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FINAL REPORT ~ FHWA-OK-08-02

DEVELOPMENT OF AN IMPROVED SYSTEM FOR CONTRACT TIME DETERMINATION (PHASE I & II)

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16. Abstract

Phase I of this study was funded by OTC and was successfully completed in December, 2006. In phase I, ODOT highway projects were classified into three different Tiers through the evaluation of recently completed highway projects and a series of technical meetings and discussions with ODOT design division engineers, schedulers, contractors and FHWA-Oklahoma Division engineers. Phase I has developed a manual system to determine the contract time for Tier II highway projects.

Phase II has expanded from Phase I and developed a standalone computer software to automatically determine the contract time of Tier II and Tier III projects when quantities of controlling activities are given. The developed software, namely, OK-CTDS uses VB.Net as a main programming language to build graphic user interfaces (GUIs) and uses the Microsoft Access as a main database. The program is linked with the Microsoft project to automatically generate a project schedule and the critical path of the project. The OK-CTDS has an internal function to automatically transfer all the project data to the Microsoft project from the developed software. The validation results show that the developed system can produce a reasonably accurate contract time for highway projects. During the Fall of 2007, the research team has trained more than 50 ODOT engineers and consultants involved in designing highway projects. The training program was very well received by the participants and their responses were very positive. The OK-CTDS software program can be used as a supporting tool for division project schedulers and also can be used as a training tool for new engineers.

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1 INTRODUCTION

Contract time is the maximum time allowed in the contract for completion of all work contained in the contract documents (FHWA 2002). An accurate forecast of contract time is crucial to contract administration as the predicted duration and associated cost form a basis for budgeting, planning, monitoring and even litigation purposes. Excessive contract time is costly, extends the construction crew's exposure to traffic, prolongs the inconvenience to the public (unnecessary increase of road user costs), and subjects motorists to less than desirable safety conditions for longer periods of time. Insufficient contract time results in higher bids, overrun of contract time, increased claims, substandard performance, and safety issues.

Title 23 Code of Federal regulations (CFR) Section 635.121 requires that States have adequate written procedures for the determination of contract time, and that Section 635.127 requires that States have written procedures for establishing project liquidated damages. FHWA must approve both of these procedures, but ODOT does not have written or approved procedures yet. ODOT, being aware of these existing problems associated with contract time determination, has tried to standardize the procedure. Joint ODOT/FHWA process reviews conducted in 2001 and 2006 examined contract time determination practices and made appropriate recommendations to improve these processes (ODOT 2001 and 2006). The latest of these joint reviews occurred in 2006 and included the following main recommendations.

a. Utilize a three tiered process for calculating contract time
    - Tier 1- individual CPM's run on complicated projects subject to congestion
    - Tier 2 - CPM's run with standard templates used for typical multiphase projects
    - Tier 3 - Table values established for use on standardized county bridge or simple surface type of projects
b. Training in these procedures to all project engineering managers as well as design consultants responsible for establishment of contract time

The main objective of Phase I of this research was to develop a structured manual system in determining contract time for highway projects by investigating different types of highway construction projects, analyzing critical construction activities in each type of projects and their associated production rates. Phase II goals were to 1) develop a standalone computer software to automatically determine the contract time of Tier II and Tier III projects when quantities of controlling activities are given and 2) to train potential users of this software such as ODOT engineers and Consultants. These two objectives were successfully accomplished and this report provides the details of the completed work in this study.

It is anticipated that this automated contract time determination system will

1) Provide a consistent, approved procedure for contract time determination
2) Allow all personnel, even those of less experience to determine contract time through use of default production rates until they gain more confidence to adjust those default values.
3) Provide better documentation for a stronger defense in contract time disputes

This report consists of five chapters. Chapter 1 introduces the background and the main objectives of the overall study (Phase I and Phase II). Chapter 2 reviews prior research in this area. Chapter 3 presents the tier system for categorizing Oklahoma highway projects and explains Tier II and Tier III projects in detail as they are included for contract time automation software program. Chapter 4 discusses the manual system for contract time determination and Chapter 5 presents the computer software program (OK-CTDS) developed for this study. Chapter 6 reports on training sessions offered. Chapter 7 summarizes this study and recommends the areas for future studies.

2 LITERATURE REVIEW

This chapter reviews current methods used by various DOTs on contract time determination. Prior research in this domain is examined and investigated for possible adaptation of existing methodologies for the development of an improved system for contract time determination for ODOT. The chapter also reviews various factors that affect the production rates of controlling activities of highway projects.

2.1 Overview of Current Practices in DOTs

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.

Most DOTs 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.

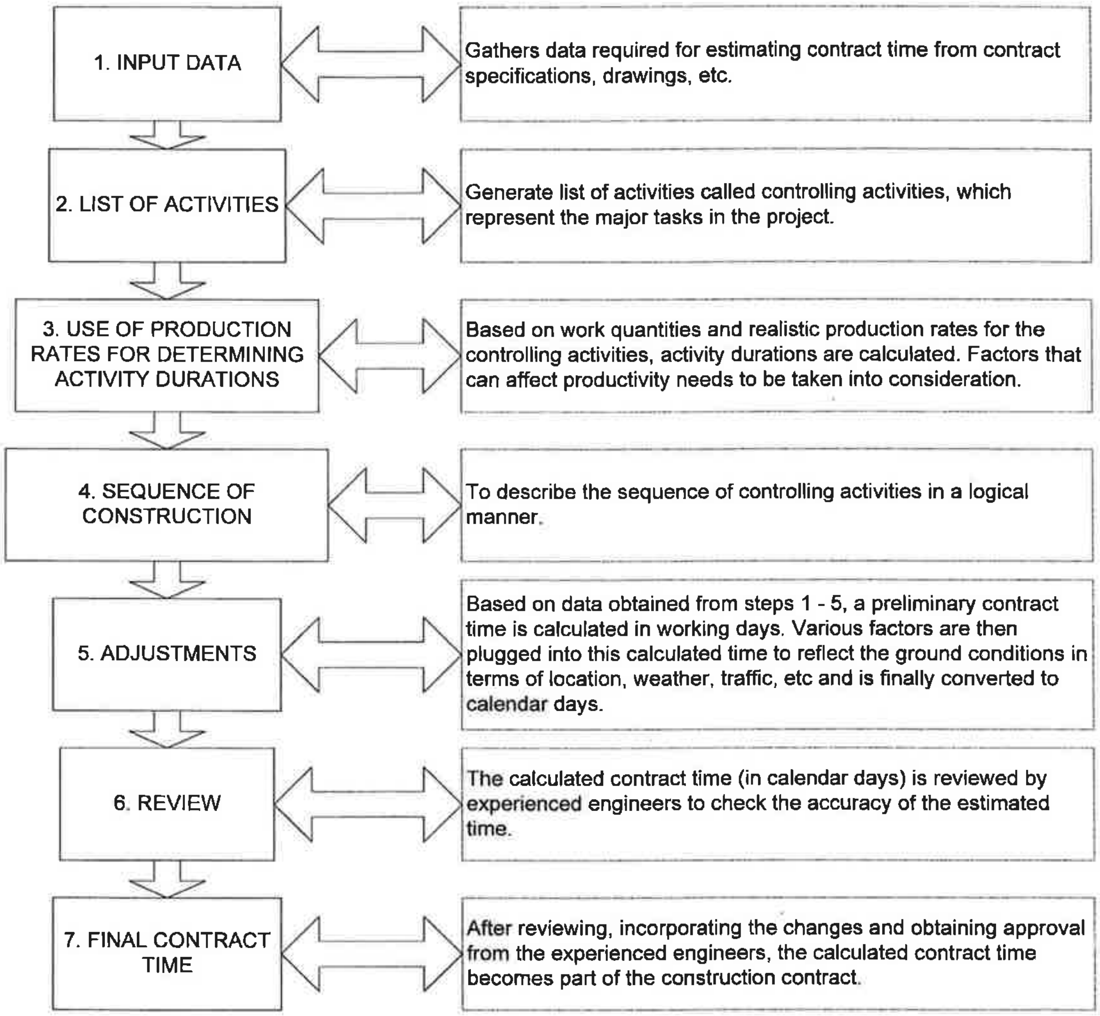

Fig 2.1: Contract Time Determination Process (Herbsman & Ellis, 1995)

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).

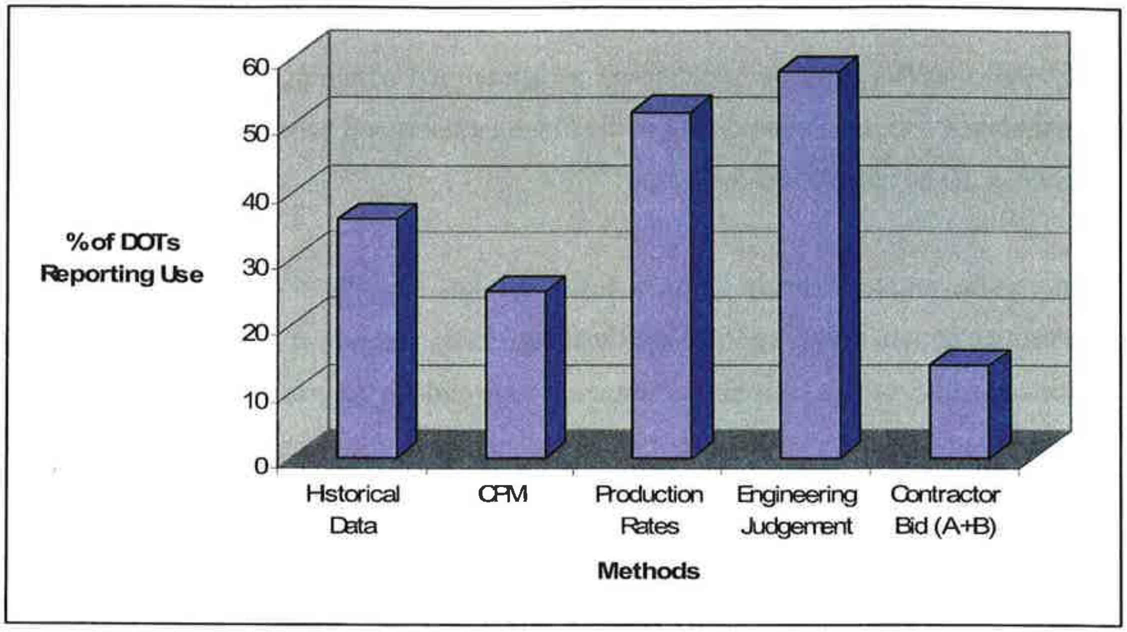

Fig 2.2: Methods used by DOT's for Contract Time Estimation on Incentive/Disincentive Contracts (Herbsman & Ellis, 1995)

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.

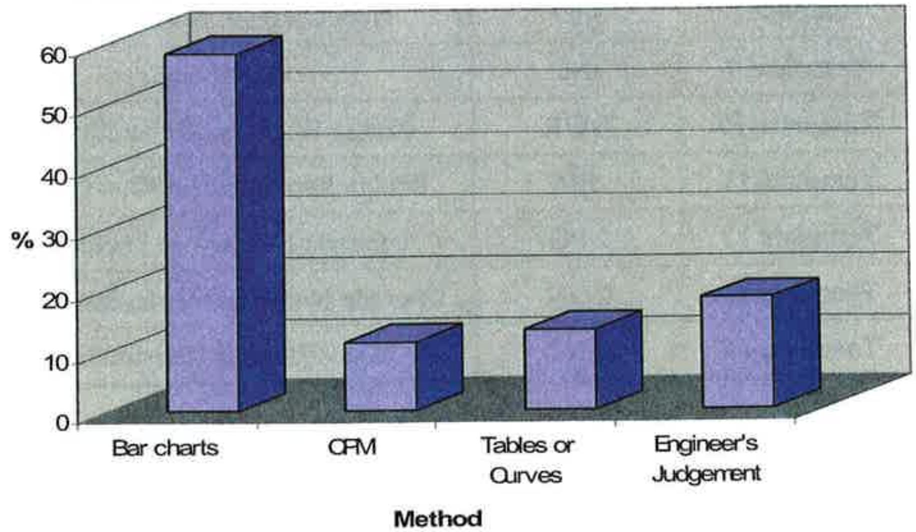

Figure 2.3: Methods used by DOT's to Establish Contract Time Duration (Hancher et al. 1992)

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

Templates	Name	Project Description
Template 1	SC	Seal Coat
Template 2	OV	Overlay
Template 3	RER	Rehabilitate Existing Road
Template 4	CNF	Convert Non-Freeway to Freeway

Templates	Name	Project Description
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.

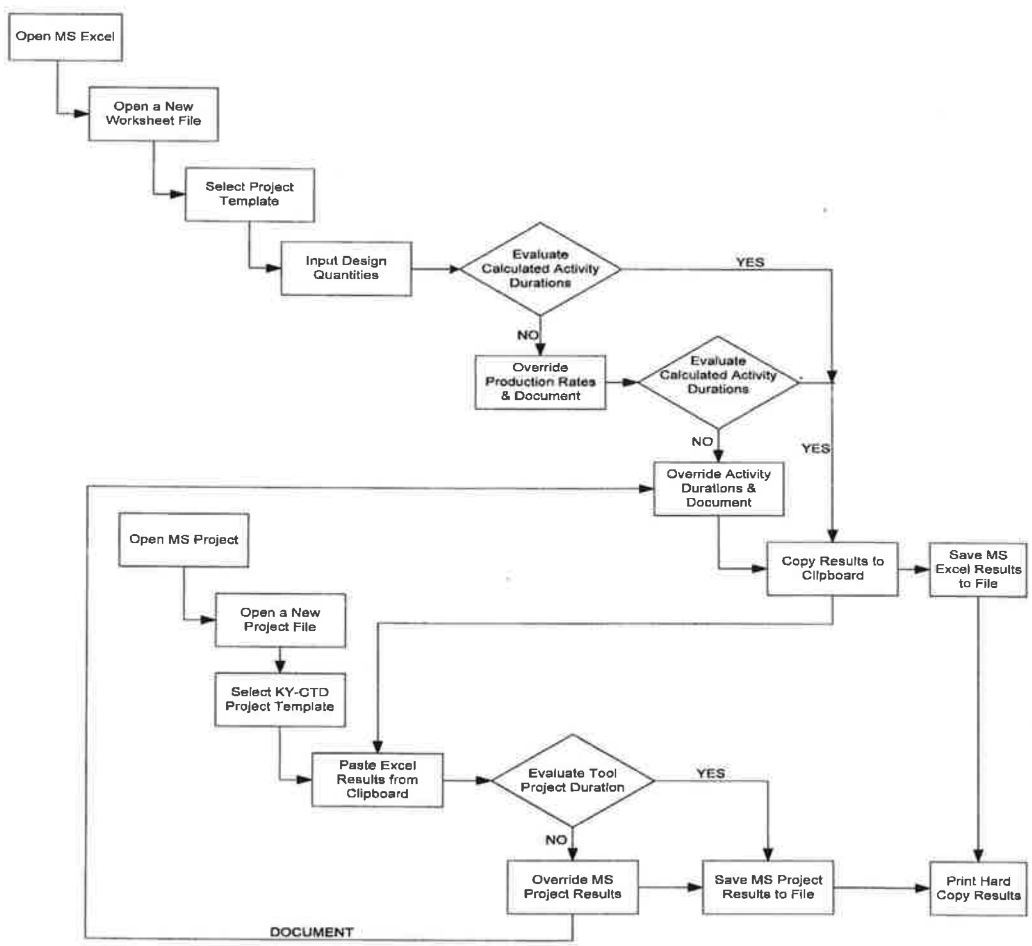

Fig 2.4: Kentucky – Contract Time Determination System Process Flowchart (Hancher & Werkmeister, 2000)

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,

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	Location , quantity of work	WAQ*, configuration

Item #	Work Item	Sensitive Factors CTDS Considered	Sensitive Factors the Research Found
	concrete pavement		
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.

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. Table 2.3 suggests the various drivers that need consideration and also compares it to the factors that were considered in the CTDS research.

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.

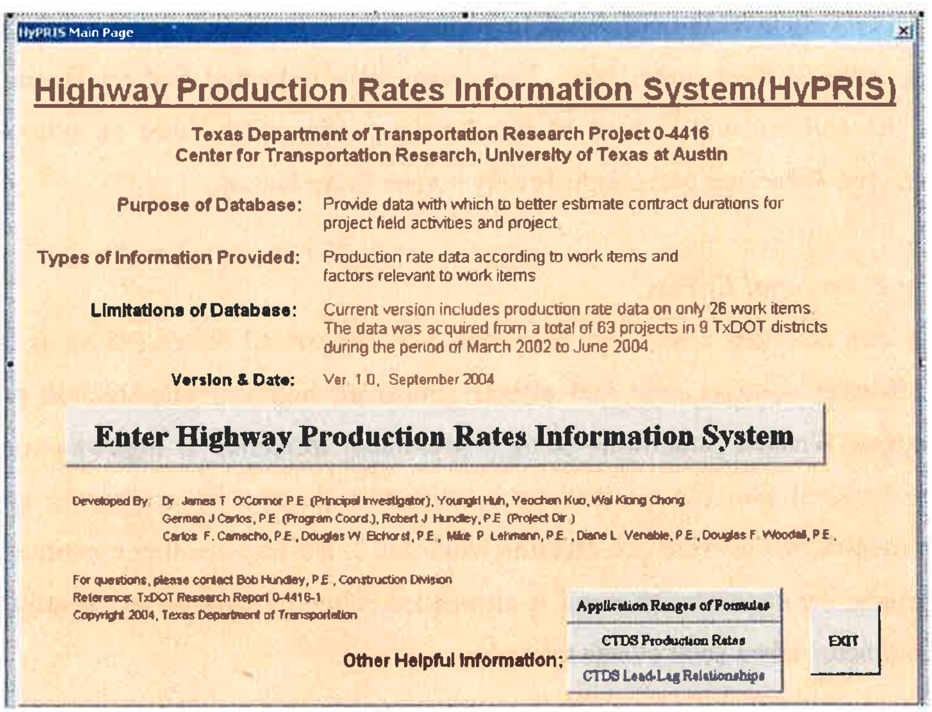

Fig 2.5: HyPRIS Main Frame

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%).

