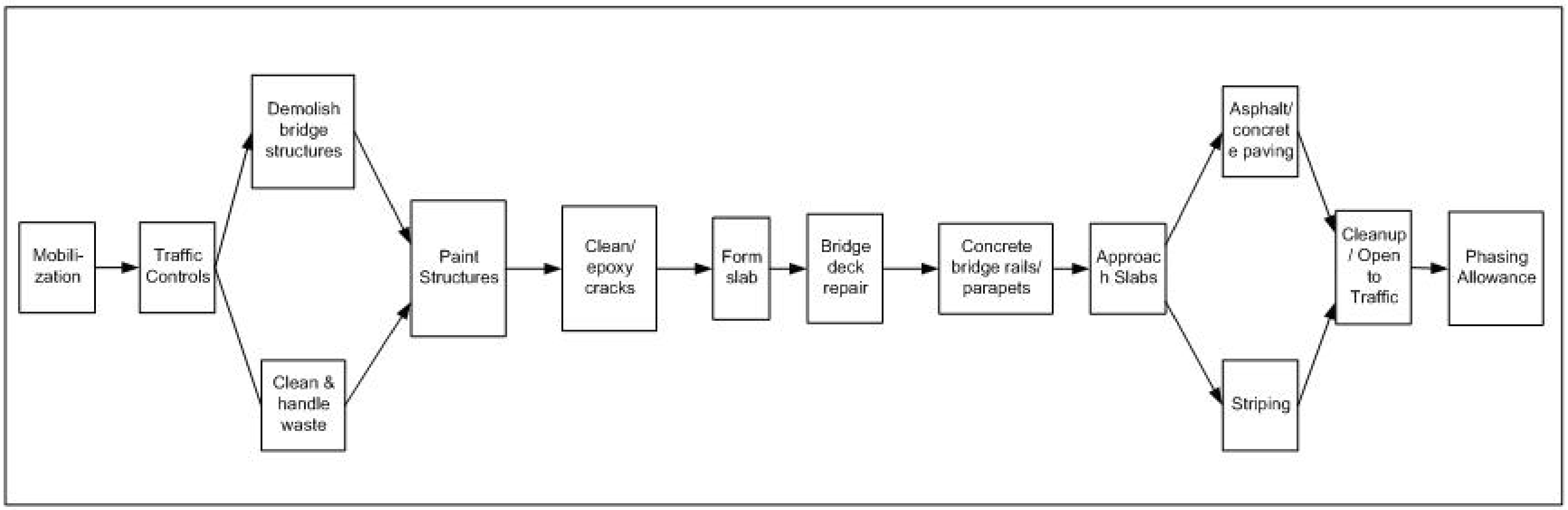
TIER II: 2e – CONSTRUCT BRIDGE BOX AND APPROACHES



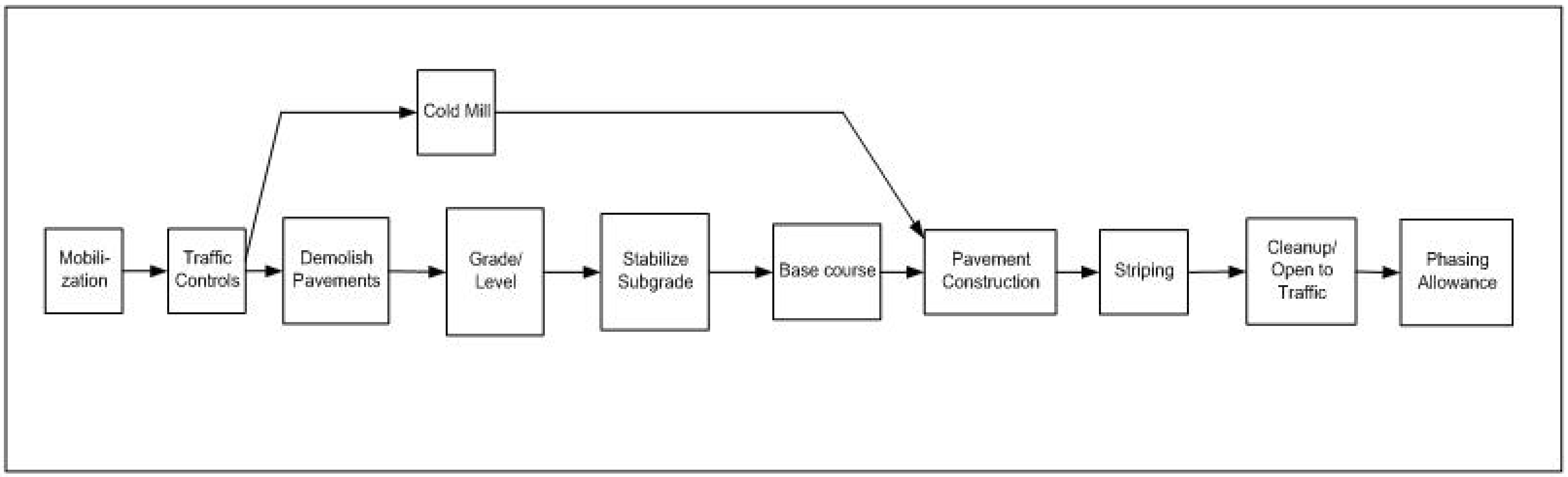
TIER II: 2f – INTERSECTION MODIFICATION



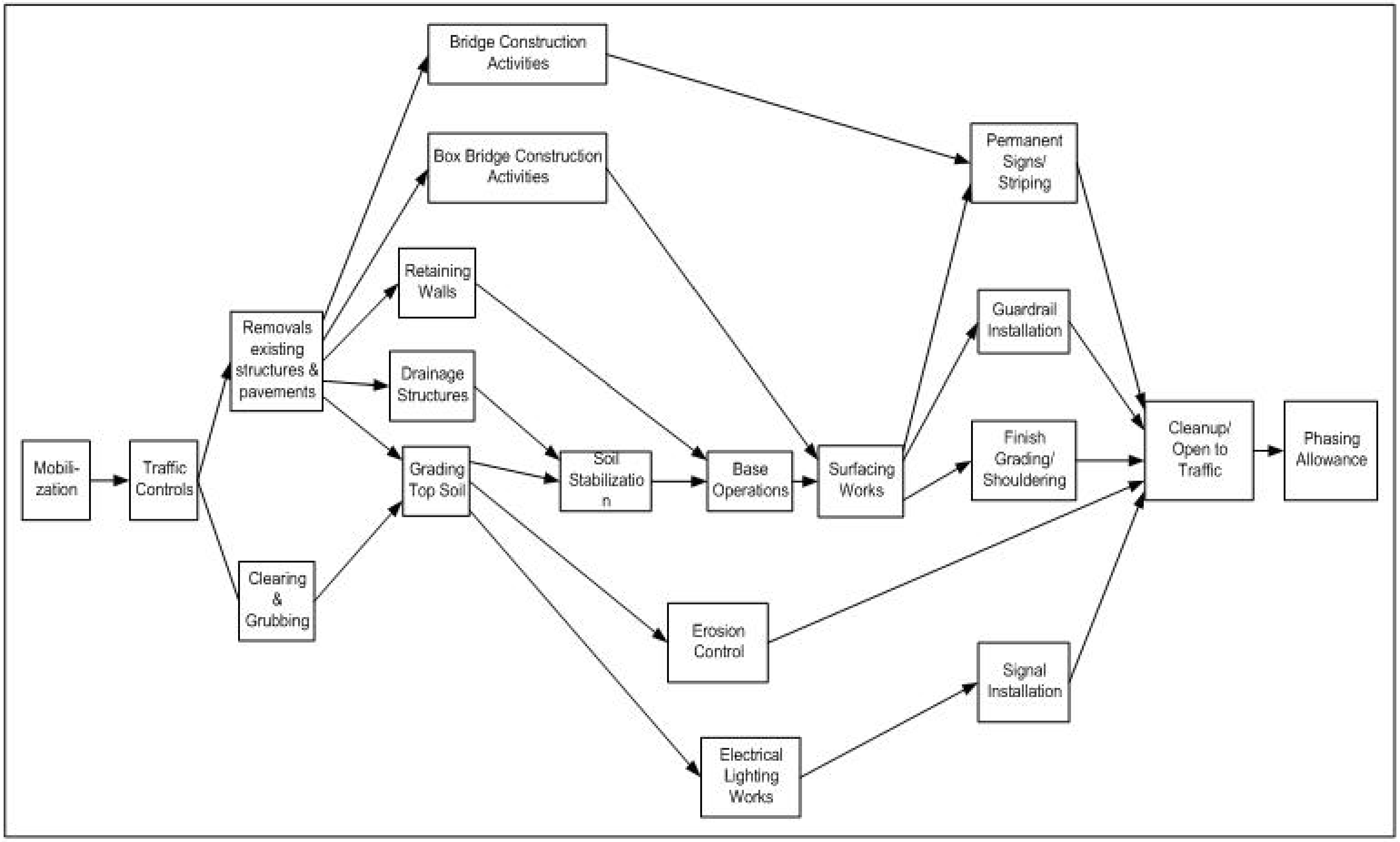
TIER II: 2g – BRIDGE REHABILITATION/ REPAIR



TIER II: 2h – ROADWAY REPAIR/ OVERLAY



TIER I - GENERAL TEMPLATE



APPENDIX D

SOFTWARE MANUAL FOR OKLAHOMA CONTRACT TIME DETERMINATION

1.0 Minimum System Requirements:

1.1. Operating System: Windows 2000, Windows XP

1.2. RAM: 256 MB (Sufficient), 512 MB (Recommended)

1.3. MS Project 2003 or higher version must be installed on the system

1.4. Screen Resolution: 1024 x 768 or higher

1.5. Microsoft .NET Framework SDK(Software Development Kit) 1.1 or higher