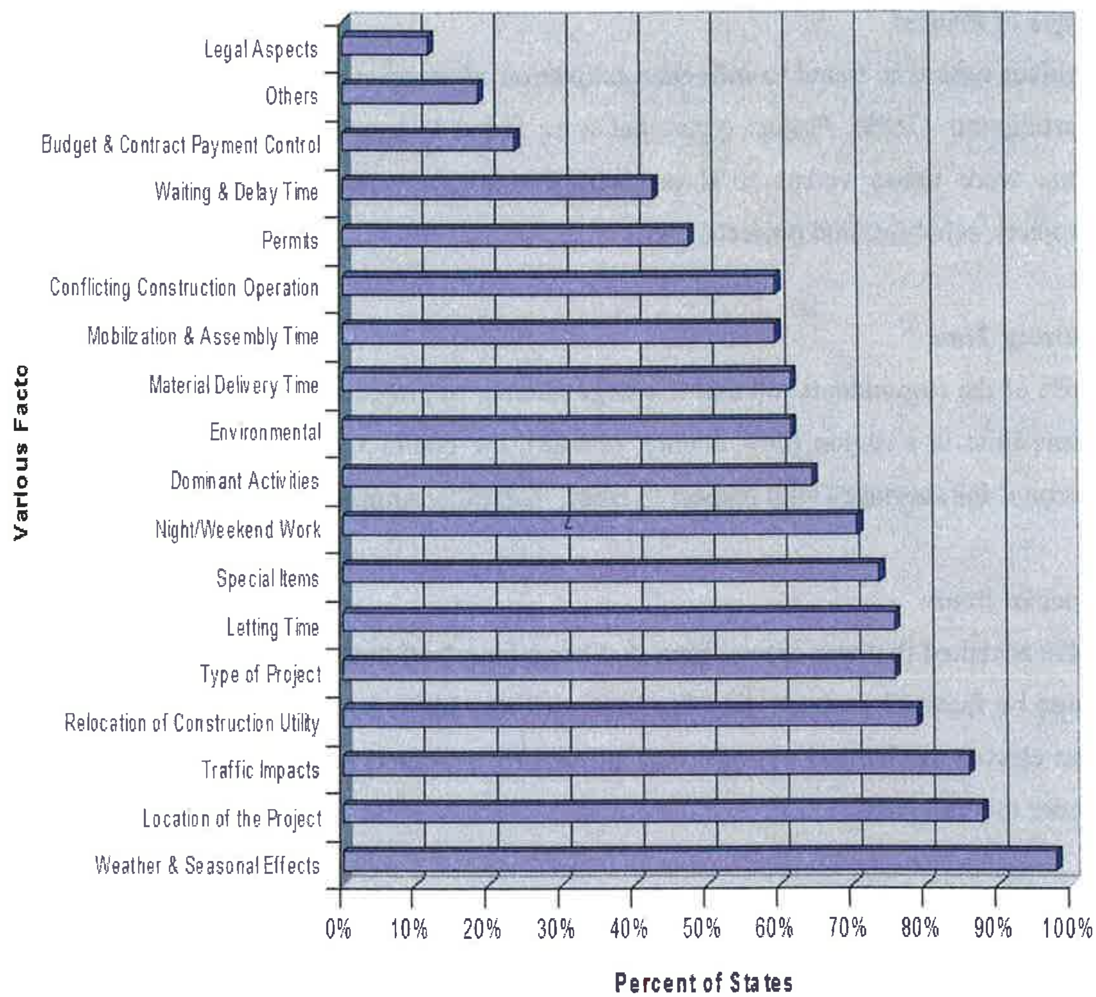

Fig 2.6: Major Factors that affect contract time, adopted from (Herbsman & Ellis, 1995)

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 survey participants (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 survey respondents rated it as 65%.

Environmental issues

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%). This mobilization time typically ranges from 3 days up to 40 days in some DOTs. An ideal mobilization time needs to be estimated based on factors such as project size, location, complexity, and equipment needs.

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 completed 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 activities that need to have the proper amount of time allotted for in order to have an accurate contract time. These activities include items such as review of shop drawings, settlement of earthwork overburden (if needed) and the curing of concrete pavement and structures.

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 constructability analysis and value engineering.
- Legal Issues.
- Budget and contract payment control.

3 CLASSIFICATION OF ODOT HIGHWAY PROJECTS

3.1 Tier System of Highway Classification

In terms of contract time determination, ODOT classifies highway projects into three different tiers or categories (See Fig 3.1.) Tier I projects include those which are highly complex, consist of multiple phases, and are subject to congestion. Examples would include A+B bid projects and most urban interstate reconstruction projects. Tier I projects require that contract time be established by highly specialized personnel using critical path method (CPM). Tier III projects are those which are very linear in nature (chip seals, overlays, guardrail replacement, etc.) or single point source (replacement of a county bridge with little roadwork, bridge redecking, traffic signal, etc.) Contract time for Tier III projects can easily be generated based upon production rates for a few linear or point source activities. These projects typically use standard designs and are not subject to as much variability due to sequencing or phasing of activities. Tier II projects are those which fall in between the Tier I and Tier III projects. While they may be multiphase in nature and involve many project components, they are not as complex as urban freeway type work. Tier II projects may occur on interstates, state highways, arterial roads and even on the local system.

It is estimated that approximately 40% of the projects let by ODOT annually fall within the Tier II classification (7.5% for Tier I and 52.5 % for Tier III). The current system of determining contract time does not adequately distinguish between these various types of projects and consequently is not consistent from project to project in terms of the effort expended for the determination of contract time. Sometimes the effort provided is commensurate with the project scope and sometimes it is not.

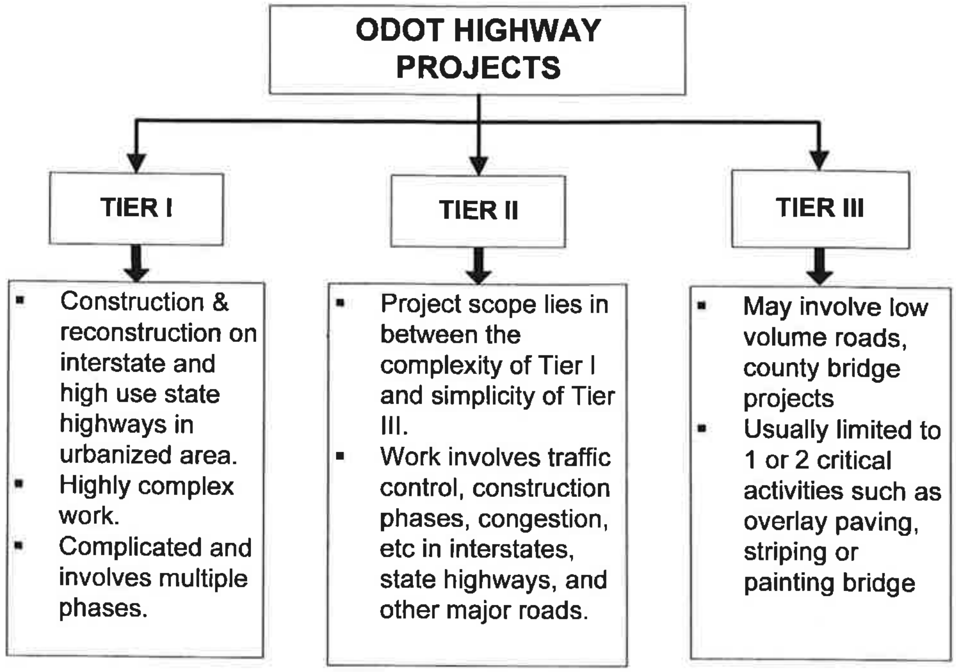

Fig 3.1: ODOT Tier System for Highway Projects

Based on the recommendations from the process review report (ODOT 2006), this study utilizes the tiered classification for calculating contract time and development of contract time procedures for ODOT highway projects. For each Tier of projects, standardized templates are developed that would fit individual projects. The characteristics of using standard templates are:

a) 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.
b) Each template may require minor adjustments to production rates and template logic which would factor in project location, soil and topography conditions, etc that would be specific to each project.

This study focuses on developing contract time estimation procedures using standardized templates for projects that are performed under Tier II and III type highway projects.

3.2 Tier II Projects

The characteristics of Tier II projects are as follows:

a) They are not as complex as Tier I type highway projects
b) These projects may have characteristics similar to Tier I projects such as congestion, complicated traffic controls and several construction phases.
c) All projects under Tier II category also require time established using CPM.
d) They do not include urban freeway, or many unique features such as railroad or pedestrian crossing structures.

Tier II projects can be classified as in Table 3.1. The following sections will describe each type in detail.

Table 3.1: Classification of Tier II Projects

No.	Project Name
a	Reconstruct Existing Alignment/ Rural Interchange
b	Widen/ Reconstruct Existing Alignment
c	Reconstruct City Street
d	Construct Bridges and Approaches
e	Construct Bridge Box and Approaches
f	Intersection Modification
g	Bridge Rehabilitation/Repair
h	Roadway Repair/Overlay

3.2.1 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 constructed or extended depending on the scope of the project.

3.2.2 Widen/ Reconstruct Existing Alignment

The projects in this category typically consist of widening a 2-lane highway to add shoulders or additional lanes. They may include construction or extension of drainage structures and existing bridge structures may require widening.

3.2.3 Reconstruct City Street

The projects in this category require reconstruction or widening of existing city streets. Typically, old pavements are replaced, drainage structures are upgraded, and often signals and lighting are added or upgraded.

3.2.4 Construct Bridges and Approaches

Projects in this category include replacing existing bridge structures on a rural highway or a county facility. The bridges may be single span or multispan and often include required detours, roadway approaches, and traffic control.

3.2.5 Construct Bridge Box and Approaches

Projects in this category include replacing existing bridge box structures on a rural highway or a county facility. The bridge boxes may be single cell or multicell and often include required detours, roadway approaches, and traffic control.

3.2.6 Intersection Modification

These projects are usually constructed on municipal city streets and involve reconstructing or upgrading an existing intersection. They typically involve traffic signal replacement and may also involve replacement of pavement, curbs, drives, and sometimes lighting. An important aspect of these types of project is that all construction work is performed while keeping the intersection open to traffic.

3.2.7 Bridge Rehabilitation/ Repair

The projects in this category are for the purpose of fixing an existing bridge structure. The work may involve everything from minor deck and joint repairs, up to complete redecking and replacement of concrete rails. The work could also include repair of columns, pier caps, or beams and painting of the bridge structure.

3.2.8 Roadway Repair/ Overlay

Projects in this category include those with minor patching and overlay of the existing surface. If shoulders are added or widened, there may also some extension of structures and minor grading. While they can occur on interstates, state highways, or city streets they are distinguished from other categories in that they typically do not require major grading, utility relocation, or acquisition of right-of-way.

3.3 Tier III Projects

The characteristics of Tier III projects are as follows:

a) They typically involve very low volume road/s and county bridge projects
b) These projects are very linear in nature (chip seals, overlays, guardrail replacement, etc.) or single point source (replacement of a county bridge with little roadwork, redecking, traffic signal, etc.)

c) Contract time for these projects can be generated based upon production rates for a few linear or point source activities.

Tier III projects can be classified as follows (Table 3.2):

Table 3.2: Classification of Tier III Projects

No.	Project Name
a	County Bridge
b	Signal Installation
c	Striping or Guardrail
d	Bridge Repair/Joints
e	Bridge Painting/Waterproofing
f	Bridge Deck Repair/Redecking
g	Overlay
h	Chip Seal

3.3.1 County Bridge

The projects in this category include replacing existing span bridge or bridge box structures on the county system. Typically these are replaced on or near existing alignment with very little grading or roadway approach work. The road is closed during construction of the bridge and traffic will be detoured to adjacent roads using appropriate signage and barricades.

3.3.2 Signal Installation

The projects in this category consist of new signal(s) or replacement of an existing traffic signal and possibly minor modification to existing intersection curb-line geometrics.

3.3.3 Striping or Guardrail

The projects in this category consist of re-striping an existing roadway or removing and replacing existing guardrail along with end treatments.

3.3.4 Bridge Repair/Joints

The projects in this category consist of repairing or replacing joints as well as minor bridge deck repair on existing span bridge structures.

3.3.5 Bridge Painting/Waterproofing

The projects in this category consist of the repainting of existing span bridge structures or the application of penetrating sealer to the concrete components of existing span bridge structures.

3.3.6 Bridge Deck Repair/Redecking

The projects in this category consist of patching the existing deck or removal and redecking of existing span bridge structures.

3.3.7 Overlay

The projects in this category consist of overlay or milling & overlay of the existing pavement. These are maintenance type overlays which are typically thinner than 3" and do not include any widening or drainage structure work.

3.3.8 Chip Seal

The projects in this category consist of application of bituminous material and aggregate chips in order to provide a smoother riding surface and seal off the pavement. Also included in this category would be any slurry seals.

In addition to these Tier II and Tier III templates, a Tier I General Template was also developed which includes the major controlling activities and can be used as a guideline for the CPM analysis of Tier I projects. Tier I level analysis is recommended for all urban interstate and complex projects on high volume arterials (average daily traffic (ADT) exceeding 60,000 vehicles per day.)

4. MANUAL SYSTEM FOR CONTRACT TIME DETERMINATION

This chapter describes each stage in developing a manual system for contract time determination for ODOT. It includes the concepts of templates and controlling activities, production rates, development of activity relationships, and the process required in using the manual system for determining contract time for highway projects.

4.1 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:

a) The project controlling activities have a huge volume of work to be performed.
b) 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.
c) 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.
d) 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. Fig 4.1 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.

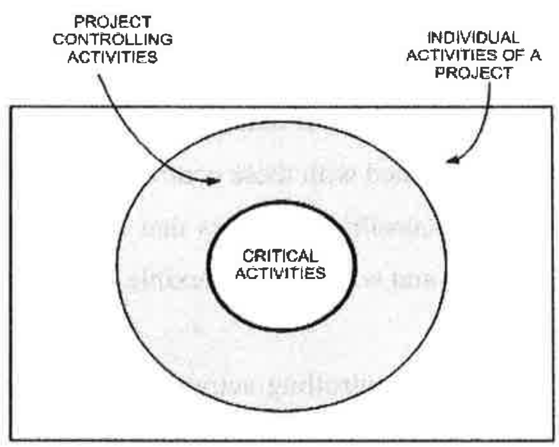

Fig 4.1: Concept of Project Controlling Activities

To explain this concept, consider a simple project of installing sewer and utility lines as shown in Fig 4.2.

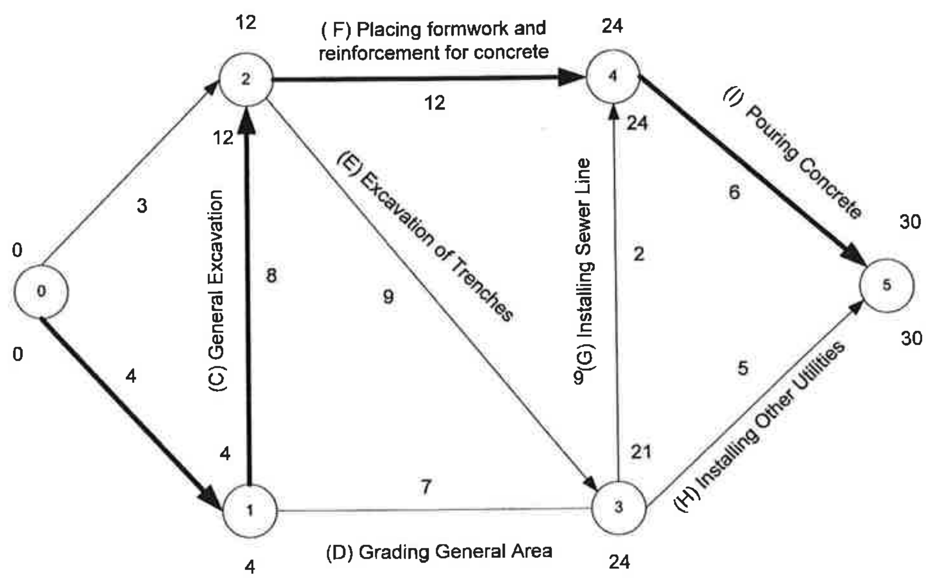

Fig 4.2: Installing Sewer and Utility Lines Project Network Diagram

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 4.1). 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 4.1: Sewer Project Activities Sorted Based on their Classification

Controlling Activities	Critical Activities	1. Site Clearing 2. General Excavation 3. Placing Formwork & reinforcement for concrete 4. Pouring concrete
	Controlling Activities	1. Excavation of trenches 2. Installing sewer lines 3. Installing other utilities
Non-controlling Activities		1.Grading general area

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.

Each project is made of several project components which include roadway, bridge, and drainage structures. In turn, the components are broken down into sub-operations called modules (See Fig. 4.3) which have to be performed for the timely completion of the project component and overall project. A module consists of a combination of controlling activities, of which some may be critical with others being non-critical. For example, a project that reconstructs existing alignment with no bridges can be broken down into one project component and 3 modules, i.e., earthwork, base and pavement and their controlling activities. A signal project could be one work module supported by the controlling activities of trenching conduit, wiring and setting the signals. There is no fixed number of controlling activities that have to be part of a module and increased or decreased to fit the scope of the project.

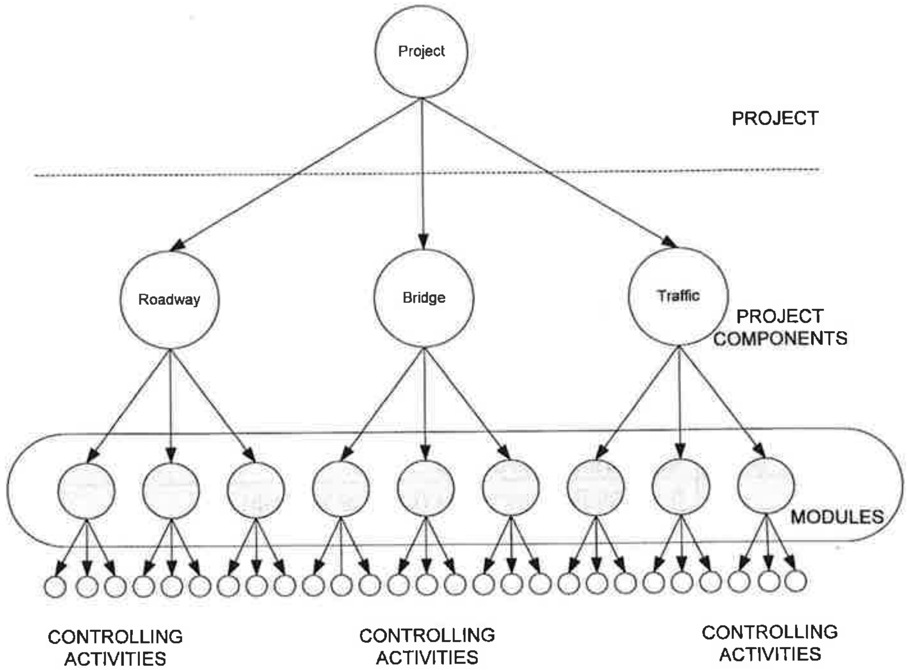

Fig 4.3: Operation Level Breakdown of a Project

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.