2.0 Instructions to install the OkCTDS software on your system:

2.1 Double Click the executable OkCTDS 1.0.exe to install Oklahoma Contract Time Determination Software

2.2 The File will begin to self extract itself as shown below

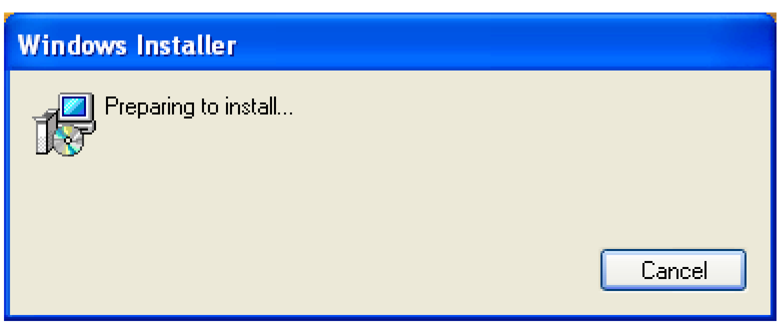


Fig 1: Startup Screen

2.3 The next screen will lead you to the OkCTDS 1.0 Setup wizard

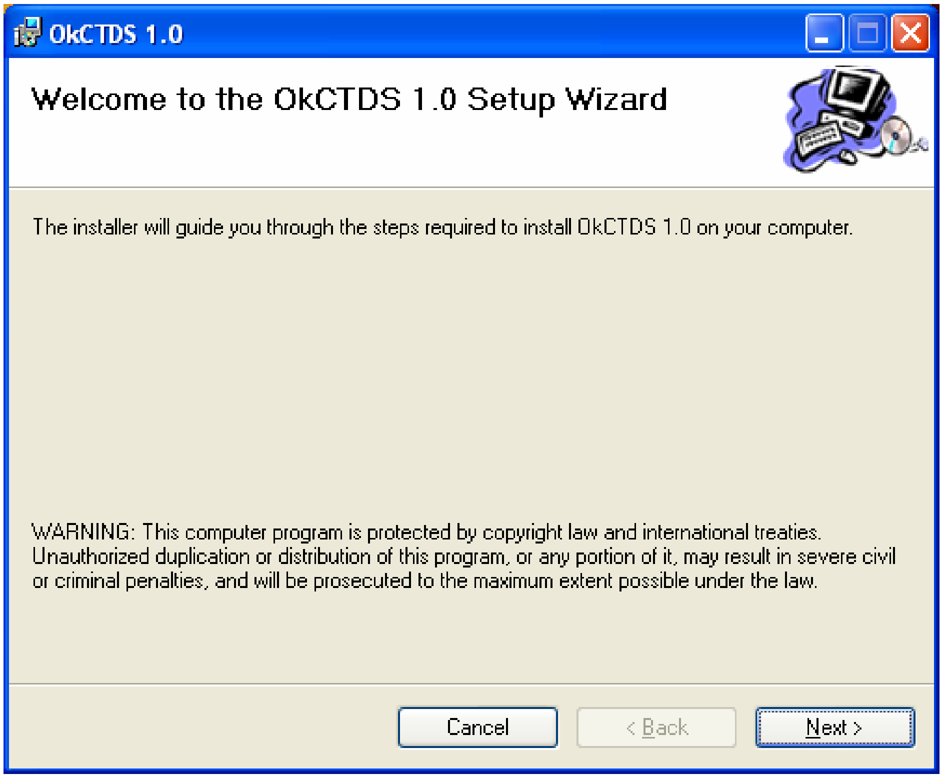


Fig 2: Welcome Screen

2.4 Click on Next and the default location of the project will be in "C:\Program Files\Oklahoma State University\OkCTDS1.0\". If you choose to have a different folder then click on the browse button and select the installation folder you prefer.