4.2 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 4.2. The Tier I template and all Tier II templates are shown in Appendices A and B.

Table 4.2: Example of Controlling Activities for Tier II Projects

S.N	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

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 Tier II project classifications, some modules may not be used in calculating a project's contract time. For example, in reconstructing a city street project the bridge or RCB modules may not be included, or in reconstructing existing alignment with rural interchange, the module for traffic signals could be excluded, thus reflecting the actual work involved in each project.

4.2.1 Ok-CTDS Tier II Templates

The next step after creating the project templates was to tie them to a project's pay item quantities for ultimately calculating the project duration. As an example, Table 4.3 shows the template for a Tier II project combined with data cells that will be filled with estimated quantities and production rate data will be necessary for calculating the contract time. The general template and other Tier II templates are included in appendix B.

Table 4.3: Reconstruction Existing Alignment/Rural Interchange

S.N	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 existing structures	sy/days					
	Excavate/ borrow Bridge Structure	cy					
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					

S.N	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Duration Override	Comments
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					

4.3 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). 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.

$$Activity\ \ Duration = \frac{Total\ estimated\ quantity\ of\ the\ activity}{\Pr oduction\ rate} \qquad (Eq.\ 4.1.)$$

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 4.4) that helped the user in estimating production rates.

Table 4.4: 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 (PR) 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 4.5 displays the entire list of controlling activities with their range of production rates.

Table 4.5: Production Rates chart for all controlling activities

S.N	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

S.N	Controlling Activities	Unit	Min Rate	Avg Rate	Max Rate
	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 judgments.

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 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. This will help project engineers avoid using "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, Texas DOT).

The production rates generated for ODOT in this research were developed using engineer's experiences and historical data which carry the 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.

4.4 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 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 diagrams will also show which activities within a certain project component will dictate the critical path necessary for the earliest completion of the project.

4.5.1 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 4.6 and Table 4.7 shows a template from the Texas and Kentucky CTDS using this approach.

Table 4.6: 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	

S.No	Major Work Items	Preceding Activities & Relationship
	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 4.7: 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

Item No	Activity	Predecessors
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 4.4). 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.

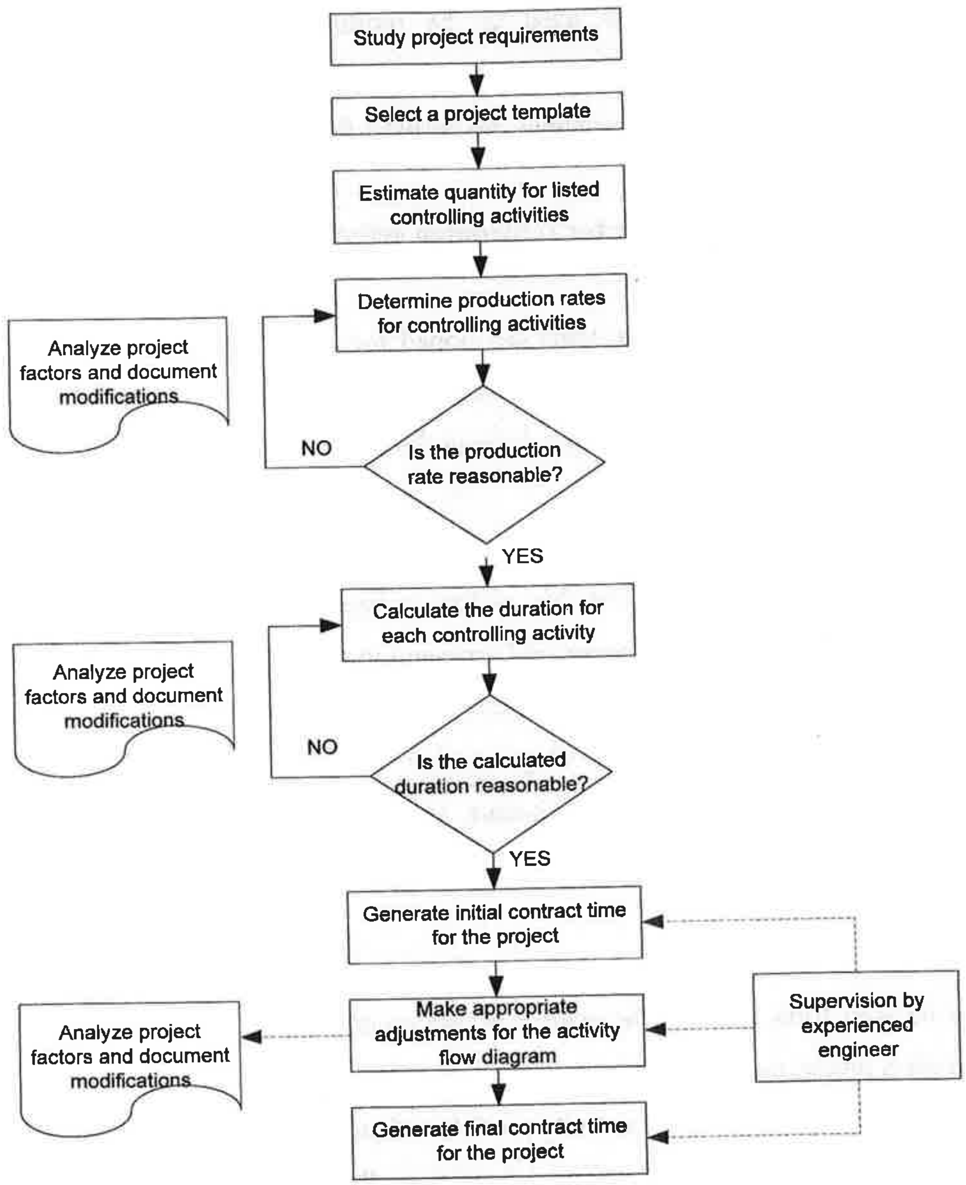

Fig 4.4: Procedure for Manual Contract Time Determination System

Once the sequence of construction 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. If they determine that the calculated duration in working days is either less or more than required, they need to recheck and re-calculate the durations for individual controlling activities by working with different production rates. If there are no issues with the production rates used and there is still a dispute with the duration calculated through the schedule, the finish-start template activity logic would need to be modified to suit the project specific characteristics and constraints thereby calculating a project duration or contract time in working days which is more reasonable and realistic for contractors to construct.

4.4.2 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 4.5). The logic defined for individual Tier II and III templates can be found in the Appendix B and 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.

As can be seen from Fig 4.5, 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.

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

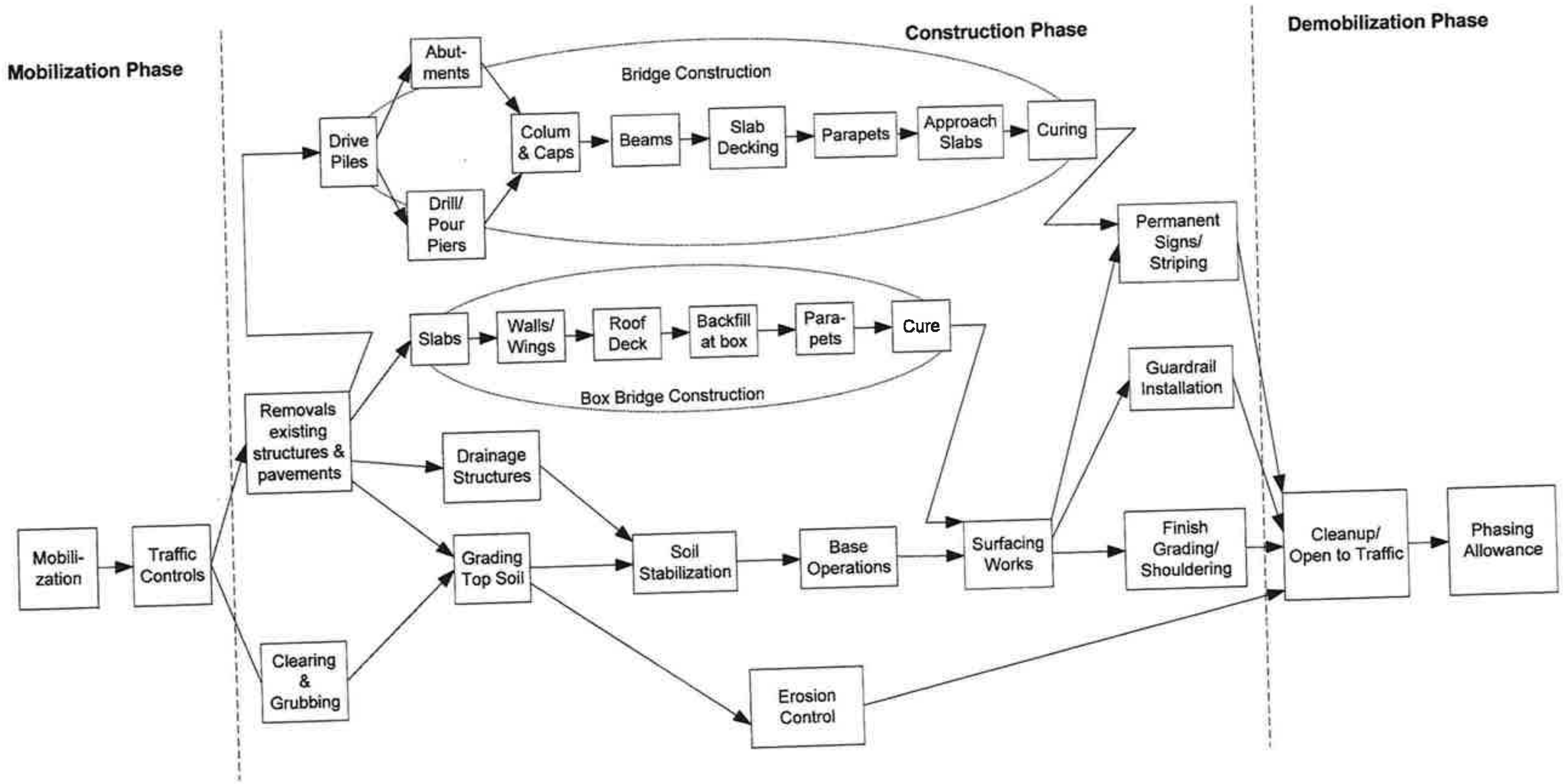

Fig 4.5: Activity Logic for Tier II – 2a Reconstruct Existing Alignment/ Rural Interchange Template

On completing the removals, the construction phase begins on the 3 project components as they pertain to the scope of the contract. Based on the project scope and its requirements, work commences simultaneously on the modules titled as bridge construction, box bridge construction and drainage structures. Timely completion of each module represents successful completion of the construction phase. 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 4.6 and Fig 4.7. 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.

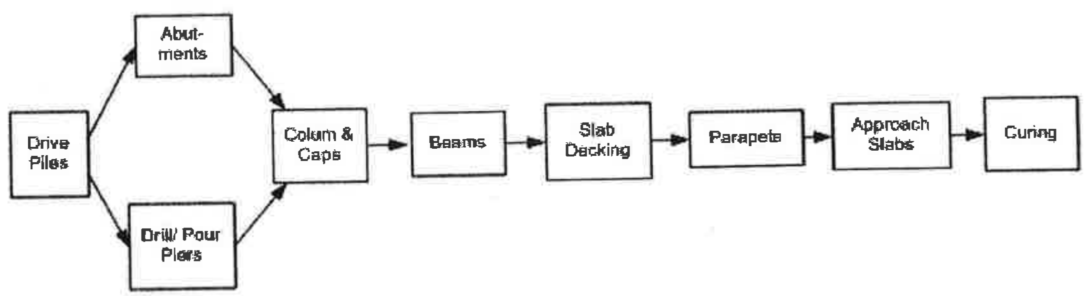

Fig 4.6 Logic for Bridge Construction Activities

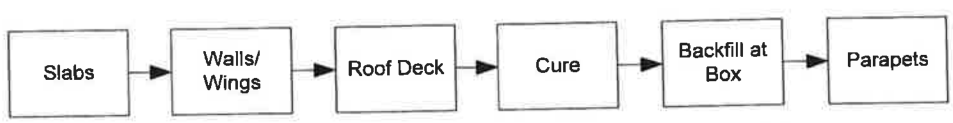

Fig 4.7: Logic for Box Bridge Construction Activities

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.

4.5 Oklahoma Contract Time Determination System- Manual system

The following section details the manual system of contract time determination and the process flow is graphically represented in Fig 4.8 (See next page).

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.

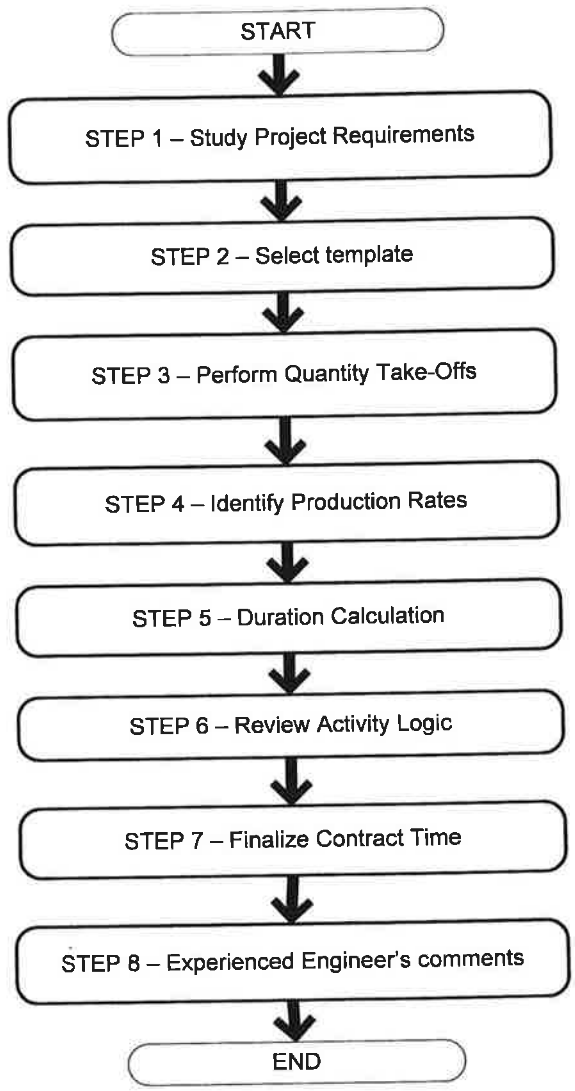

Fig 4.8: OK-CTDS Manual System Flow Process

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 contract drawings 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.

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: Finalize Contract Time

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 calendar 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. DEVELOPMENT OF COMPUTER PROGRAM :OK-CTDS

A computer software program is developed incorporating all the aspects of contract time determination system described in Chapter 4 in order to assist the users 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. In this chapter, the validation results of this software are also discussed. Finally, it discusses how OK-CTDS is different from other states' contract time determination system.

5.1 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.

5.1.1 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 5.1 shows a screenshot of the main input screen.

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 5.1).
b. List All Projects: When this function is activated, all the existing projects are retrieved and are displayed in the list box (see Fig 5.1).
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 5.1).
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.

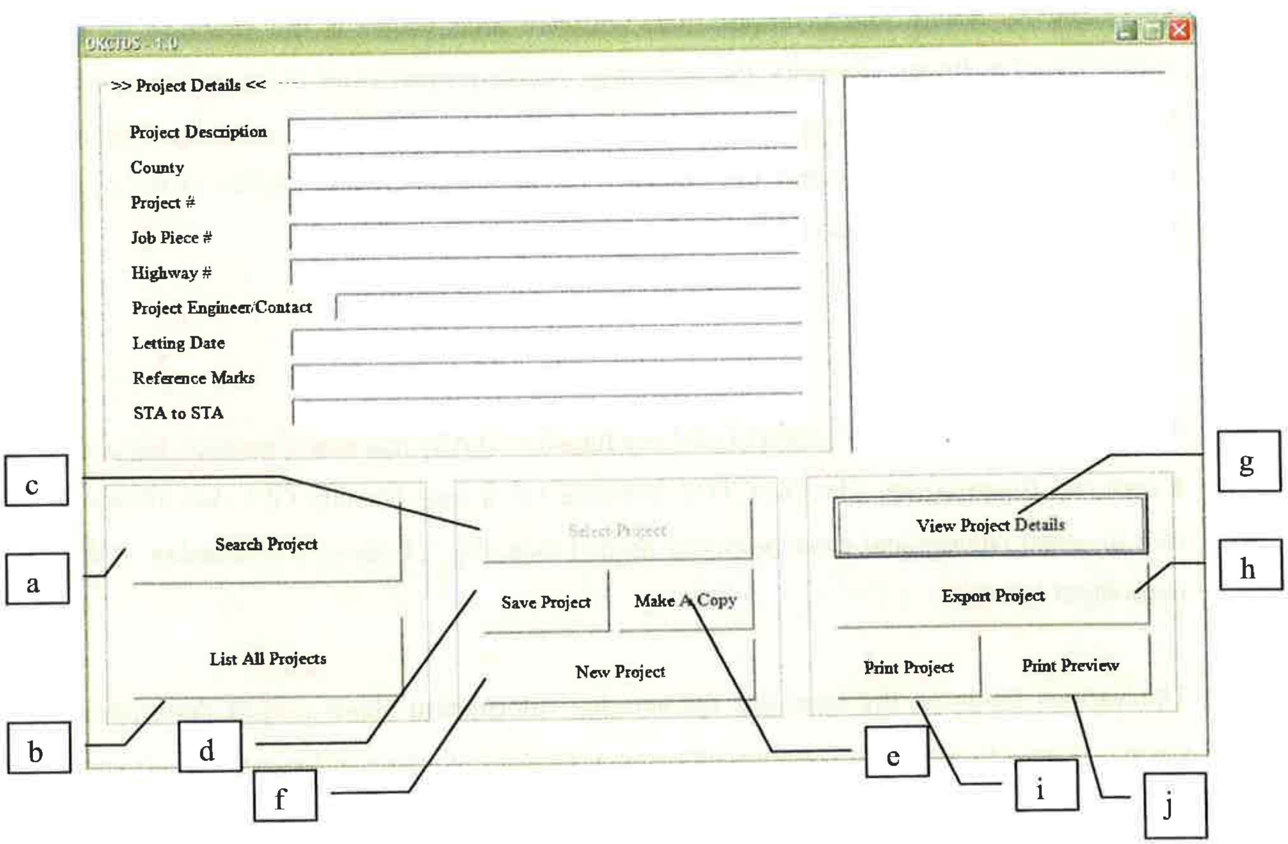

Fig 5.1: Screenshot of Ok-CTDS Application

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.