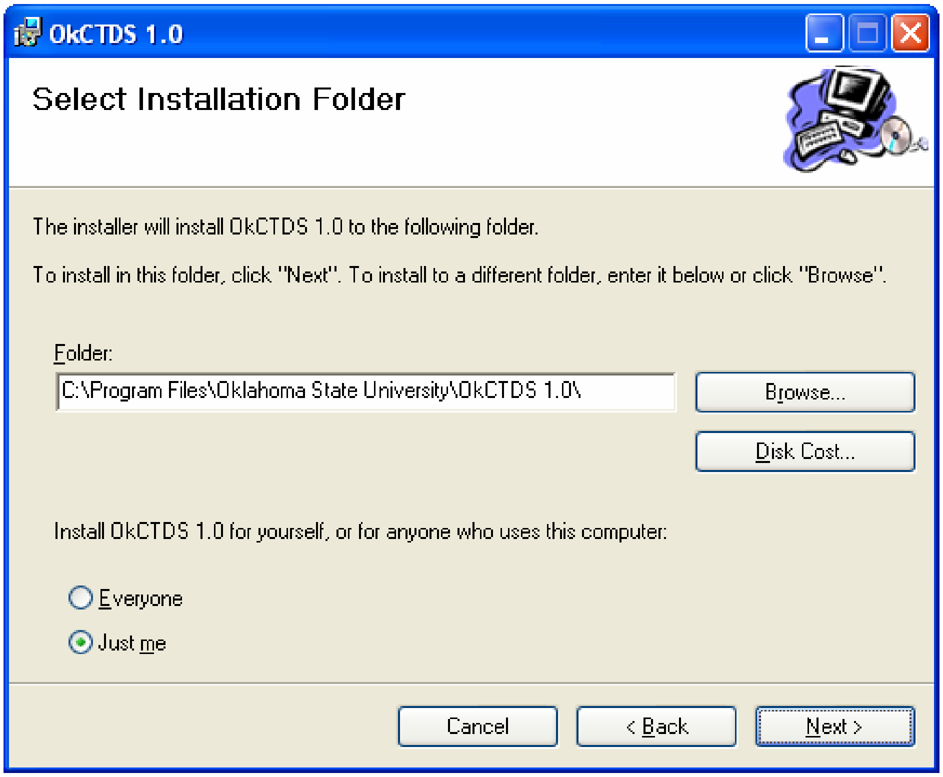


Fig 3: Installation - Folder Selection Screen

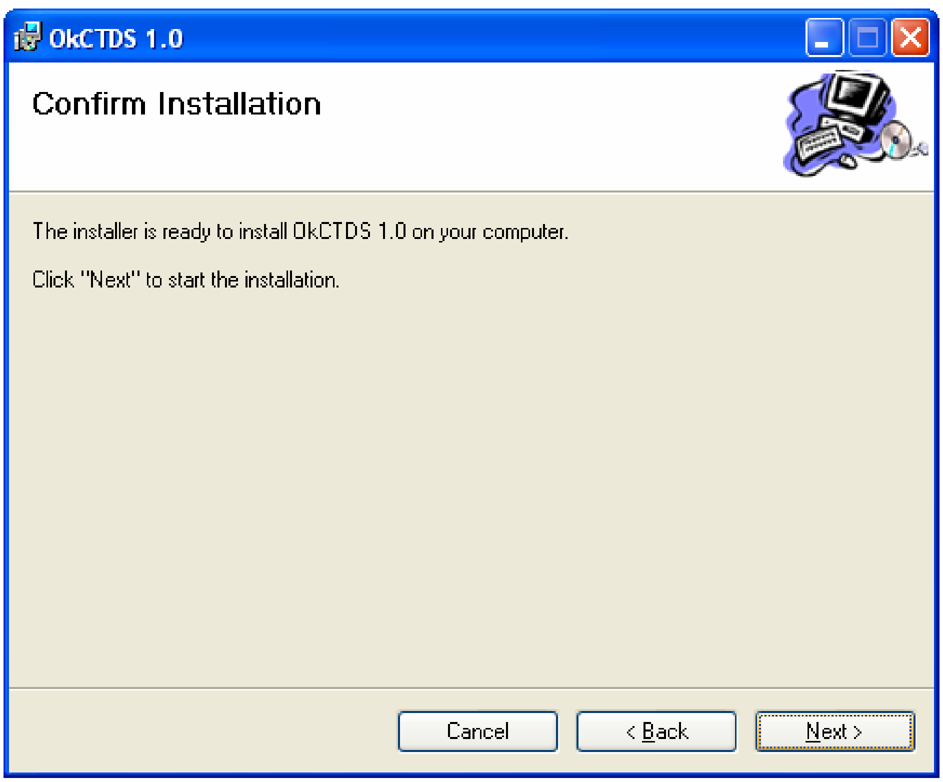


Fig 4: Confirmation Screen

2.5 Click on Next and confirm installation

2.6 The software will get installed on the system and shortcuts to the application file "Odot_1.0.exe" are created on desktop and start menu.

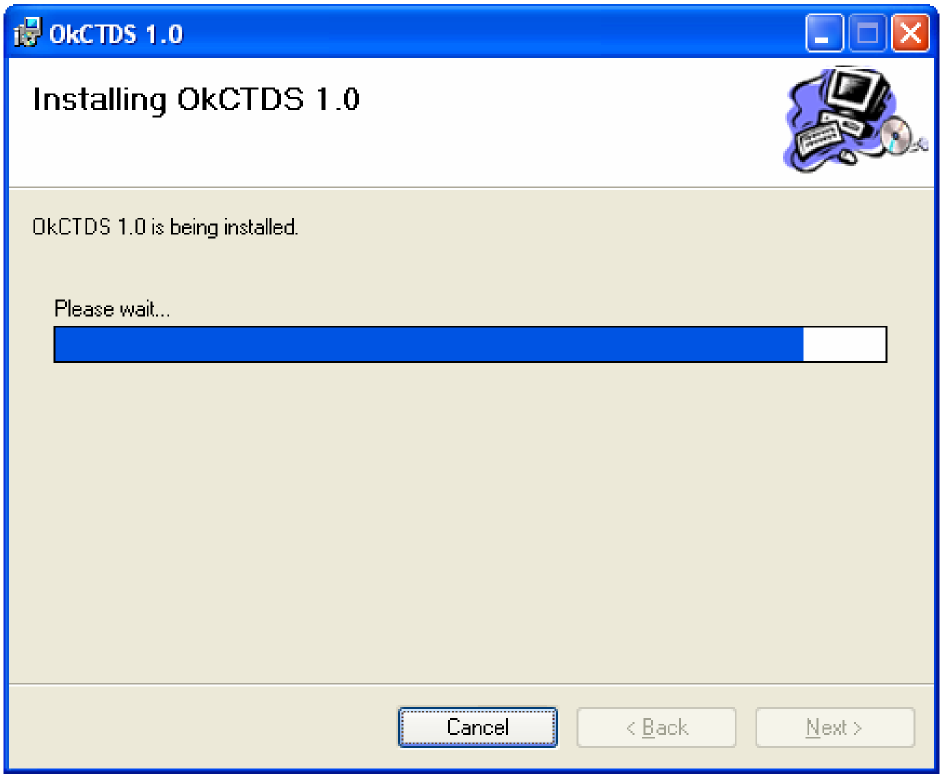


Fig 5: Installation Screen

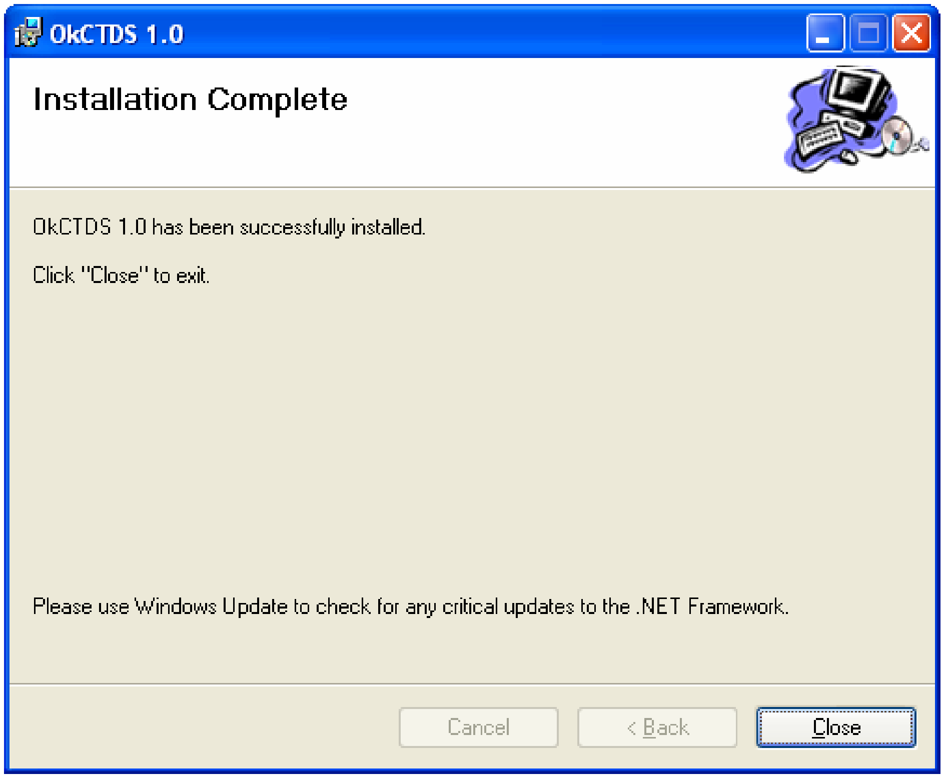


Fig 6: Installation Completion Screen

3.0 Steps to Open the file and run the software:

3.1 Click on the OkCTDS 1.0 icon on the desktop. Alternatively, click start menu, go to programs and select the OkCTDS 1.0 to launch the application.

A startup screen will pop up on the monitor and after that you will be directed to the following screen. Click on the file “OkCTDS_data”.

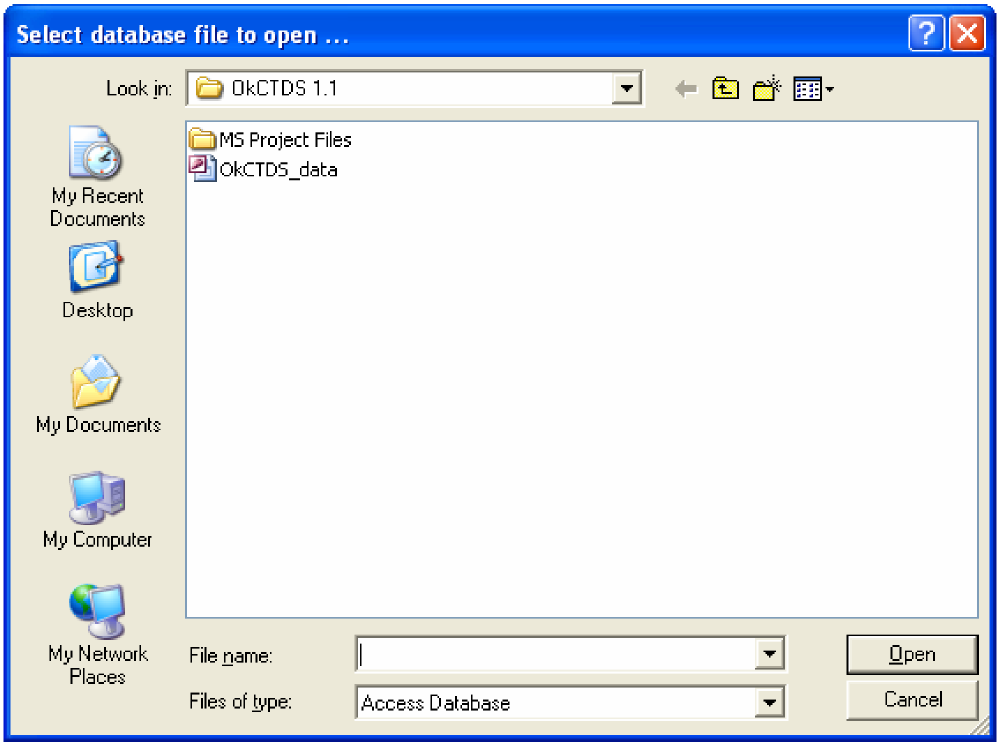


Fig 8: Database File Selection Screen

3.2 Open the file and you will be directed to the following form.

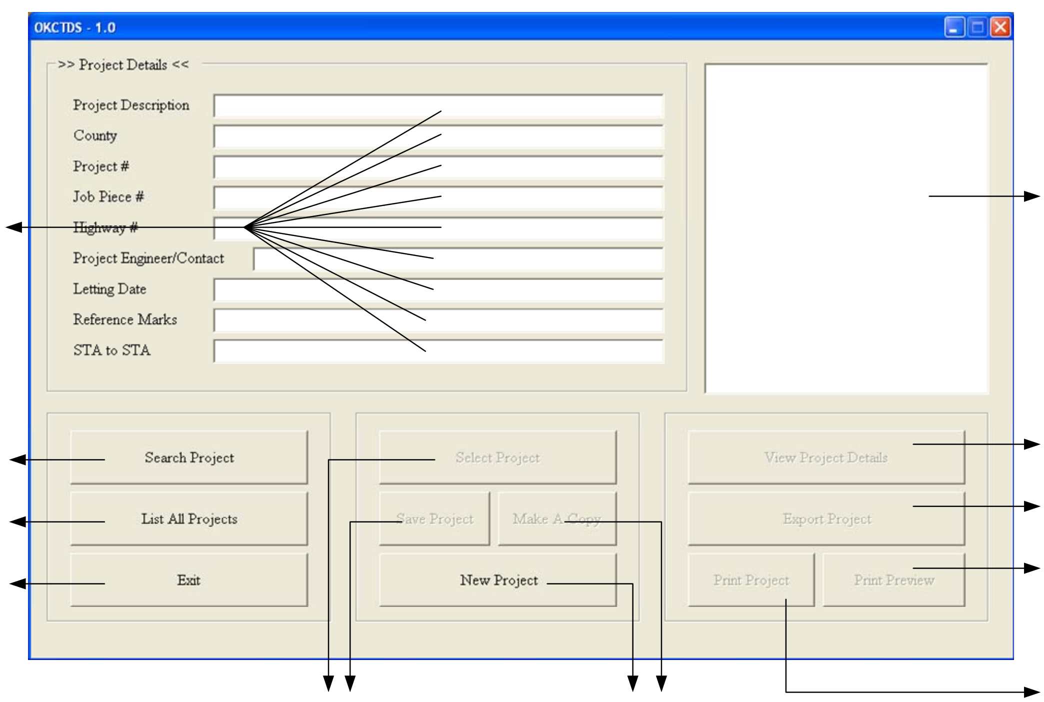


Fig 9: Project Header Form

3.3 This form has textboxes to the left, a list-box to the right and buttons at the bottom of the form. A brief description on the functionality of each of the items seen in the form will be given below.

3.3.1.1 Textboxes: Each textbox is used to display the details of the corresponding project information listed to its left respectively.

3.3.1.2 List-box: List box is used to display the names of the projects stored in the database based on the search criterion. If no criteria are listed, then the entire project database is shown.

3.3.1.3 Buttons: Each button, when pressed, performs the corresponding task associated with that button.

A. Search Project: This function searches the database to find existing projects that match any given search criteria such as Job Id, Project Description, County, etc. All the projects that satisfy the search criterion are retrieved and their names are displayed in the list box (see Fig 9).

B. List All Projects: When this function is activated, all the existing projects are retrieved and are displayed in the list box (see Fig 9).

C. Exit: When this button is clicked, the application exits.

D. Select Project: The above functions will display projects that satisfy the search criteria and this function opens the selected project from the list box (see Fig 9).

E. Save Project: In order to save any modifications made to any old/archived projects this function must be activated to overwrite the previous data in the project and stores this information in the database.

F. New Project: Opens a New Project with default values.

G. Make A Copy: When any modifications are made to any old/archived projects, this function stores the information under a new project name.

H. View Project Details: This opens a new form displaying the finer details of the project such as activity, duration, quantity, additional technical details etc.

I. Export Project: This transfers all the activities, sub activities and their durations into a Microsoft Project file and displays the Gantt bar chart.

J. Print Preview: It displays a print preview of the template.

K. Print Project: Prints the current project.

3.4 After selecting a particular project, if a user wants to look at the project details, 'view project details' button has to be clicked upon which the user will be directed to the following form.

3.5 View Project Details: Opens the Project details form which the user can view/check/modify/refer.

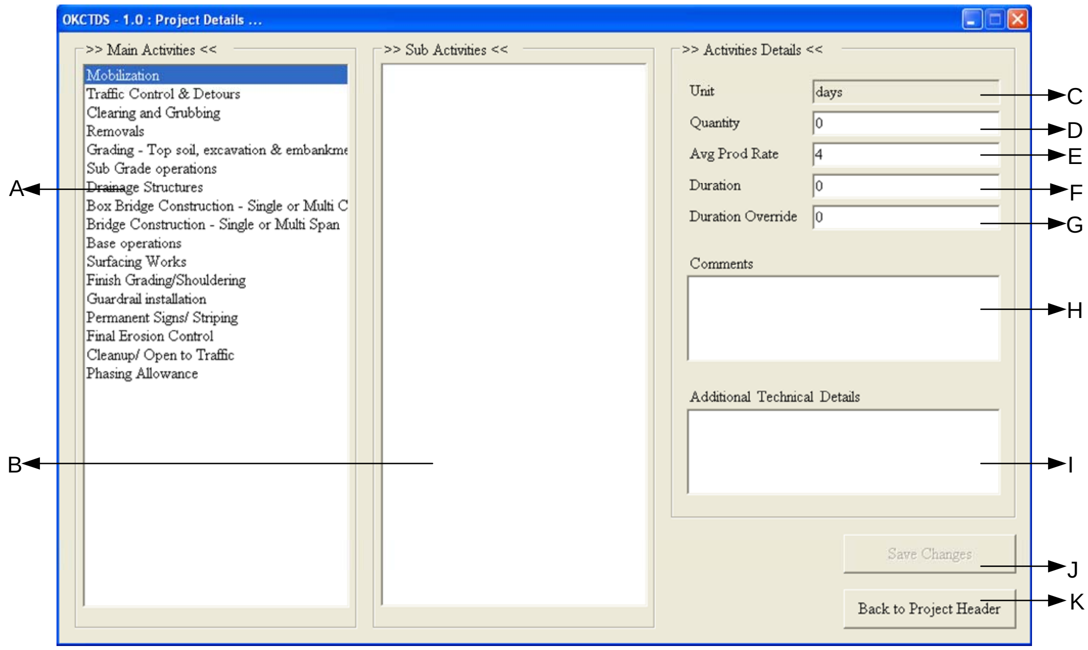


Fig 10: Project Details Form

A. Main Activities: List-box that displays the main activities of the template/project.

B. Sub Activities: List-box that displays the sub activities of the template/project

C. Units: Textbox that displays the unit of the current main activity/sub activity.

D. Quantity: Displays the quantity input by the user.

E. Average Production Rate: Displays the default average production rate of each activity. The default values are stored in the database. Also, when the mouse cursor is on this textbox it displays a tool tip that has the default minimum and maximum production rates for the current main activity/sub activity.

F. Duration: Calculates the duration using the formula Quantity/Avg Prod Rate.

G. Duration Override: Overrides the calculated duration obtained and considers this as the duration, if the user inputs any value into this textbox. By default this will be zero for any activity.