5.1.2 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 5.2.

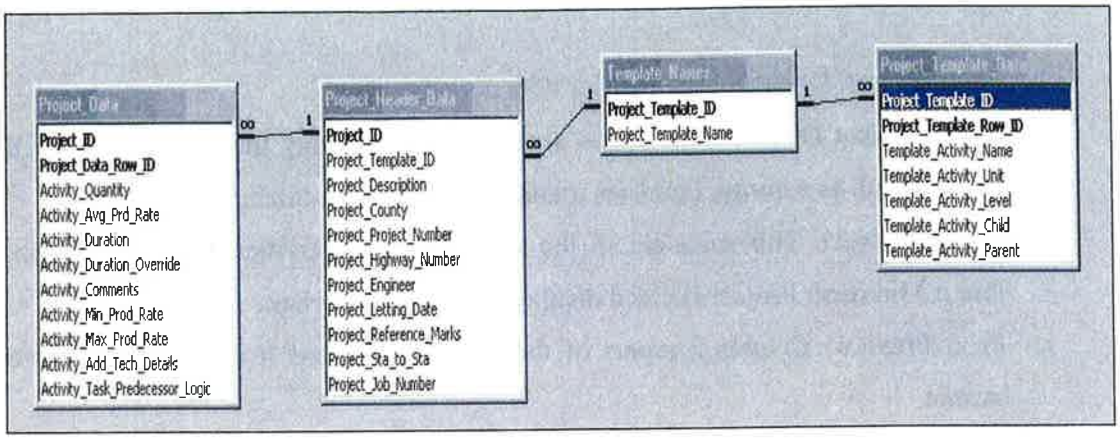

Fig 5.2: Relation between Various Tables in the Database.

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.

5.2 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 5.3 shows the data flow diagram for Ok-CTDS tool.

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.

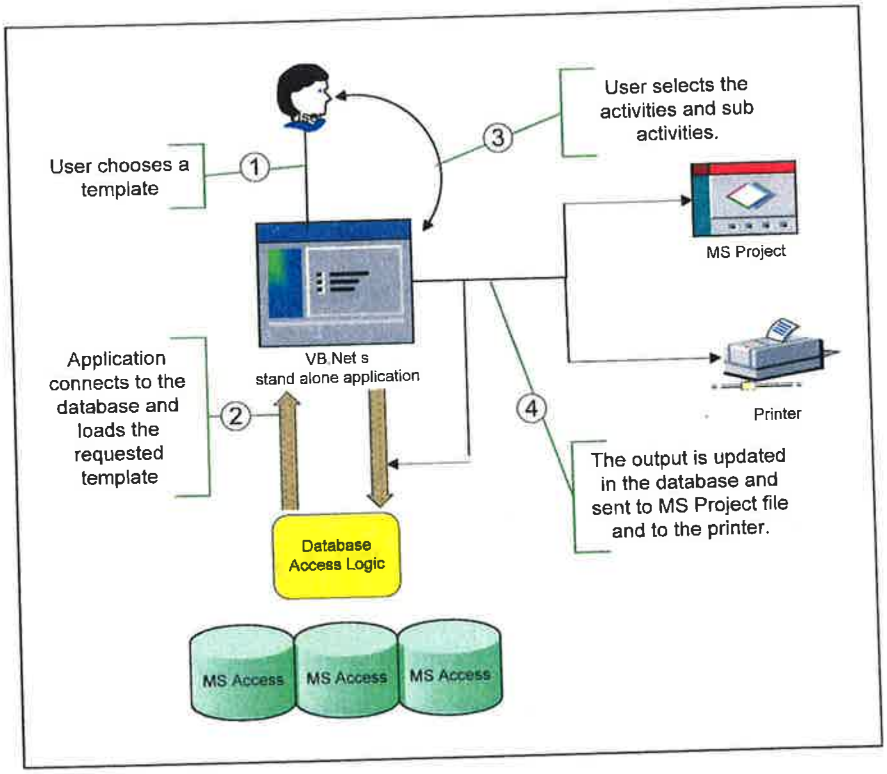

Fig 5.3: Schematic Representation of Process Flow

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 5.4 which gives a schematic representation of the algorithm that a process follows. 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.

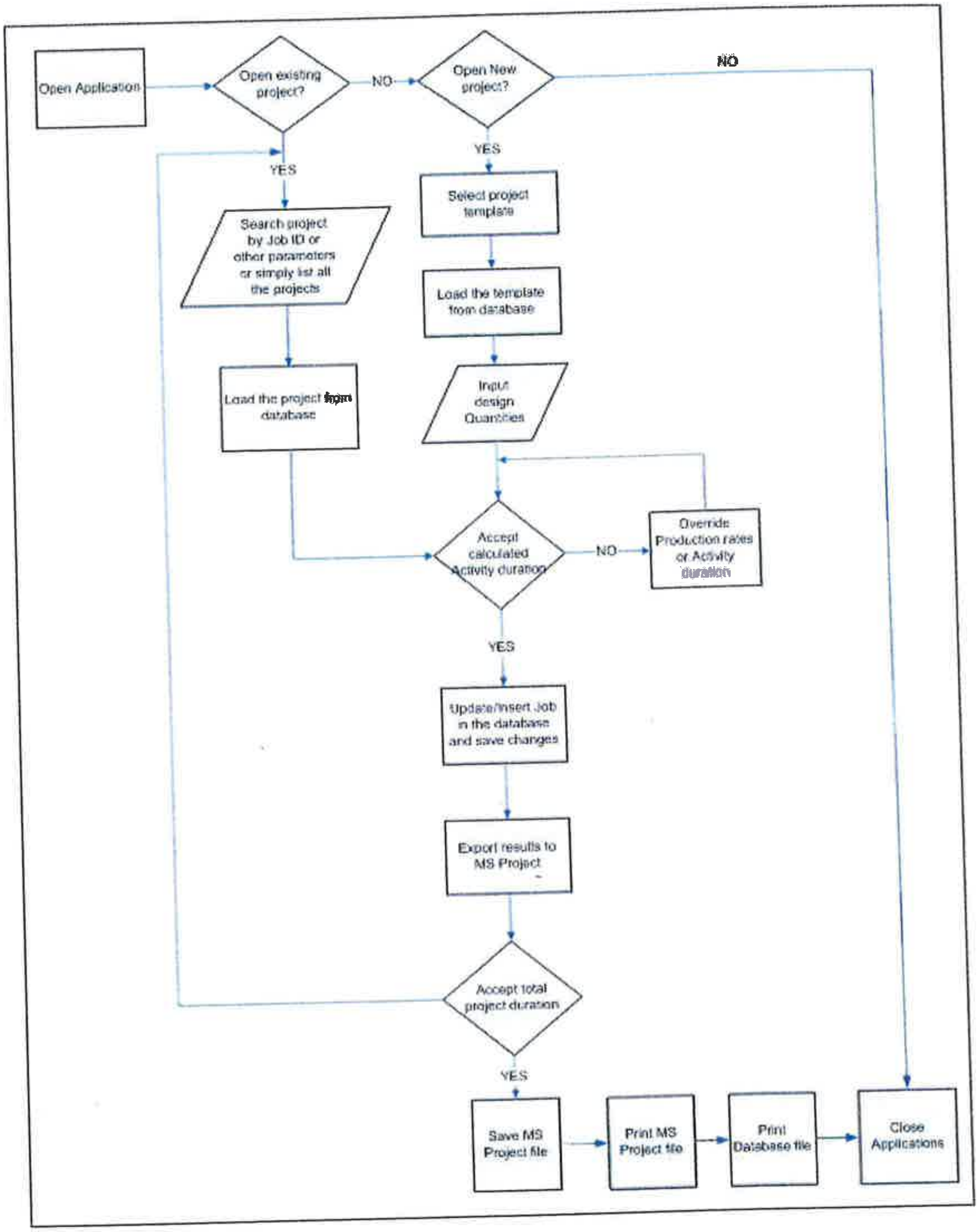

Fig 5.4: Process Control Flowchart of the Software

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.

5.3 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 (2^{nd} 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

5.3.1 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 5.5). The user needs to select the odot_data file and open it.

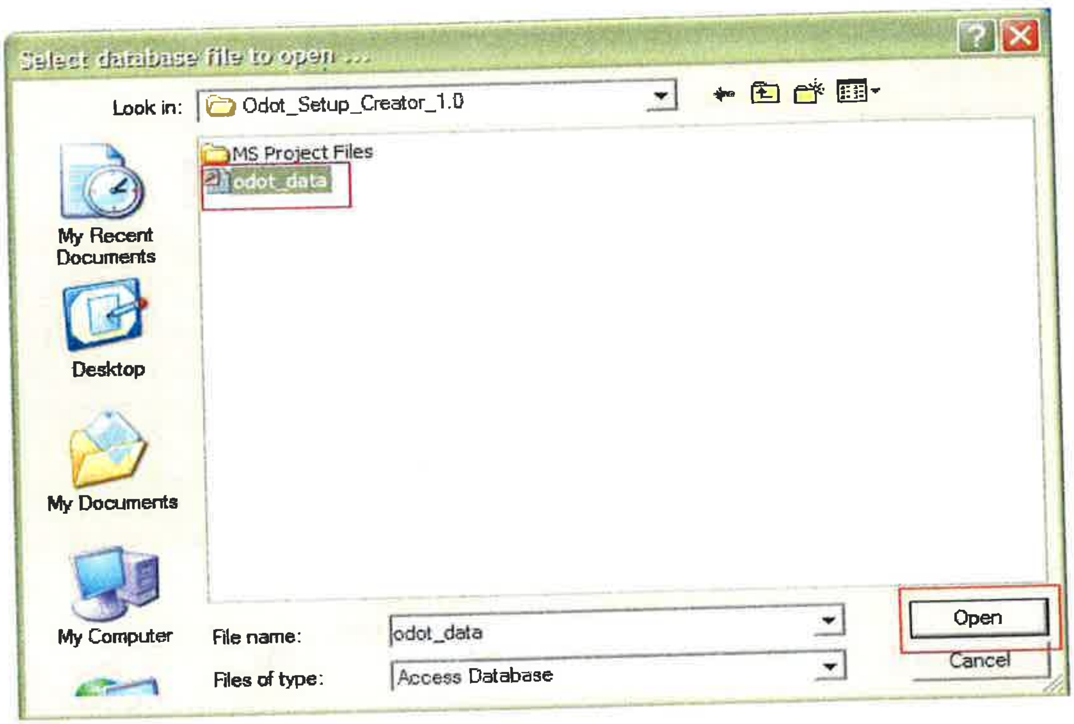

Fig 5.5: Opening Database File

5.3.2 Project Header Screen

On selecting the ODOT database file, a project header screen opens up as shown in Fig 5.6. 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.

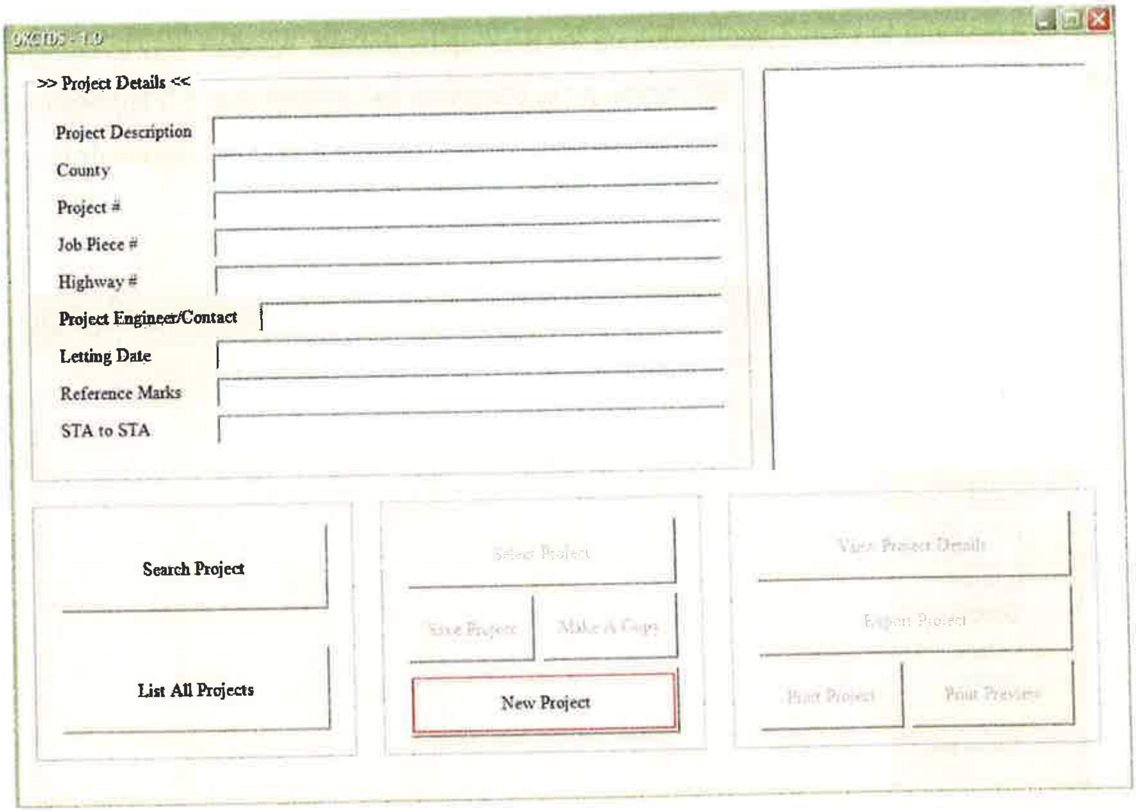

Fig 5.6: Project Header Screen

5.3.3 New Project Selection

Once the "New Project" button is clicked, a screen pops up, as can be seen in Fig 5.7, 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.

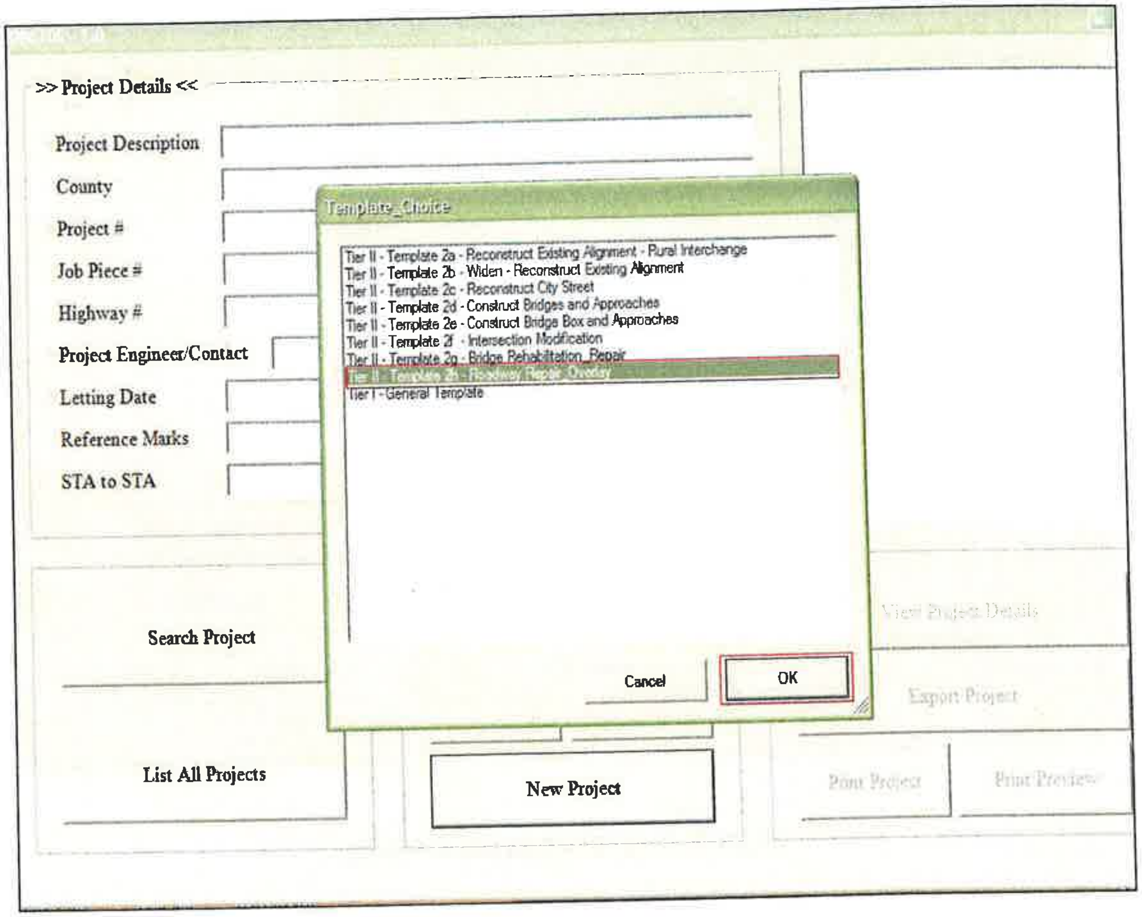

Fig 5.7: New Project Selection Screen

5.3.4. 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 5.8). After entering all the relevant information, click on "View Project Details" button.