H. Comments: Contains the comments for the activity selected.

I. Additional Technical Details: Contains any additional technical details for the current activity that can be of help for the user to make a better judgment of values for duration, production rates etc.,

J. Save Changes: Saves any changes that were made during the current session.

K. Back to the Project header: Exits this form and takes the control back to the project header form.

3.6 Any changes that the user desires can be made here and once everything is taken care of, user can go back to the previous form by clicking on the 'Back to Project Header' button or if you want to exit this form, click on the 'X' button on the top right of your form.

3.7 To exit the 'Project Header' form, click on 'Exit' Button to exit the form or click on the 'X' button on the top right of your form.

4.0 Demonstration using an example :

4.1 Search Project: This button searches the entire project database for any user query and returns the results obtained in the list box.

For example, there is a default project 'Default_Job_Number_1' in the database that is used for demonstration purposes. If we want to find all projects that have a number '1' in their job numbers, the user enters '1' in the textbox of job number and searches for it.

The default screen of the software is shown below:

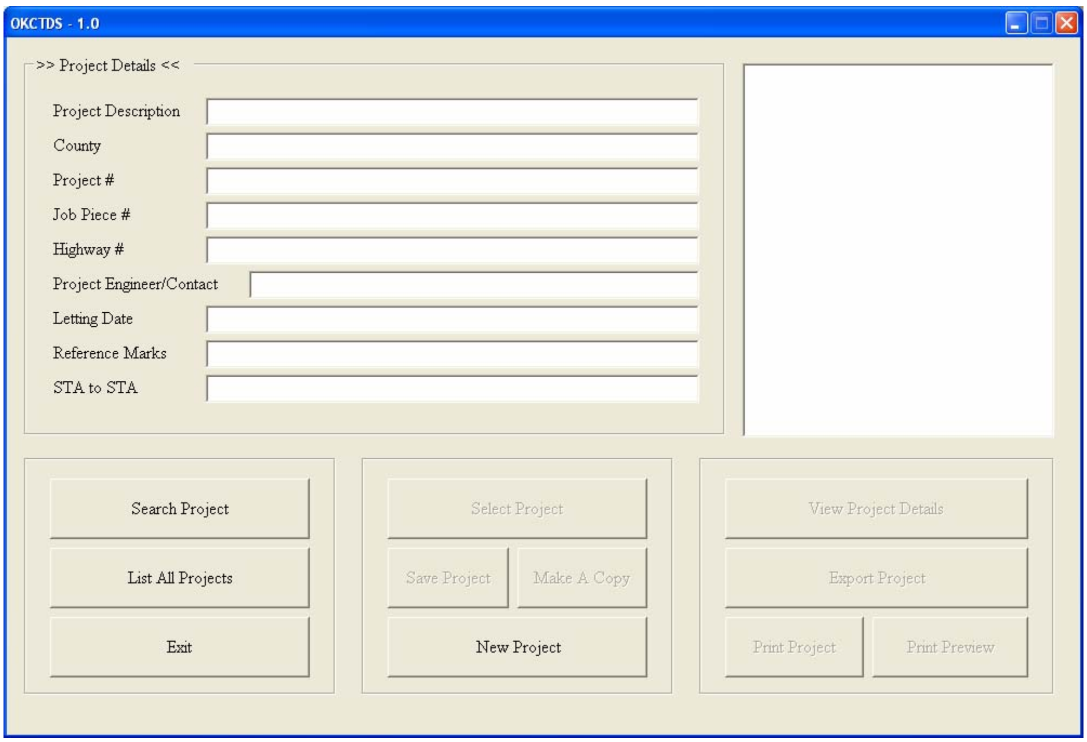


Fig 11: Project Header Form – Default Screen

Now the user types 1 in the job number and searches the database and the list box displays the obtained results.

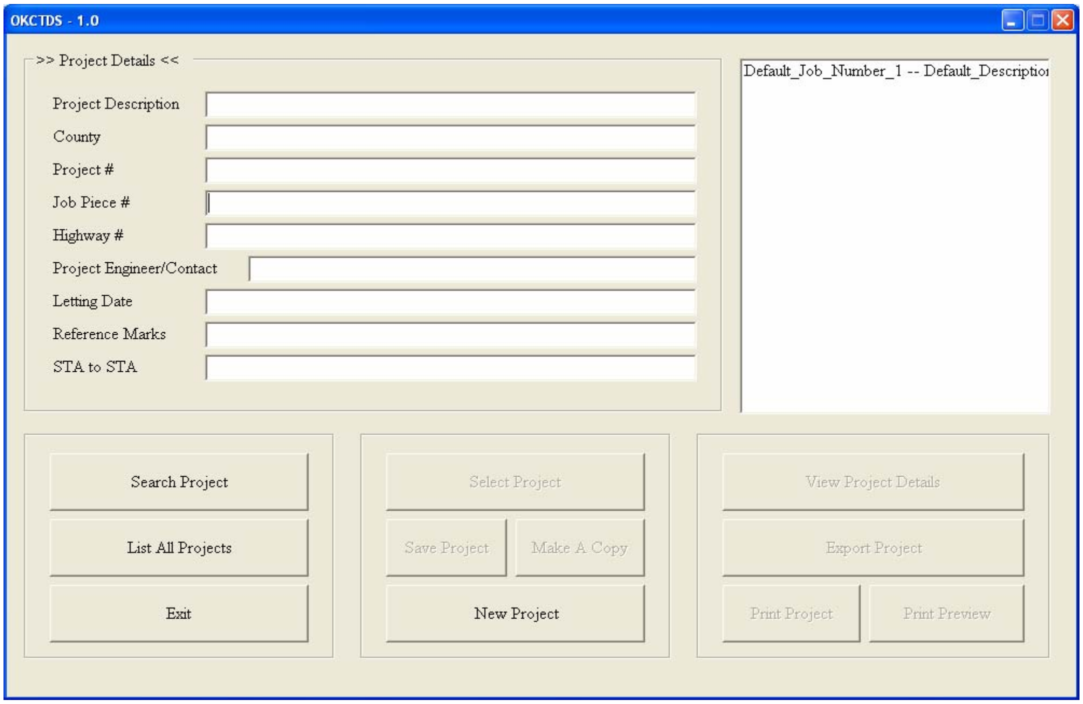


Fig 12: Search Option - Project Header Form

4.2 List All Projects: Lists all the projects in the database. In this case, since only one default file is present, it will list that project in the list-box.

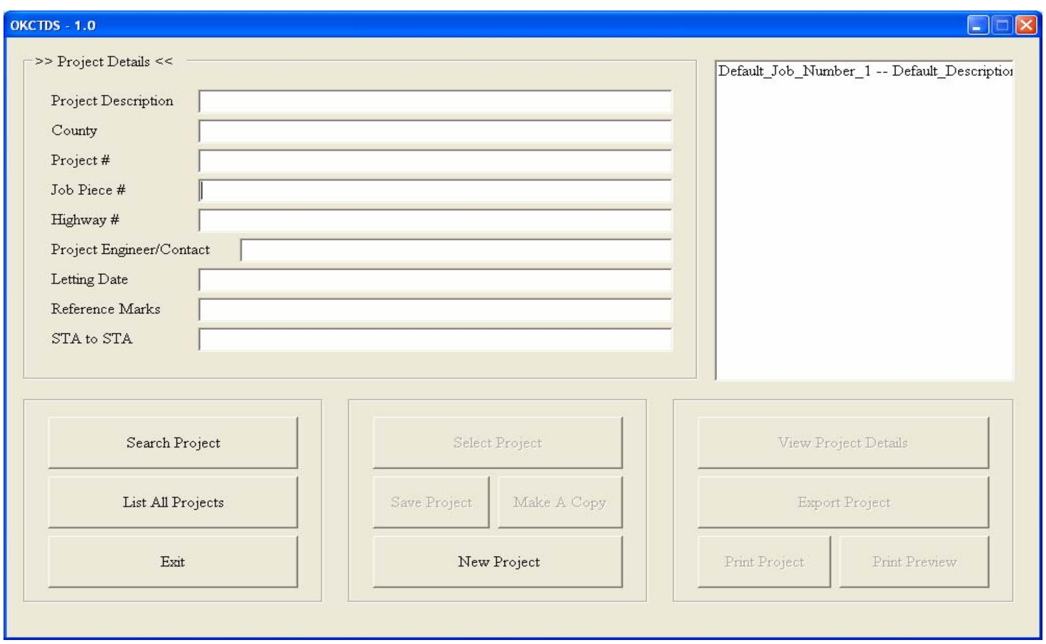


Fig 13: List Option - Project Header Form

4.3 Select Project: Selects the highlighted project and makes it the active project.

Highlights the default_project_1:

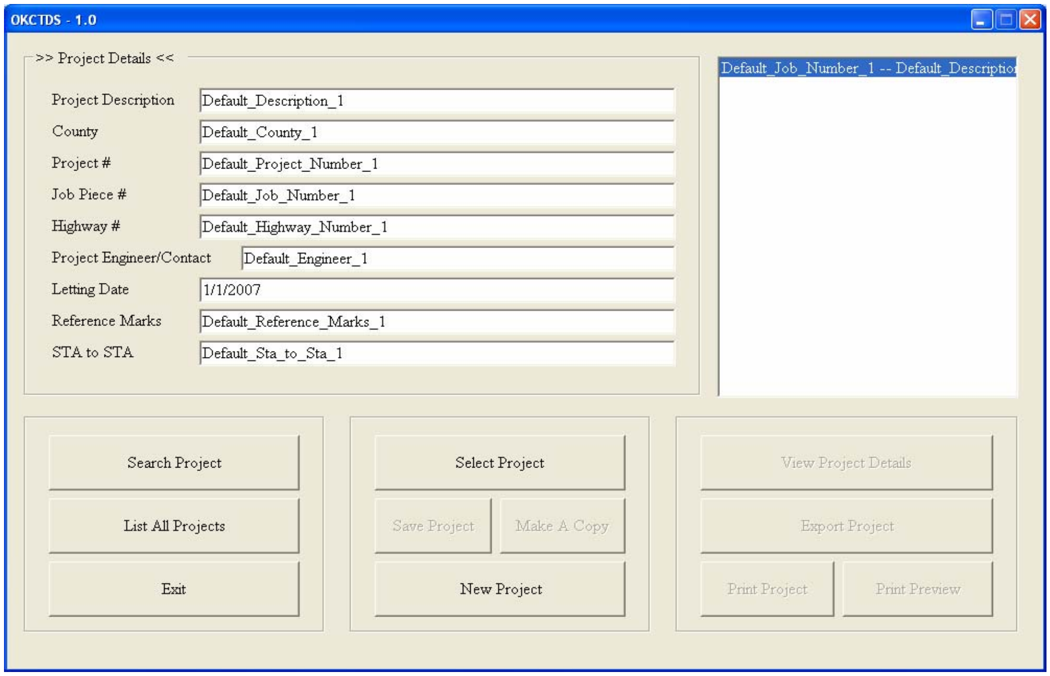


Fig 14: Project Choice – Project Header Form

Selects the default_project_1 and makes it active:

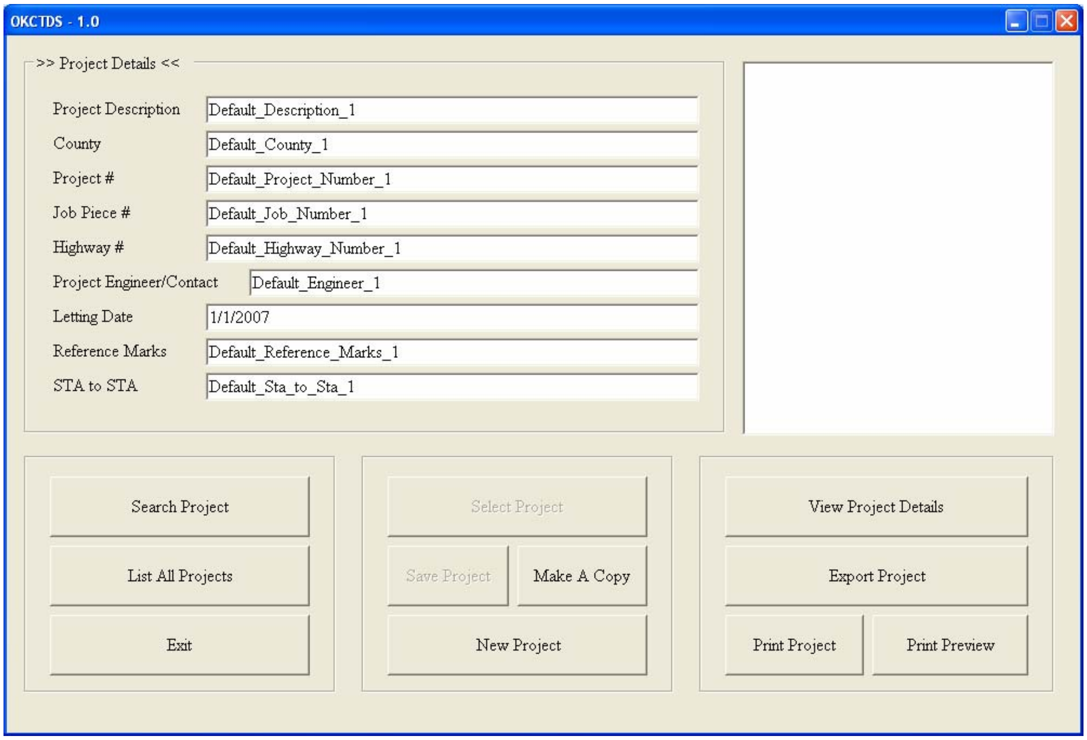


Fig 15:

4.4 Save Project: Saves any changes made to the project header details and overwrites them in the place of the current project

4.5 Make a Copy: Makes a new copy of the present project.

4.6 New Project: Opens a New form and displays a choice of templates for the user to start a new project. A New Project, upon selection, with a default project data will be created, which the users can modify according to their requirement.

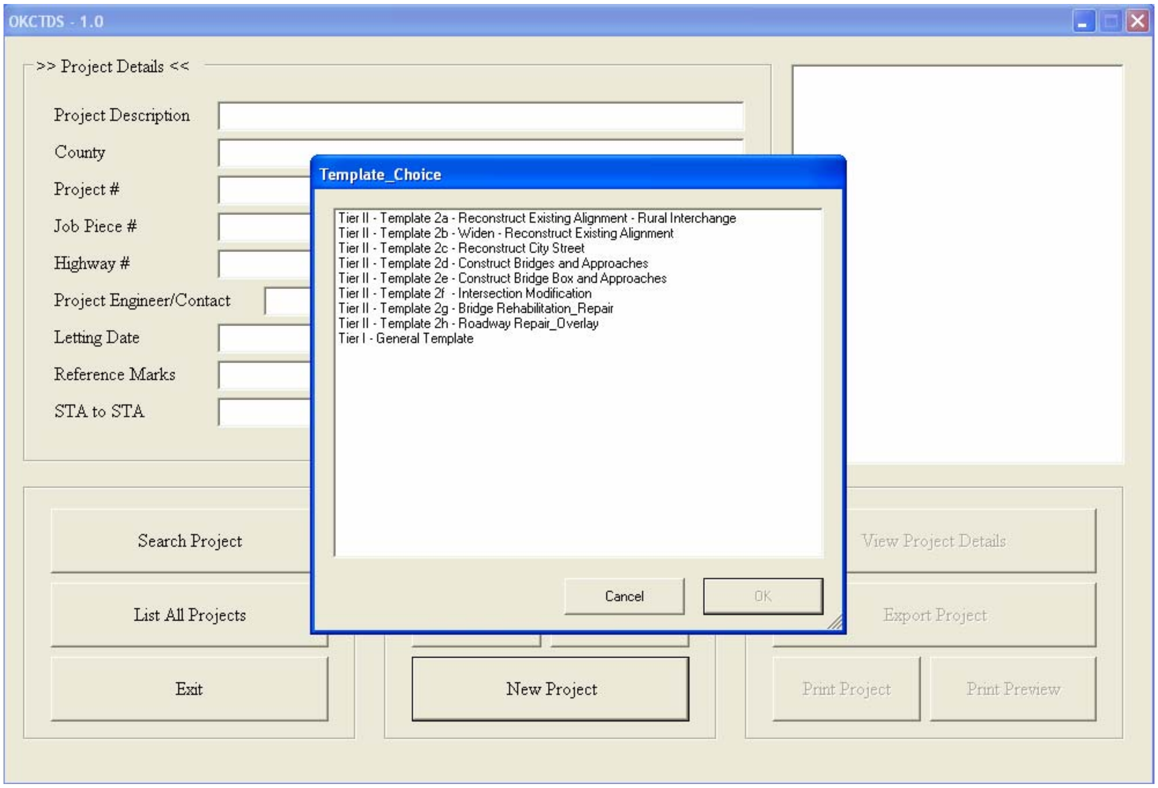


Fig 16: New Template Selection – Project Header Form

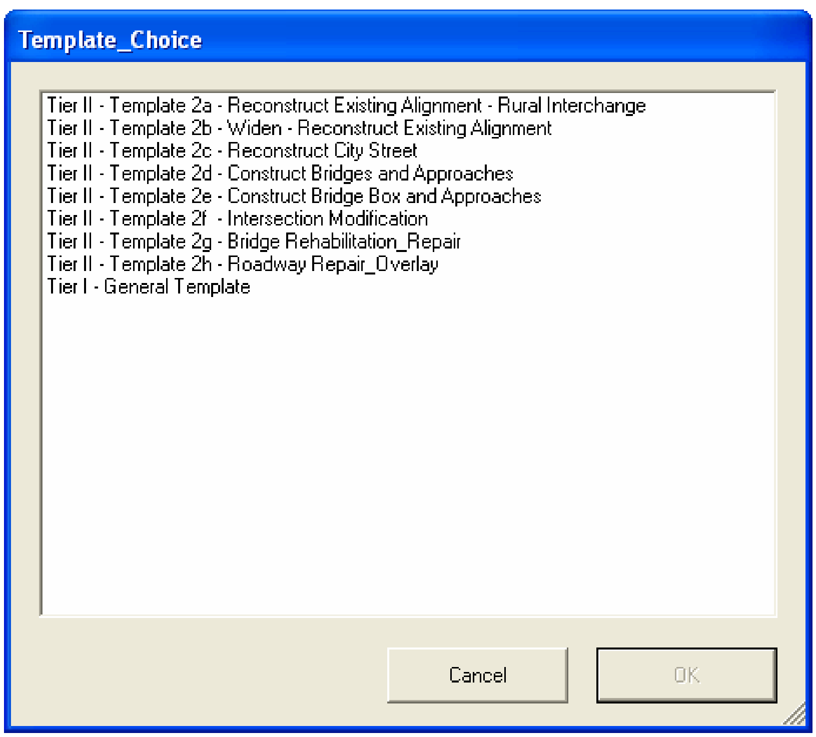


Fig 17: New Template Selection Form

4.7 View Project Details: Opens the Project details form which the user can view/check/modify/refer.

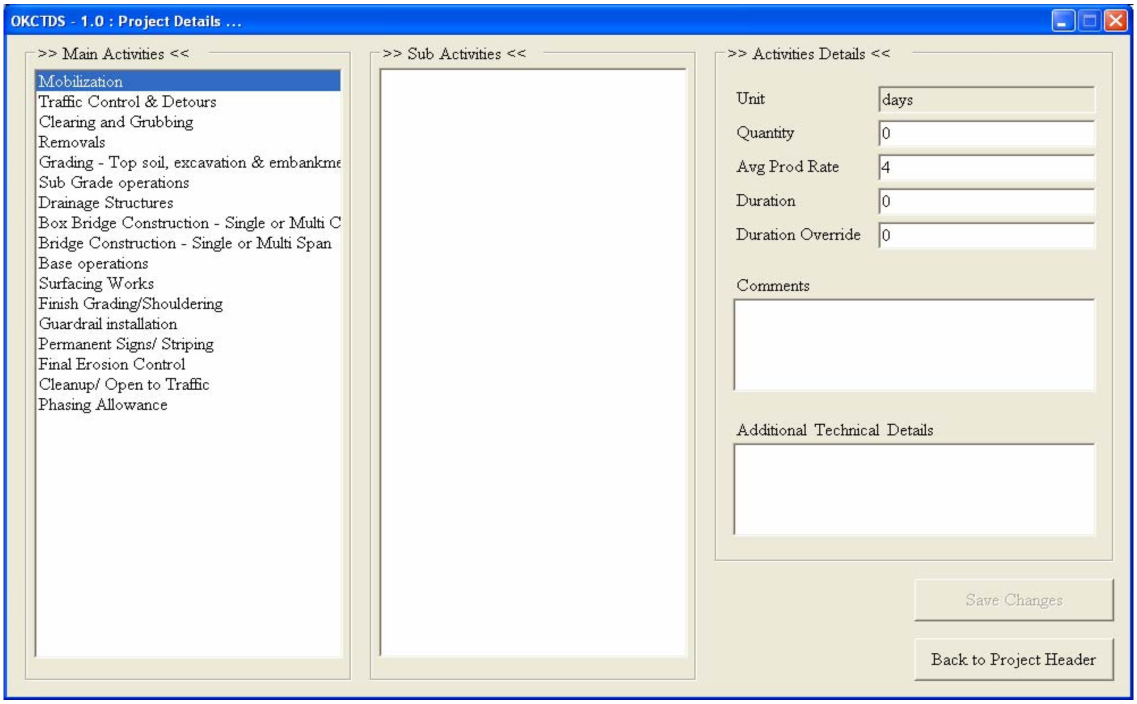


Fig 18: Project Details Form

4.8 Export Project: This button will export the duration, activities and production rates of the current project into Microsoft project and display them in a CPM chart.