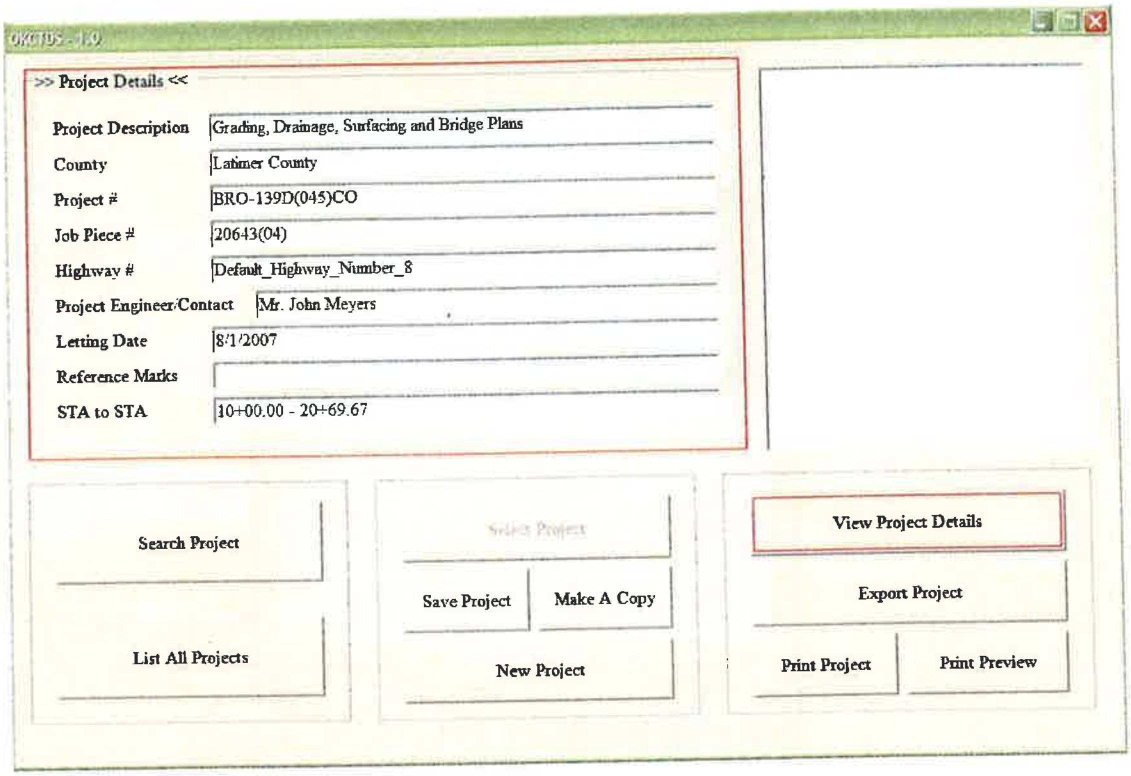

Fig 5.8: Project Information Screen

A new window opens up as can be seen in Fig 5.9. 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.

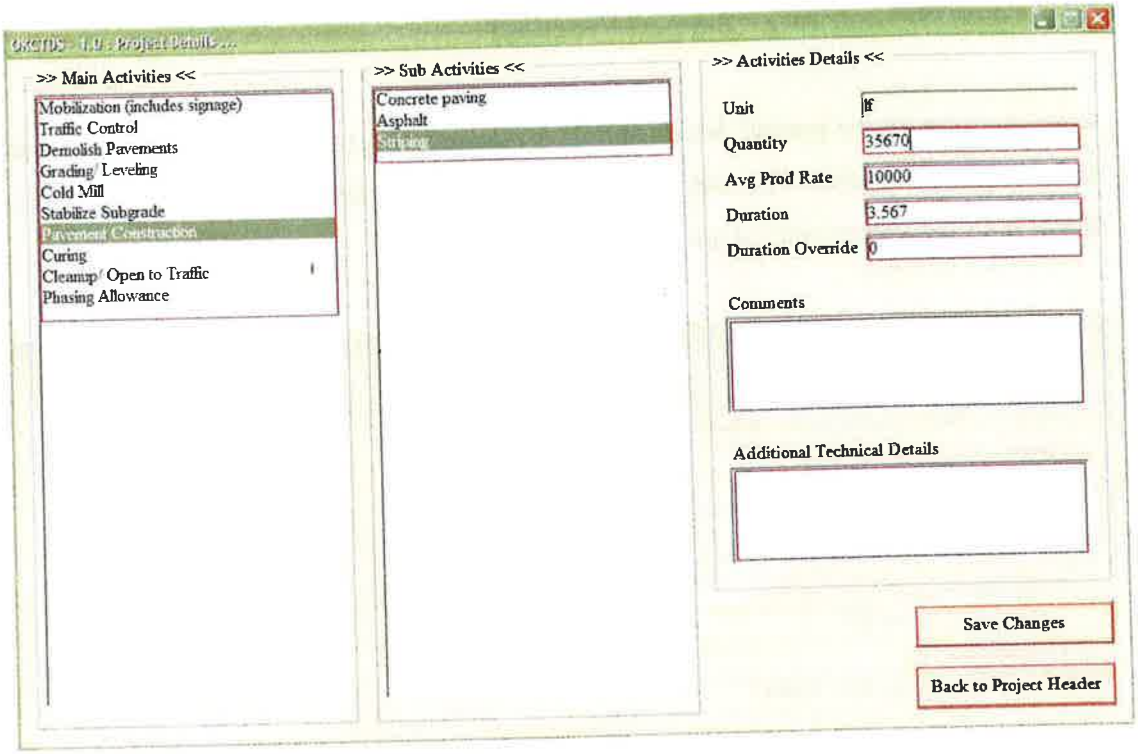

Fig 5.9: Detailed Project Information Screen

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".

5.3.5 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 5.10) to check if all the values entered are reasonable and realistic.

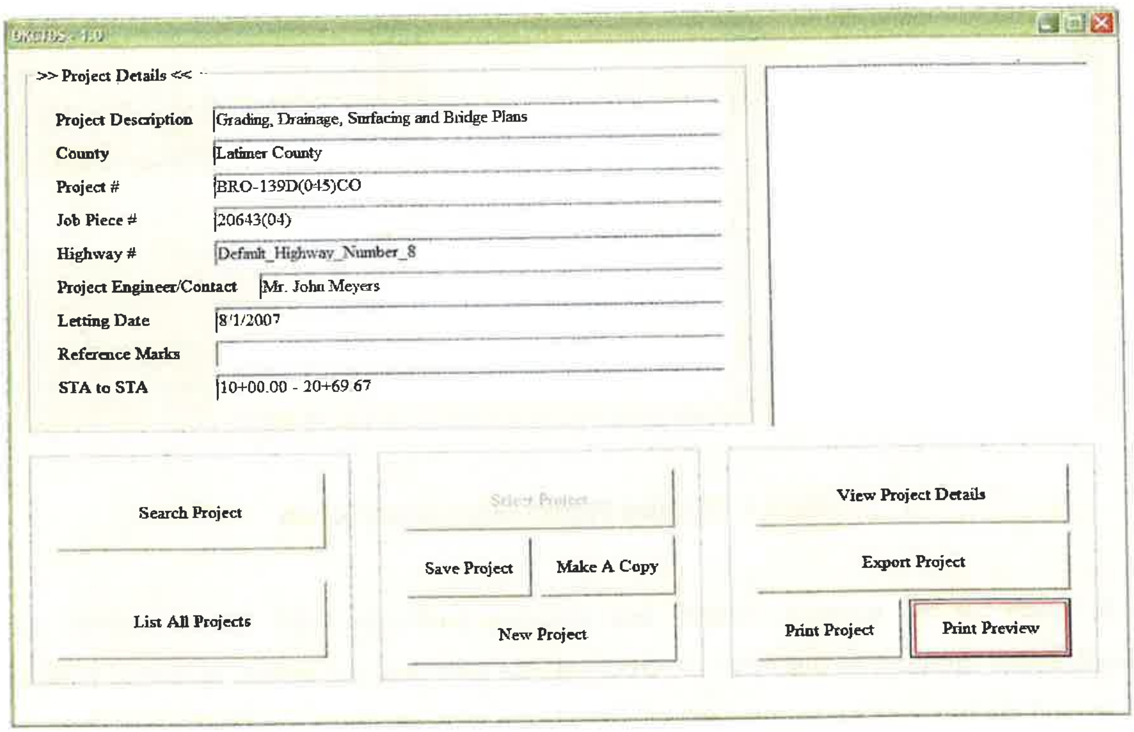

Fig 5.10: Software Command Functions

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 5.11.

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 5.11: 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 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 5.12.

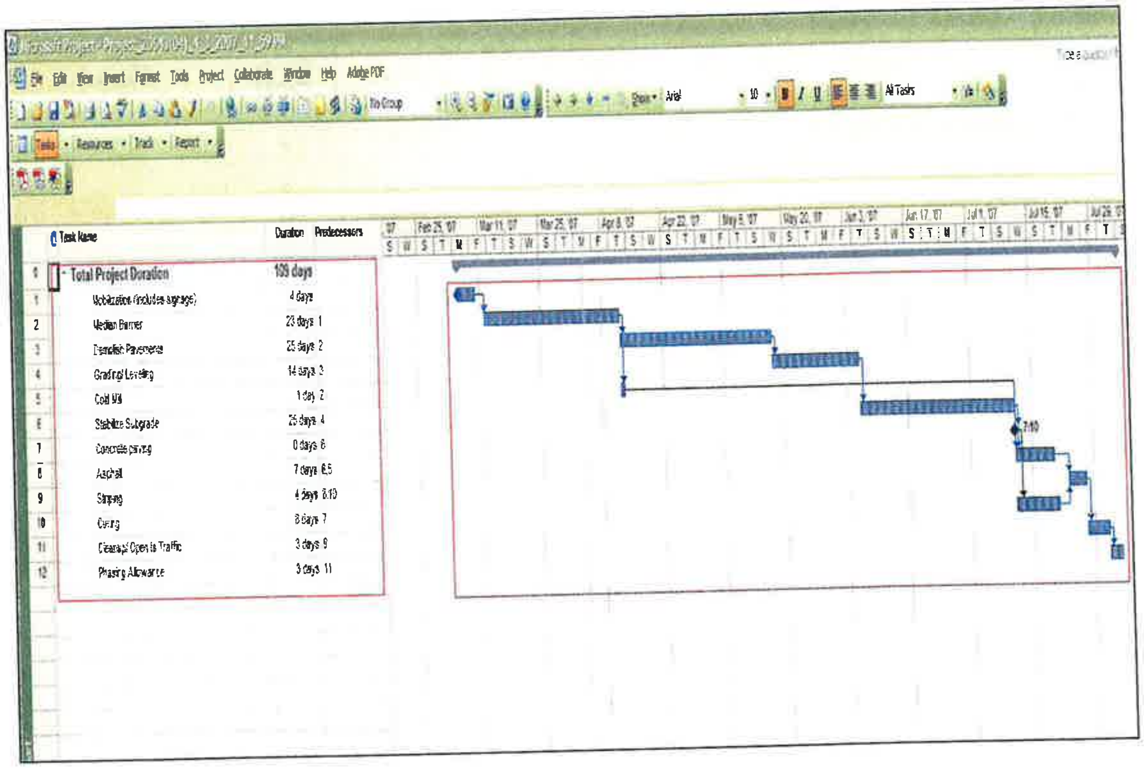

Fig 5.12: Total Project Duration and CPM Network Diagram in Microsoft Project

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

5.4 Conversion of Working days into Calendar Days

The OK-CTDS system produces contract time in working days. Contract time in working days should be converted into calendar days. When contract time is on a calendar day basis, it shall include all Sundays, holidays, and not working days. The number of actual working days in a week and number of days the work stopped due to adverse weather conditions and the holidays must be considered to determine the calendar days. The following section explains how to convert the contract time in working days into calendar days.

5.4.1 Working Days per Week

A contractor may work 5 or 6 days a week during the life of the contract in order to complete the project within the allotted contract time. Project duration calculated in working days should be divided by a certain ratio to get a project duration considering non-working days per week. If the crew works five days a week, the ratio would be 5/7 so, the weekend of Saturday and Sunday can be added to get the calendar days. If the crew works six days a week, the ratio would be 6/7 and Sunday is included to get the number of calendar days.

5.4.2 Weather Days

Normal adverse weather days should be included in contract time. Normal adverse weather means adverse weather which, regardless of its severity, is to be reasonably expected for the particular place at the particular time of the year. The normal adverse weather days included in the Contract time are based on historical records of temperature and precipitation for the eight Department Field divisions shown in Table 5.1.

Actual adverse weather days are those meeting one or more of the criteria in “a”, ”b”, “c”, “d” below. Time extensions for days meeting more than 1 criteria will take into consideration only that criteria having the greatest impact. Those actual adverse weather days covered by criteria a, b or c that are in excess of the days in the Table 5.1 will be allowed without regard to when they occur (except prior to mobilization or during suspension for other reasons) or their impact on contract completion. However, those days covered by criteria d will be subject to the limitations as noted.

a. Days with maximum temperature of +32 degrees Fahrenheit (0 degrees Celsius) or less – one full day allowed.

b. Days with minimum temperature of +32 degrees Fahrenheit (0 degrees Celsius) or less, but whose maximum temperature is over +32 degrees Fahrenheit (0 degrees Celsius) – one – half day allowed.

c. Days when ½ inch (12.7 mm) or more precipitation (rain or snow equivalent) occurs – one full day allowed.

d. Days when weather related conditions exist which prohibit proper performance of work as specified – one full day allowed. Allowance of such days will be subject to the work which is being delayed, being critical to timely Contract completion and the Contractor making every reasonable effort to minimize the adverse impact of the conditions.

Table 5.1 Normal Adverse Weather Days by ODOT Division

MONTH	DIVISIONS							
	1	2	3	4	5	6	7	8
JANUARY	8	7	8	8	7	9	8	9
FEBRUARY	6	6	6	7	6	7	6	7
MARCH	6	5	5	5	4	6	3	6
APRIL	4	4	4	3	2	3	3	3
MAY	4	4	4	3	3	3	3	3
JUNE	3	2	3	3	2	2	2	3
JULY	2	2	2	2	2	2	2	2
AUGUST	2	2	2	2	1	2	2	2
SEPTEMBER	3	3	2	2	2	1	2	3
OCTOBER	3	3	3	3	2	2	3	3
NOVEMBER	5	4	4	4	4	5	4	5
DECEMBER	7	7	6	7	7	8	6	7

5.4.3 Holidays

National and State Holidays must be added to the contract time in calendar days. One needs to estimate the expected project start date and project duration. Based on this estimation, the number of holidays is estimated and added to the contract time in calendar days.

5.5 Validation of OK-CTDS

In order to validate the OK-CTDS, two recently completed highway projects were selected. One was constructed in Choctaw County, OK and the other in Roger Mills County, OK. The Choctaw County project falls under Tier II's second project type - widen & reconstruct of existing alignment in which the main scope of work includes grading, widening, drainage and resurfacing works. The project took about 180 calendar days to reach completion. The Roger Mills County project falls under the Tier II's eighth project type - roadway repair and overlay and it took around 30 calendar days to complete. These two projects didn't have any major delays during their construction.

The following procedure was used to validate the program. First, a project scheduler in the Central office of ODOT was asked to estimate contract time of the two projects using his traditional method. The scheduler was provided with the contract specifications and plans. Second, the OK-CTDS was used by the scheduler to develop contract time for these two projects. The calculated project durations from OK-CTDS were converted into Calendar days for comparing with real duration of the projects and the contract time determined by the traditional method. Table 5.2 shows the results of this comparison.

Table 5.2: Comparison of Project Durations

Projects	Actual Duration	OK-CTDS	ODOT Scheduler
Choctaw County Project	180 days	177 days	175 days
Roger Mills County Project	30 days	35 days	38 days

For the Choctaw country project, the contract time calculated by OK-CTDS is very close to the contract time determined by the ODOT scheduler and the actual duration of the project. For the Roger Mills county project, both OK-CTDS's and ODOT scheduler's contract time were higher than the actual project duration. The activity flow diagram for this type of project was revisited to make any corrections, if necessary. However, it was determined to be appropriate. Since it was not possible to obtain actual construction data such as daily resources used for the project, the reasons for this difference were not identified. However, the possible causes for this difference were attributed to such factors as continuously good weather conditions throughout the project duration, employment of more resources including crews and equipment that led to higher production rates for some activities and overtime work during weekend or holidays by the contractor. The closeness of contract times for the two projects calculated by the OK-CTDS and the ODOT Scheduler indicates the OK-CTDS is reliable to use for establishing contract time for bidding purpose (conceptual estimate) when a right project type and appropriate production rates for controlling activities are selected. However, it was also noted that the experienced schedulers in the central office must use his or her traditional manual method and this software to continue to test the OK-CTDS with more real projects until it is fully proven and before the software is released for use by division engineers.

5.6 Comparison between Various CTDS

Table 5.3 summarizes some key differences between OK-CTDS and contract time determination systems developed and used by other states. First, CTD systems for Texas, Kentucky, Louisiana and Oklahoma use predetermined sequential relationships of controlling activities for each type of highway projects while Florida and Indiana CTD systems do not mention any logic used for sequencing their controlling activities. In terms of arranging controlling activities, OK-CTDS has arranged controlling activities under the concept of modules so that it could help users classify controlling activities under different groups of construction components or operations. Similar approach was employed in Texas CTDS and Louisiana CTDS where controlling activities were grouped under different construction operations. Kentucky CTDS simply lists controlling activities and does not use any framework to arrange them other than graphical sequential flow of activities. Florida and Indiana CTDS only list controlling activities and are not arranged in any manner.

Table 5.3 Comparison Between OK-CTDS and other CTD Systems

Description	Texas CTDS	Kentucky CTDS	Louisiana CTDS	Florida & Indiana CTDS	OK-CTDS
Logical Flow of Activities	Sequenced flow.	Sequenced flow.	Templates are listed with selected activities.	No sequenced flow followed.	Sequenced flow
Arrangement of Activities	Sorted and arranged under main operations	No sorting and arranging of activities.	No arrangements performed.	No order set for arranging the activities.	Controlling activities arranged under the concept of modules.
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.	Similar approach to Texas CTDS	Published production rates are used	Chart provides default rate and range of values in terms of minimum, average and maximum.
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.	Similar approach to Texas CTDS	Engineer's opinion to factor project conditions.	No sensitivity factors used to adjust production rates.
Relationships between controlling activities.	Complex logic, leads and lags to define the relationships between controlling activities	Complex logic, leads and lags to define the relationships between controlling activities	Complex logic, leads and lags to define the relationships between controlling activities	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.
Method of scheduling	Bar chart	CPM	Bar chart	CPM	CPM
Type of system.	Partially automated system, using Lotus 1-2-3, Flash-up and SuperProject to generate bar charts.	Partially automated system, using Microsoft Excel and Microsoft Project to generate CPM schedule.	Partially automated system. Computers are used for production rate analysis and software is used for developing bar-charts.	Manual system. No software used	Automated system, which is a stand alone application. Microsoft Project is internally linked to generate CPM schedule.

In handling production rates, CTD systems for Texas, Kentucky, Louisiana and Oklahoma use production rate charts with a range of values (minimum, average, and maximum) for all their controlling activities. However, Texas CTDS uses five factors including location, soil conditions, quantity of work, traffic conditions and complexity as adjustment factors for localizing production rates of controlling activities. Louisiana

CTDS uses a similar approach to that of Texas CTDS to adjust the production rates. Kentucky, Florida, Indiana and Oklahoma CTD systems do not use any specifically defined factors for adjusting production rates but the user's experience and judgments. Florida and Indiana CTD systems use published production rates.

In terms of tools used for scheduling activities, Texas and Louisiana CTD systems both use bar charts while other CTD systems including OK-CTDS use CPM. Texas, Kentucky and Louisiana CTD systems use the successor and predecessor relationships to allow leads and lags in defining sequences of controlling activities. No pre-established logics are set for Florida and Indiana CTD systems. OK-CTDS utilizes a simple finish-to-start relationship to define the logic between controlling activities.

One of the most advanced features in OK-CTDS is the complete automation of the entire process from data input to the printout of CPM based schedule in a single program. It is a standalone computer software program which can automatically transfer input data to Microsoft Project for generating graphical schedule. Texas CTDS is a software system based on Lotus 123, Flash-up and SuperProject. Kentucky CTDS is a software program using Microsoft Excel and Microsoft Project. In order to develop a CPM schedule from Microsoft Project, the user needs to copy data from Microsoft Excel and manually paste into Microsoft Project. Louisiana CTDS is a partially automated system. Louisiana CTDS is used for production rate analysis and for developing project bar-charts. Florida and Indiana CTDS are manual systems which do not involve computers.

6 TRAINING

A series of training sessions was offered to ODOT engineers, district engineers, and consultants in Oklahoma. In total, five different training sessions have been offered on the following dates.

- August 7, 2007 (two sessions: morning and afternoon)
- August 8, 2007 (two sessions: morning and afternoon)
- August 13, 2007 (one session: morning session)

These training sessions were offered at the ODOT training Center, 1025 Southeast 59th Street, Oklahoma City, Oklahoma. A training manual was distributed on site. This training manual includes agenda, presentation slides, installation CD for OK-CTDS and manual for the software program. Each session took about two hours. It started with a brief explanation about how the system works, which is a theory oriented presentation and then, OK-CTDS software was explained step by step from software installation to the final printout of project schedule. After a short break, the drawing sets of two actual projects were given to participants for practice. Participants had hands-on experiences on how to determine contract time when drawing sets and OK-CTDS are available.

In addition to these training sessions, Brian Schmitt (ODOT Office Engineer) made a presentation at a Division Engineers' regular monthly meeting on August 9, 2007 to encourage them to use this software program.

7 CONCLUSIONS

7.1 Summary

This project (Phase II) has classified Tier III projects into eight different templates and a logic diagram has been developed for each of them. With Tier II and III templates and their logic diagrams (Tier II templates and their logic diagrams were developed in Phase I), a standalone computer application program has been developed. This software allows users to determine contract time in working days for all Tier II and III types of projects. 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.

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 to accommodate wide range of projects and conditions undertaken by ODOT.

The research team has also offered five training sessions for ODOT engineers and consultants in Oklahoma for fast dissemination and use of the software program.

7.2 Recommendations for Future Studies

The successful completion of Phase I and II of this study will allow ODOT engineers and consultants in Oklahoma to take advantage of the developed computer software when they try to determine contract time for their new projects. The developed software saves their time but improves the accuracy and confidence of their calculated contract time. However, one main limitation of the currently developed software is that it uses production rates from the ODOT production chart which was developed and updated more than 10 years ago. A 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). Bellanca et al. (1981) also recommends that a construction data file that covers the previous 3 to 5 yr should be used in determining production rates and contract time. It is also unrealistic to use production rates from commercially available cost estimating manuals such as RS Means Cost Guide or Richardson's Manual as their production rates are consistently lower than actual production rates on site (ODOT 2006).

The current ODOT production chart was developed based on the following data sources: 1) ODOT engineer's field experience, 2) ODOT construction control directive No. 92073 – Production rate posting, 3) production rates from neighboring states and 4) published construction industry data. Improvements in equipment technology since 1992 have made some of the production rates now in use inaccurate. During Phase I and Phase II, the research team collected current production rate data for some of the controlling activities from contractors and compared them to the ODOT production chart. Some of the actual production rates were well beyond the maximum production rate range and others were somewhat higher than ODOT's listed production ranges.

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. There is a need to investigate what factors are critically affecting the production rates of activities and how much. Once these factors and their degree of impact are identified and measured, it will assist project engineers to more reasonably estimate the production rates of controlling activities, and more accurately calculate the contract time of highway projects.

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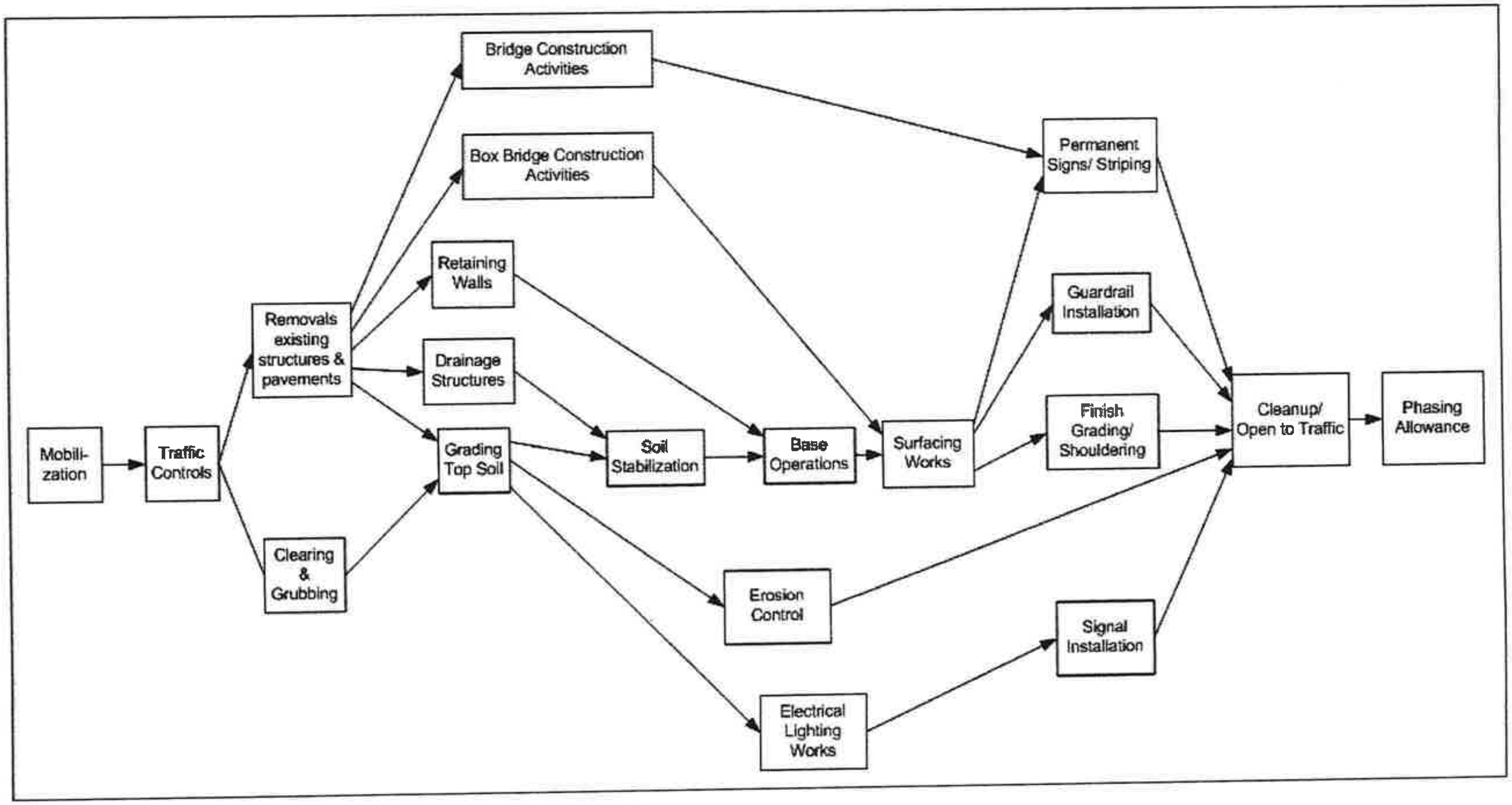
APPENDICES

APPENDIX A

TIER I GENERAL TEMPLATE AND ACTIVITY LOGIC

TIER I - GENERAL TEMPLATE



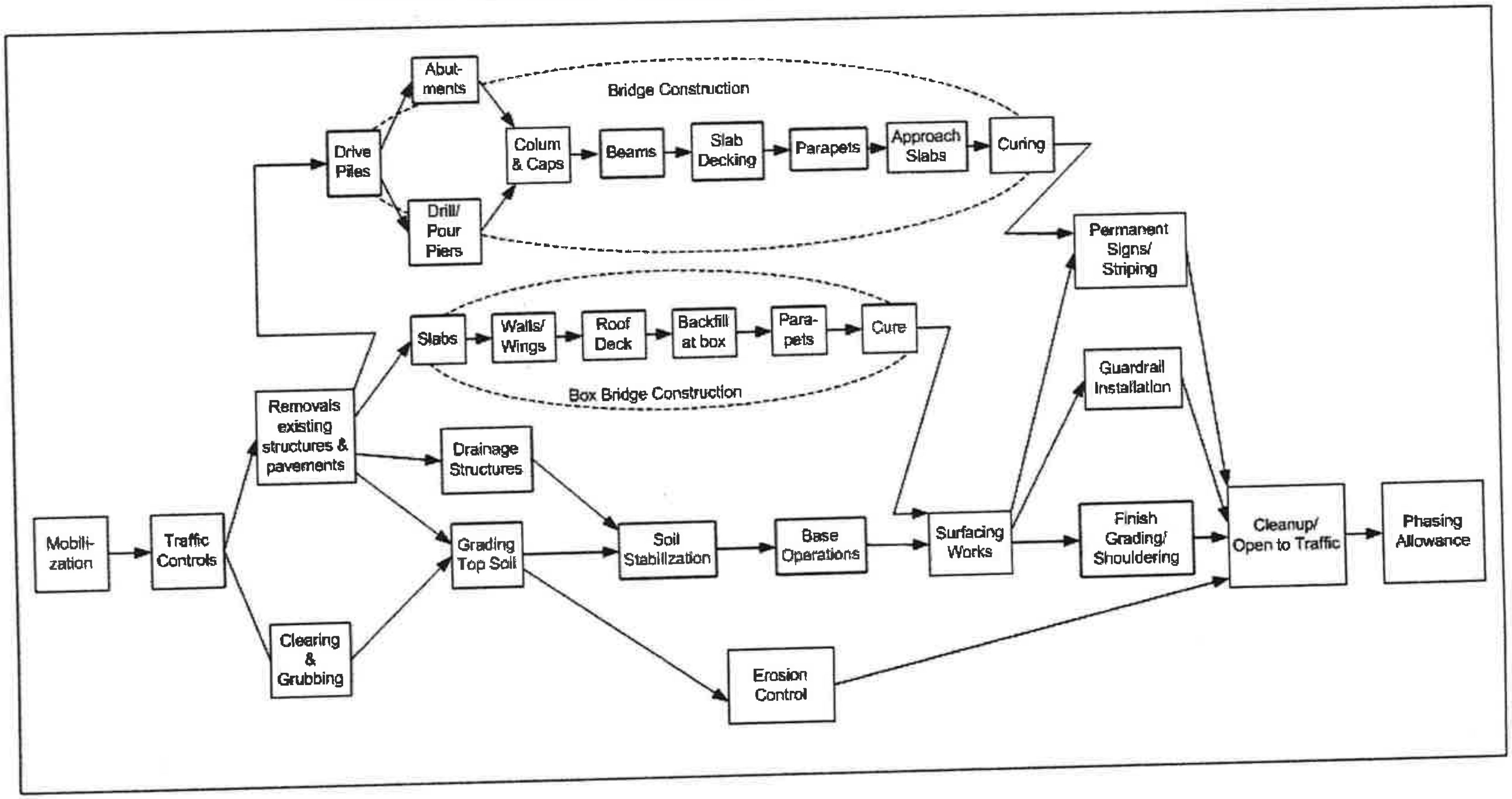
TIER I - GENERAL TEMPLATE

No	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	Mobilization					
2	Traffic Control & Detours					
3	Clearing and Grubbing					
4	Removals					
5	Grading - Top soil, excavation & embankment					
6	Sub Grade operations (Soil Stabilizations Lime/Fly Ash)					
7	Drainage Structures					
8	Box construction (single or multi-cell)					
9	Bridge construction (Single or Multi-Span)					
10	Retaining Walls					
11	Base operations (aggregate base/ asphalt base/ fabrics/ Conc Curb)					
12	Surfacing work					
13	Finish Grading and Shouldering					
14	Guardrail installation					
15	Permanent Stripping, Traffic signs					
16	Electrical/ Lighting works					
17	Signals Installation					
18	Final Erosion Control (Sodding/Mulching/Seeding)					
19	Cleanup/ Open to Traffic					
20	Phasing Allowance					

APPENDIX B

TIER II TYPE HIGHWAY PROJECT TEMPLATES AND ACTIVITY LOGICS

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

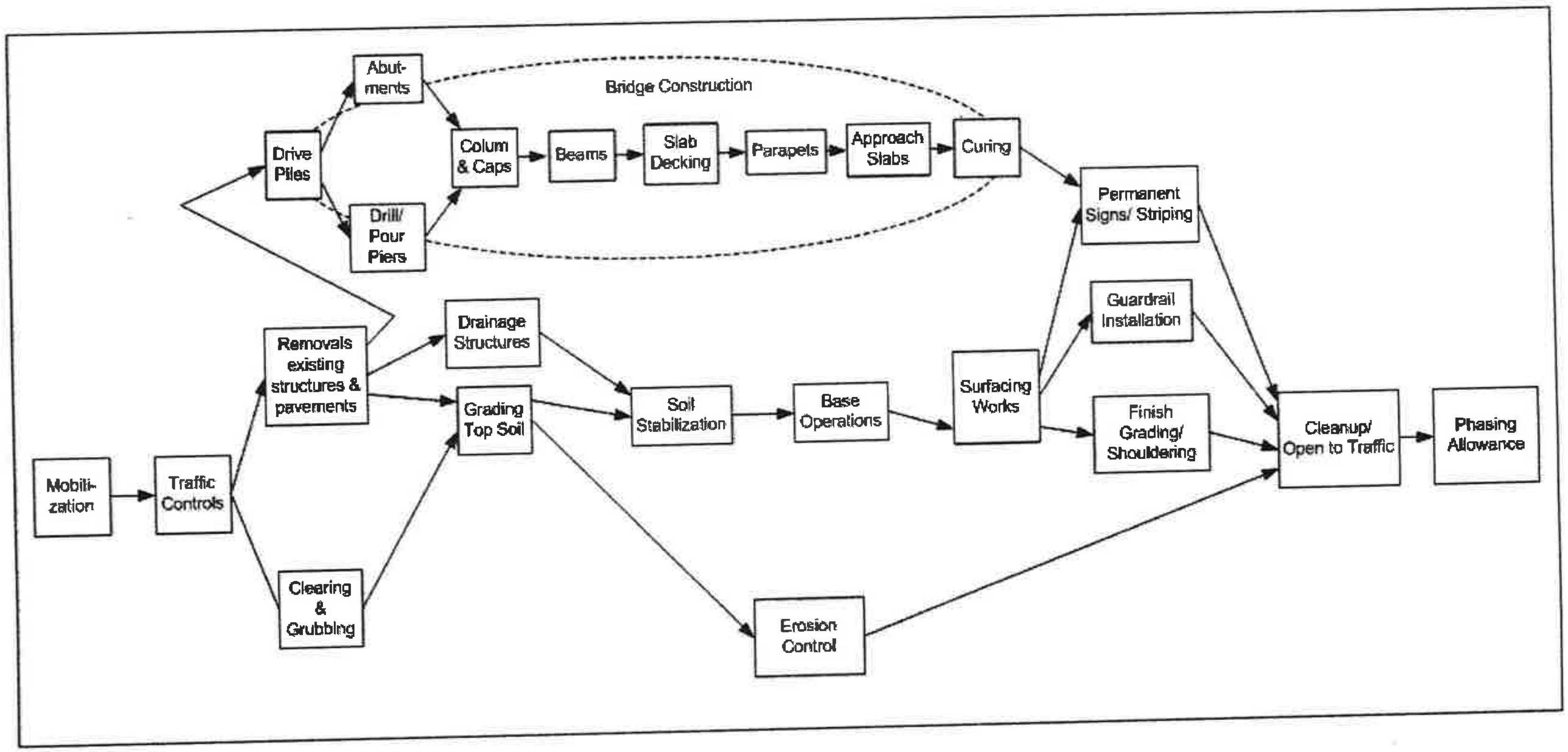


Tier II: 2a - Reconstruct Existing Alignment/ Rural Interchange

No	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	days				
	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**					
	Excavate/Borrow Box Bridge	days				
	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)	cy				
	Parapets (forming, rebars, concrete)	lf				

No	Critical Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
	Approach Slabs	sy				
	Curing	days				
10	**Base operations**					
	Agg base 10"	cy				
	Asphalt base/ fabric installation	tons				
11	**Surfacing Works**					
	Asphalt Type S3	tons				
	Asphalt Type S4	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				