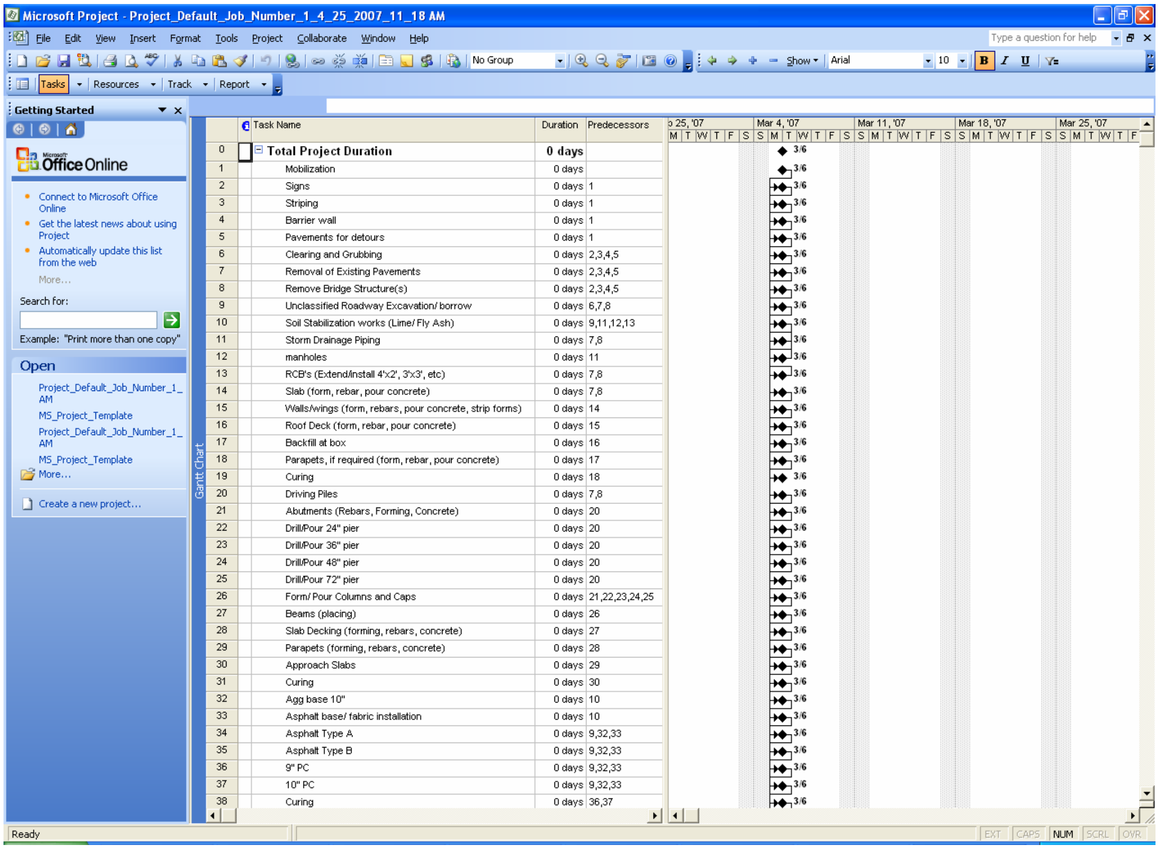
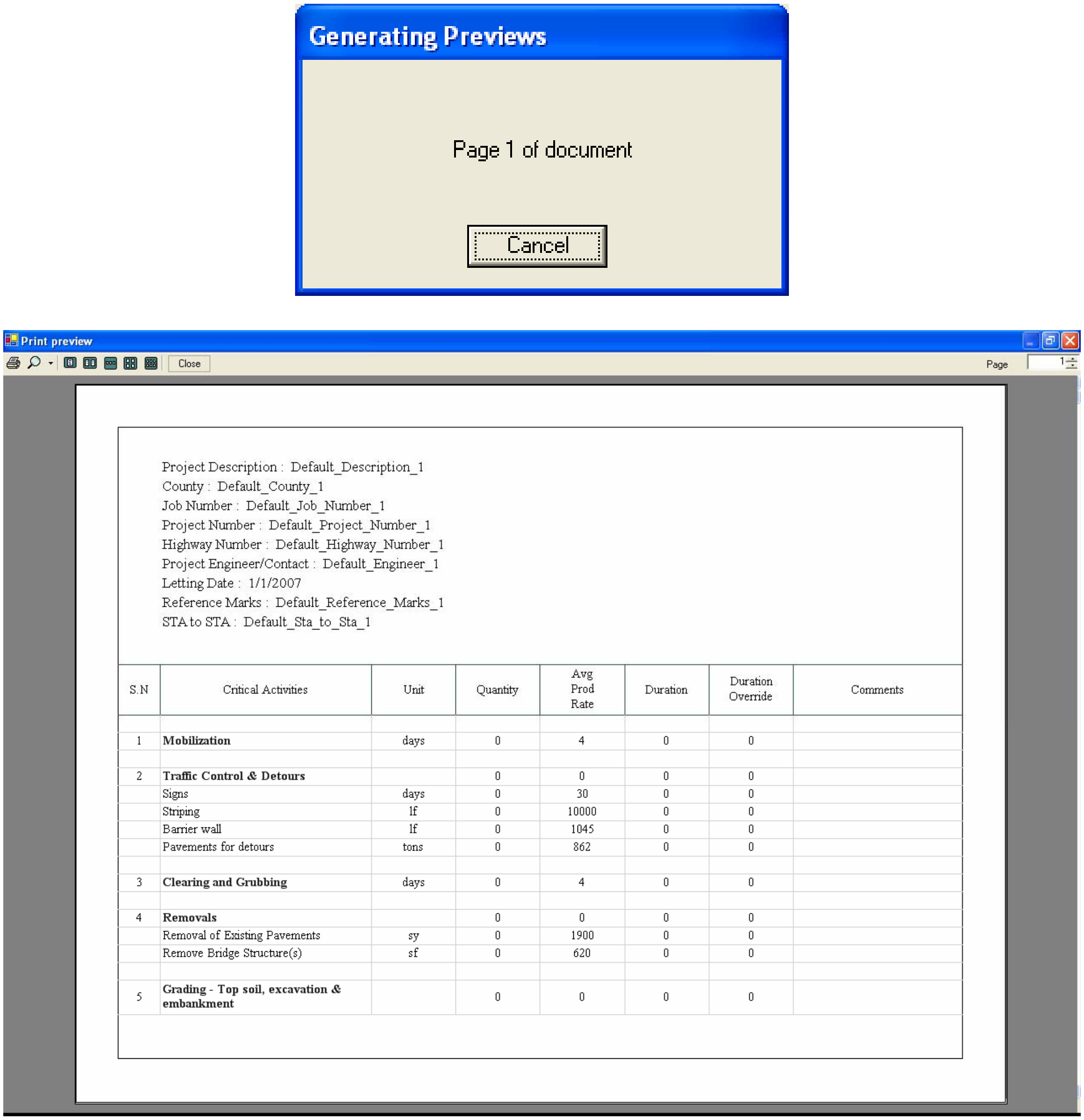


Fig 19: MS Project Screen

4.9 Print Project: This button will print the project details with the project header details at the top.

4.10 Print Preview: This button will generate a print preview of the project for the user.



Project Description : Default_Description_1
County : Default_County_1
Job Number : Default_Job_Number_1
Project Number : Default_Project_Number_1
Highway Number : Default_Highway_Number_1
Project Engineer/Contact : Default_Engineer_1
Letting Date : 1/1/2007
Reference Marks : Default_Reference_Marks_1
STA to STA : Default_Sta_to_Sta_1

S.N	Critical Activities	Unit	Quantity	Avg Prod Rate	Duration	Duration Override	Comments
1	**Mobilization**	days	0	4	0	0	
2	**Traffic Control & Detours**		0	0	0	0	
	Signs	days	0	30	0	0	
	Striping	lf	0	10000	0	0	
	Barrier wall	lf	0	1045	0	0	
	Pavements for detours	tons	0	862	0	0	
3	**Clearing and Grubbing**	days	0	4	0	0	
4	**Removals**		0	0	0	0	
	Removal of Existing Pavements	sy	0	1900	0	0	
	Remove Bridge Structure(s)	sf	0	620	0	0	
5	**Grading - Top soil, excavation & embankment**		0	0	0	0	

Fig 20: Print Preview Screen

<u>DO NOTS</u>

1. Do not open two instances of the software at the same time.
2. Do not change values or interrupt the software when the program is busy executing any activity desired by the user such as printing document, generating print previews, opening new/existing projects, exporting project to MS Project etc.,

3. Do not enter inappropriate values(like entering alphabets in areas where numbers are supposed to be entered and vice versa etc.)
4. Do not enter the database file. Only an administrator with password will have access to the database. There is a possibility of loss of information/database or the computer might perform in an unexpected manner if an unauthorized operation takes place in the database file due to negligent handling.
5. If there is any change desired then kindly contact Dr.David Jeong, Civil Engineering Department, Oklahoma State University.

VITA

Siddharth K. Atreya

Candidate for the Degree of

Master of Science

Thesis: DEVELOPMENT OF AN IMPROVED SYSTEM FOR CONTRACT TIME DETERMINATION

Major Field: Civil Engineering

Biographical:

Personal Data: Born in India, on August 5^{th}, 1980, son of C. Kasturirangan and Rajeshwari Kasturi.

Education: Received Bachelor of Science Degree in Civil Engineering from Mumbai University in June 2002; received Post Graduate Diploma in Advanced Construction Management from the National Institute of Construction Management and Research (NICMAR), Pune in September 2005; completed the requirements for the Degree of Master of Science at the Civil and Environmental Engineering Department at Oklahoma State University in May 2007.

Experience: Worked as a Field Engineer in a Building construction firm called B.E.Billimoria in Mumbai. Interned in a Nuclear Power Plant construction project in Kaiga, India. Worked as a Contracts Engineer for highway construction projects in AFCONS, Mumbai.

Name: Siddharth K. Atreya Date of Degree: May, 2007

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: DEVELOPMENT OF AN IMPROVED SYSTEM FOR CONTRACT TIME DETERMINATION

Pages in Study: 170 Candidate for the Degree of Master of Science

Major Field: Civil Engineering

Scope and Method of Study: Contract time, is the maximum time allowed for completion of all work described in contract documents. The determination of contract time affects not only the actual duration of the construction project, but also such aspects of construction such as costs, resource planning, selection of contractors and traffic problems. An accurate estimation of contract time reduces the impact of a delayed project on the local economy and provides justification to contractors during construction claims. This research performed an extensive literature review on various contract time determination procedures and systems developed and used by various state agencies to estimate contract time for their highway projects. This study surveyed 24 DOTs in the United States to determine the prevalent contract time procedures and determined their advantages and disadvantages.

Findings and Conclusions: Oklahoma Contract Time Determination System (Ok-CTDS) is a contract time estimating system for Tier-II type highway projects of ODOT which are categorized into eight types of road projects. The manual CTD system consists of nine templates, one general template for Tier I type category and eight templates for Tier II type category. The CTDS user supplies the system with actual work quantities for established controlling activities for a project and by applying average or project specific production rates, durations for each controlling activity can be calculated. A standalone computer software was developed using VB.Net linked with Microsoft Access database and Microsoft Project for estimating contract time in working days. This software is recommended to be used in ODOT for effectively running the contract time determination system. The major benefit of this system to ODOT is that its continuous use would provide a structured approach towards contract time estimation. This system will expedite the contract time estimation process, provide documentation for a stronger defense in contract time disputes and allow less experienced schedulers to gain confidence as they learn how to estimate reasonable and realistic contract times.

ADVISER'S APPROVAL: Dr. Hyungseok (David) Jeong