TIER II: 2b – WIDEN/ RECONSTRUCT EXISTING ALIGNMENT

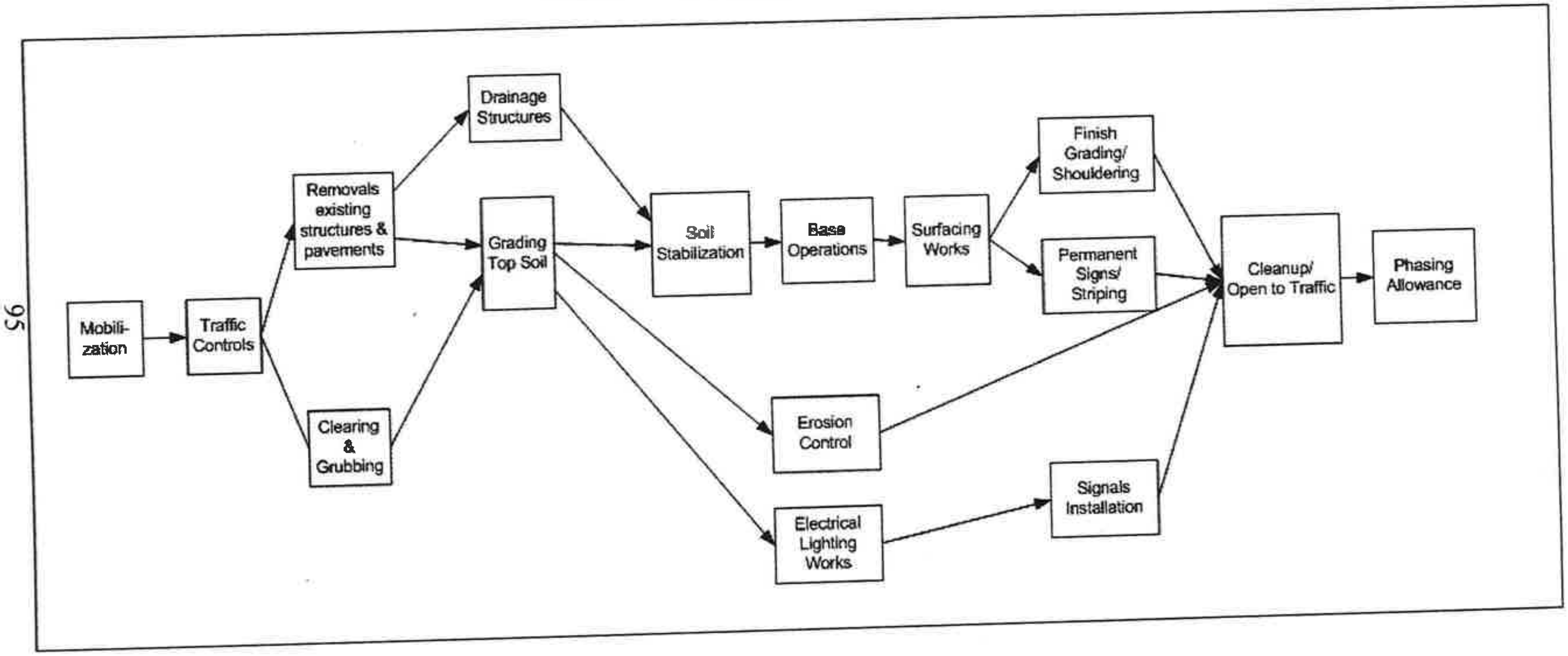


Tier II: 2b - Widen/ Reconstruct Existing Alignment

No	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	days				
	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**					
	Excavate/Borrow Bridge structure	days				
	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)	cy				
	Parapets (forming, rebars, concrete)	lf				
	Approach Slabs	sy				
	Curing	days				
9	**Base operations**					
	Agg Base 10"	cy				
	Asphalt Base/ fabric installation	tons				
10	**Surfacing Works**					

No	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
	Asphalt Type S3	tons				
	Asphalt Type S4	tons				
	9" PC	sy				
	10" PC	sy				
	Curing	days				
	TBSC	tons				
11	**Finish Grading/Shouldering**	cy				
12	**Guardrail installation**	lf				
13	**Permanent Stripping, Traffic signs**	lf				
14	**Final Erosion Control**					
	riprap, filter blanket	tons				
	sodding	sy				
	mulching	acres				
	seeding	acres				
15	**Cleanup/ Open to Traffic**	days				
16	**Phasing Allowance**	days				

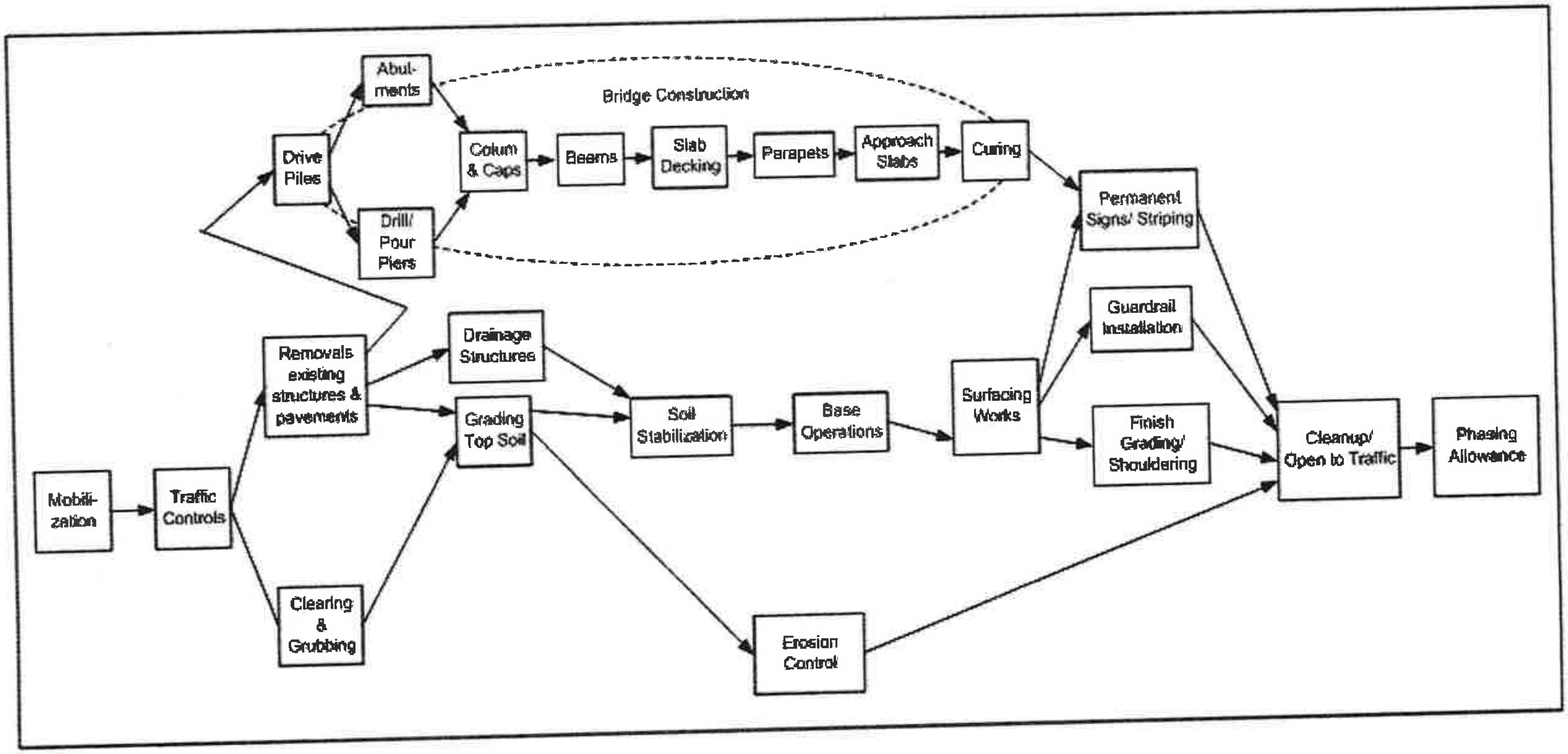
TIER II: 2c – RECONSTRUCT CITY STREET



Tier II: 2c - Reconstruct City Street

No	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	days				
	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				
	Asphalt base/fabric installation	tons				
	Pour Concrete Curb	lf				
	Curing	days				
9	**Surfacing Works**					
	Asphalt Type S3	tons				
	Asphalt Type S	tons				
	9" PC	sy				
	10 " PC	sy				
	HES Drives	sy				
	Curing	days				
10	**Finish Grading/Shouldering/Sidewalks**	sy				
11	**Permanent Signs/ Striping**	lf				
12	**Electrical Lighting Works**	poles				
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

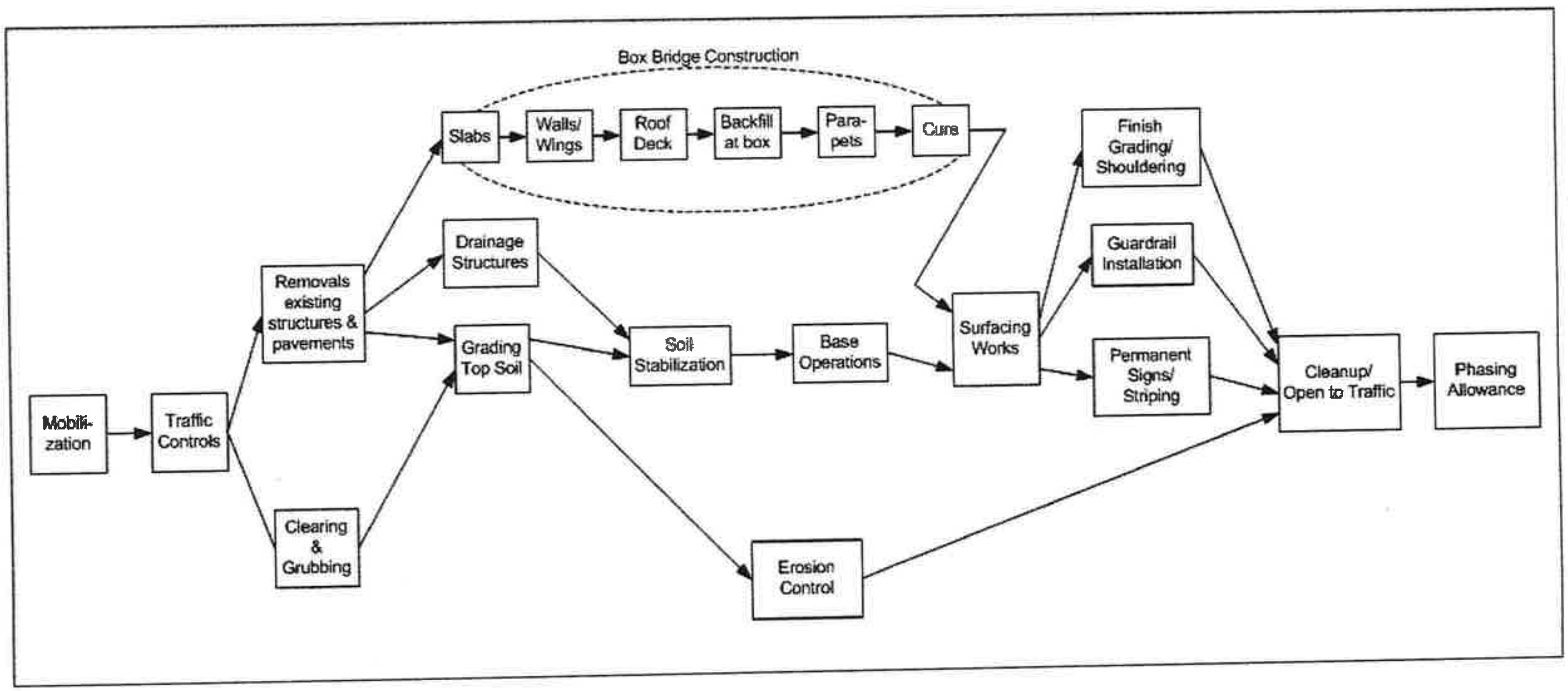


Tier II: 2d - Construct Bridges and Approaches

No	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	days				
	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**					
	Excavate/Borrow Bridge Structure	days				
	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)	sy				
	Parapets (forming, rebars, concrete)	lf				
	Approach Slabs	sy				
	Curing	days				
9	**Base operations**					
	Agg Base 10"	cy				
	Asphalt Base/ fabric installation	tons				
10	**Surfacing Works**					
	Asphalt Type S3	tons				

No	Critical Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
	Asphalt Type S4	tons				
	9" PC	sy				
	10" PC	sy				
	Curing	days				
	TBSC	tons				
11	**Finish Grading/Shouldering**	sy				
12	**Guardrail installation**	lf				
13	**Permanent Signs/ Striping**	lf				
14	**Final Erosion Control**					
	riprap, filter blanket	tons				
	sodding	sy				
	mulching	acres				
	seeding	acres				
15	**Cleanup/ Open to Traffic**	days				
16	**Phasing Allowance**	days				

TIER II: 2e – CONSTRUCT BRIDGE BOX AND APPROACHES

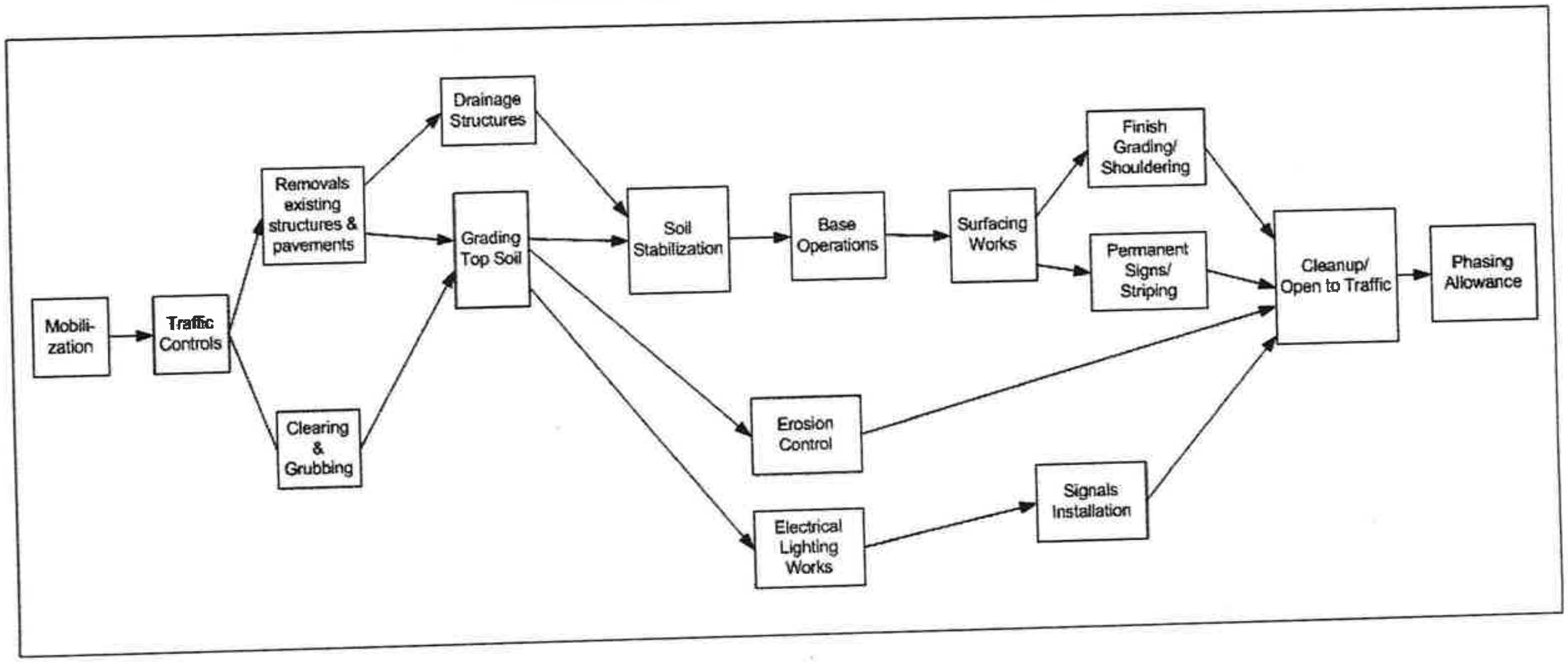


Tier II: 2e - Construct Bridge Box And Approaches

No	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	days				
	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**					
	Excavate/Borrow Box structure	days				
	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				
	Asphalt Base/ fabric installation	tons				
10	**Surfacing Works**					
	Asphalt Type S3	tons				
	Asphalt Type S4	tons				
	9" PC	sy				
	10" PC	sy				
	Curing	days				
	TBSC	tons				
11	**Guardrail installation**	lf				
12	**Permanent Signs/ Striping**	lf				

No	Critical Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
13	**Finish Grading/Shouldering**	sy				
14	**Final Erosion Control**					
	riprap, filter blanket	tons				
	sodding	sy				
	mulching	acres				
	seeding	acres				
15	**Cleanup/ Open to Traffic**	days				
16	**Phasing Allowance**	days				

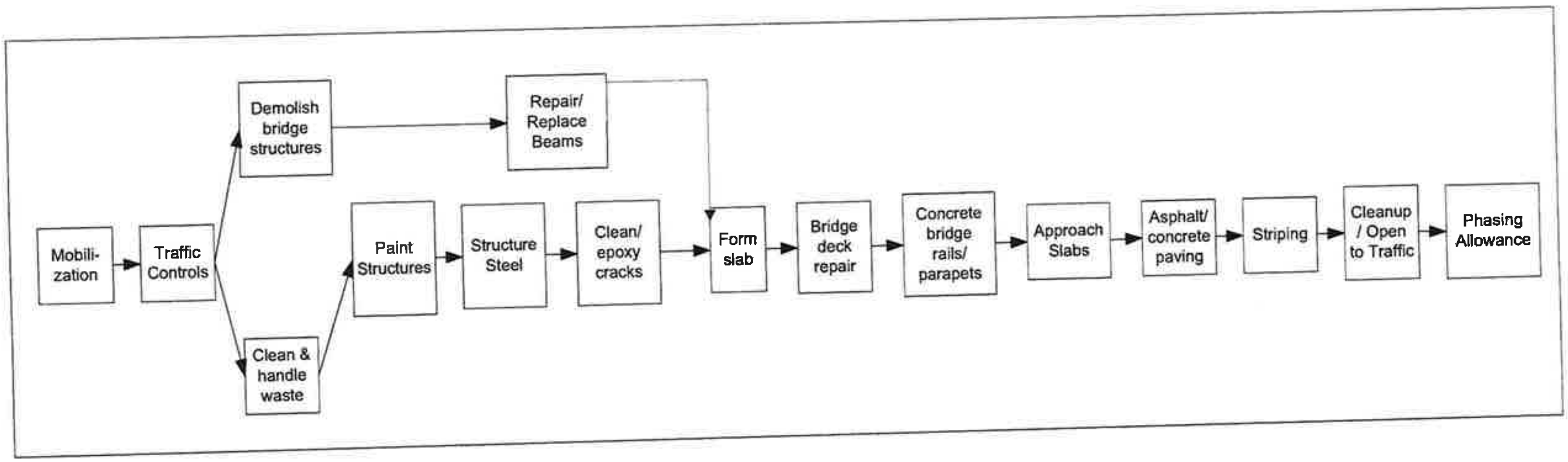
TIER II: 2f – INTERSECTION MODIFICATION



Tier II: 2f - Intersection Modification

No	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	days				
	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				
	Asphalt base/fabric installation	tons				
	Concrete Curbs	lf				
	Curing	days				
9	**Surfacing Works**					
	Asphalt Type A	tons				
	Asphalt Type B	tons				
	9" PC	sy				
	10" PC	sy				
	HES Drives	sy				
	Curing	days				
10	**Finish Grading/Shouldering**	cy				
11	**Permanent Signs/ Striping**	lf				
12	**Electrical/ Lighting Works**	poles				
13	**Signals Installation**	days				
14	**Final Erosion Control**					
	sodding	sy				
	mulching	acres				
	seeding	acres				
15	**Cleanup/ Open to Traffic**	days				
16	**Phasing Allowance**	days				

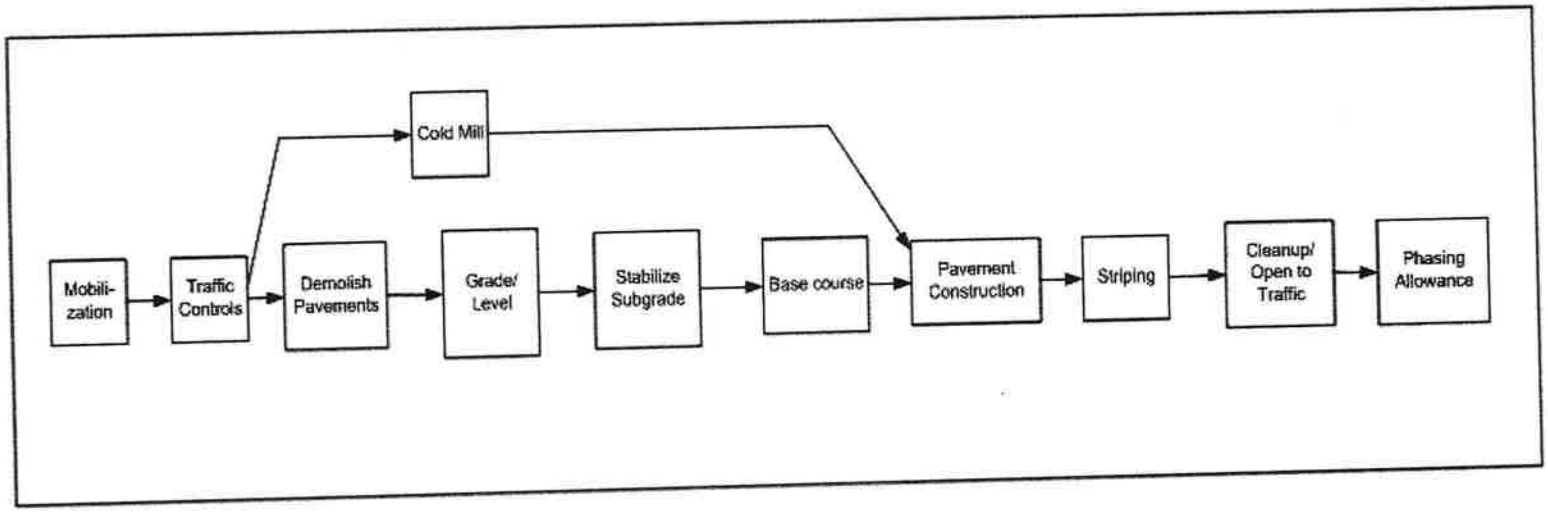
TIER II: 2g – BRIDGE REHABILITATION/ REPAIR



Tier II: 2g - Bridge Rehabilitation/ Repair

No	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization**	days				
2	**Traffic Control**					
	Median Barrier	lf				
	Detour paving	tons				
3	**Demo Bridge Structure**	days				
4	**Paint Bridge** (Includes clean/handle waste)	days				
5	**Repair/Replace Beams**	lf				
6	**Structural Steel**	tons				
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, Type S3	tons				
	Asphalt, Type S4	tons				
	9" PC Concrete	sy				
	10" PC Concrete	sy				
	Curing	days				
9	**Striping**	lf				
10	**Cleanup/ Open to Traffic**	days				
11	**Phasing Allowance**	days				

TIER II: 2h – ROADWAY REPAIR/ OVERLAY



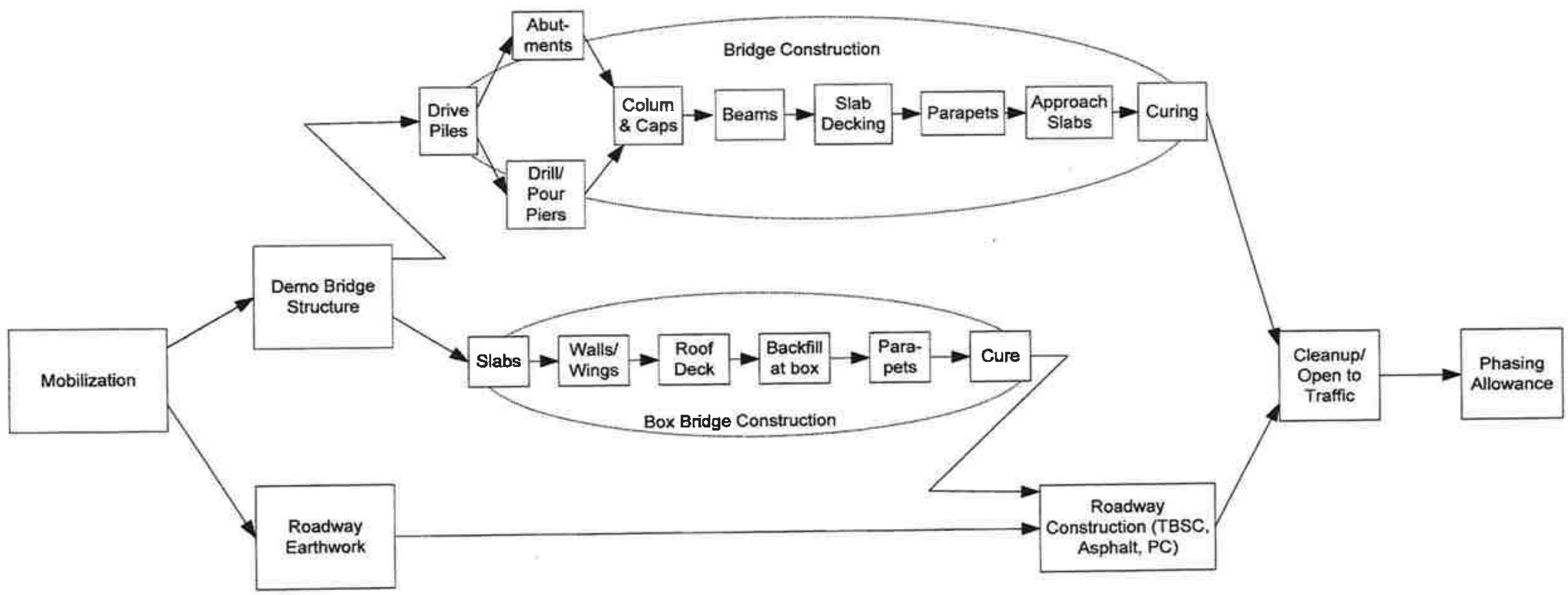
Tier II: 2h - Roadway Repair/ Overlay

No	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	tons					
	Curing	days					
8	**Striping**	lf					
9	**Cleanup/ Open to Traffic**	days					
10	**Phasing Allowance**	days					

APPENDIX C

TIER III TYPE HIGHWAY PROJECT TEMPLATES AND ACTIVITY LOGICS

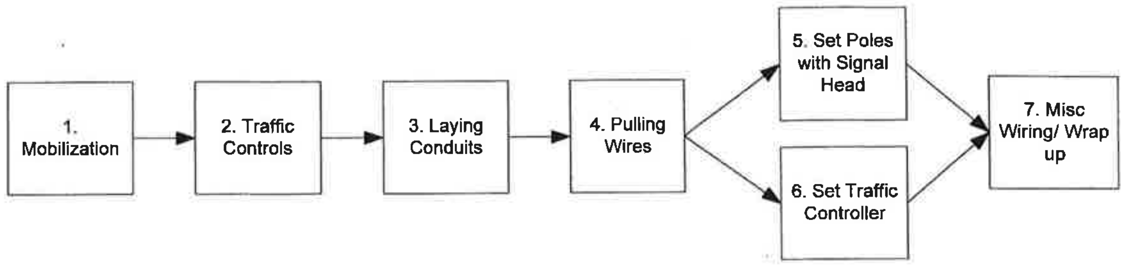
TIER III: 3a – COUNTY BRIDGE



TIER III: 3a – County Bridge

No	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization (includes signage)**	days				
2	**Demolition Bridge Structure**	days				
3	**Roadway Earthwork**	cy				
4	**Box Construction - Single or Multi Cell**					
	Excavate/Borrow Box Bridge	days				
	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				
5	**Bridge Construction - Single or Multi Span**					
	Excavate/Borrow Box Bridge	days				
	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)	cy				
	Parapets (forming, rebars, concrete)	lf				
	Approach Slabs	sy				
	Curing	days				
6	**Roadway Construction**					
	Asphalt, Type S3	tons				
	Asphalt, Type S4	tons				
	PC pavements	sy				
	TBSC	tons				
7	**Cleanup/ Open to Traffic**	days				
8	**Phasing Allowance**	days				

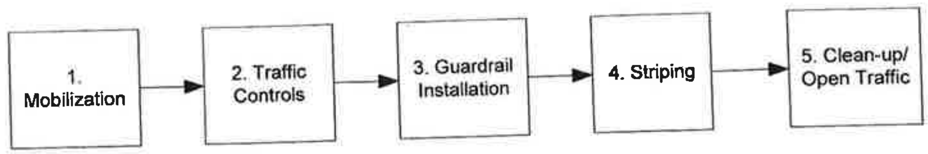
TIER III: 3b – SIGNAL INSTALLATION



TIER III: 3b – Signal Installation

No	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilize**	days				
2	**Traffic Controls**	days				
3	**Laying Conduits**	lf				
4	**Pull Wire**	lf				
5	**Setting Poles with Signal Heads**	EA				
6	**Set Controller**	days				
7	**Misc Wiring/Wrap Up**	days				

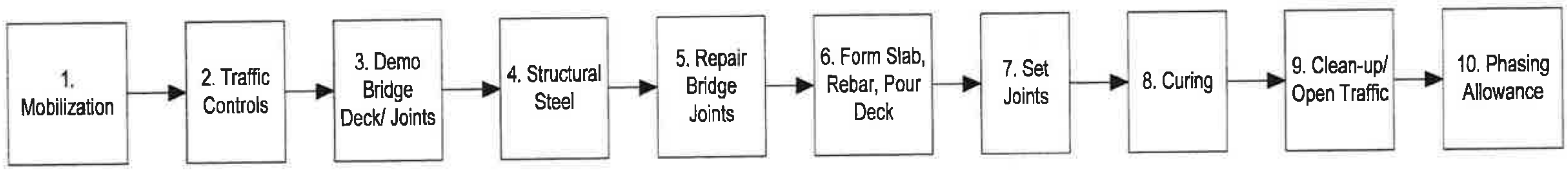
TIER III: 3c – STRIPING OR GUARDRAIL



TIER III: 3c – Stripping or Guardrail

No	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization (includes signage)**	days				
2	**Traffic Control**	days				
3	**Guardrail installation**	lf				
4	**Striping**	lf				
5	**Cleanup/ Open to Traffic**	days				

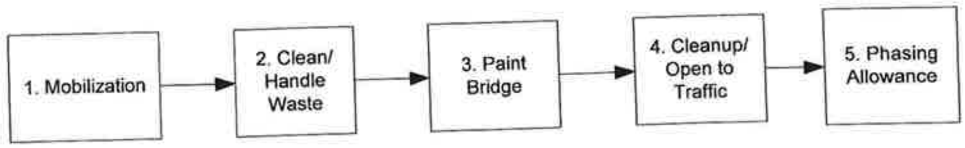
TIER III: 3d – BRIDGE REPAIR JOINTS



TIER III: 3d – Bridge Repair Joints

No	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	Mobilization (includes signage)	days				
2	Traffic Control	days				
3	Demo Bridge Deck/ Joints	days				
4	Structural Steel	tons				
5	Repair Bridge Joints	lf				
6	Form slab, rebar, pour deck	cy				
7	Set Joints	lf				
8	Curing	days				
9	Cleanup/ Open to Traffic	days				
10	Phasing Allowance	days				

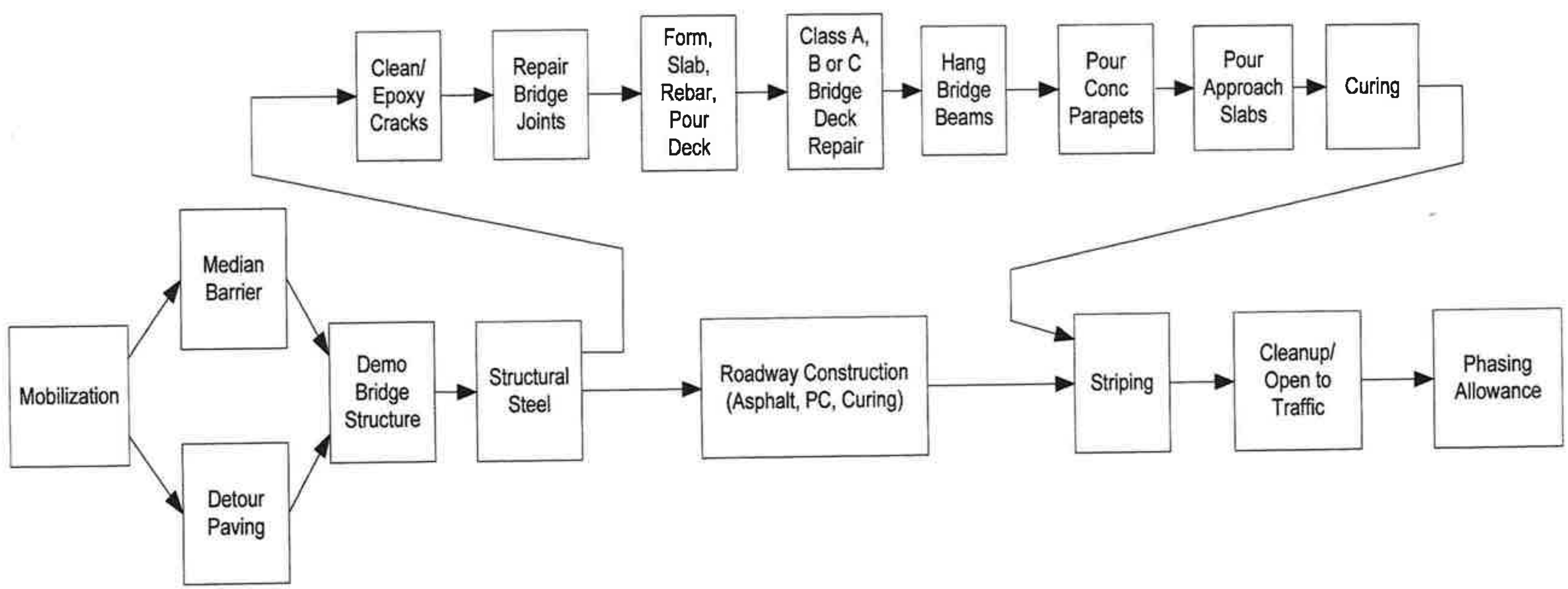
TIER III: 3e – BRIDGE PAINT



TIER III: 3e – Bridge Paint

No	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	Mobilization (includes signage)	days				
2	Clean/ Handle Waste	days				
3	Paint Bridge	days/br				
4	Cleanup/ Open to Traffic	days				
5	Phasing Allowance	days				

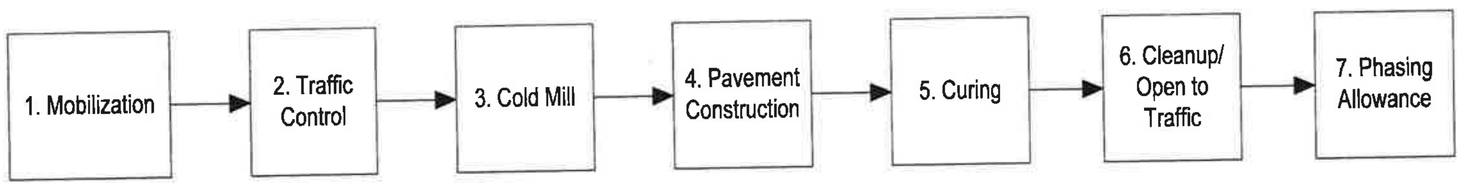
TIER III: 3f – BRIDGE DECK REPAIR/ REDECKING



TIER III: 3f – Bridge Deck Repair/Redecking

No	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization (includes signage)**	days				
2	**Traffic Control**					
	Median Barrier	lf				
	Detour paving	tons				
3	**Demo Bridge Structure**	days				
4	**Structural Steel**	tons				
5	**Rehab Bridge**					
	Clean/ epoxy cracks	lf				
	Repair Bridge Joints	lf				
	Form slab, rebar, pour deck	cy				
	Class A, B or C bridge deck repair	sy				
	Hang bridge beams	lf				
	Pour concrete parapets	lf				
	Pour approach slabs	lf				
	Curing	days				
6	**Roadway Construction**					
	Asphalt, Type S3	tons				
	Asphalt, Type S4	tons				
	9" PC Concrete	sy				
	10" PC Concrete	sy				
	Curing	days				
7	**Striping**	lf				
8	**Cleanup/ Open to Traffic**	days				
9	**Phasing Allowance**	days				

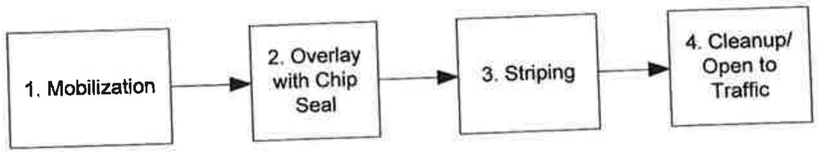
TIER III: 3g – OVERLAY



TIER III: 3g – Overlay

No	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization (includes signage)**	days				
2	**Traffic Control**	days				
3	**Cold Mill**	days				
4	**Pavement Construction**					
	Concrete paving	sy				
	Asphalt	tons				
	curing	days				
5	**Striping**	lf				
6	**Cleanup/ Open to Traffic**	days				
7	**Phasing Allowance**	days				

TIER III: 3h – CHIP SEAL



TIER III: 3h – Chip Seal

No	Controlling Activities	Unit	Quantity	Avg Prod Rate	Duration	Comments
1	**Mobilization**	days				
2	**Overlay with Chip Seal**	tons				
3	**Striping**	lf				
4	**Open to Traffic**	days				

APPENDIX D: Software Manual for OK-CTDS

1. **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. **Instructions to install the OkCTDS software on your system:**

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

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

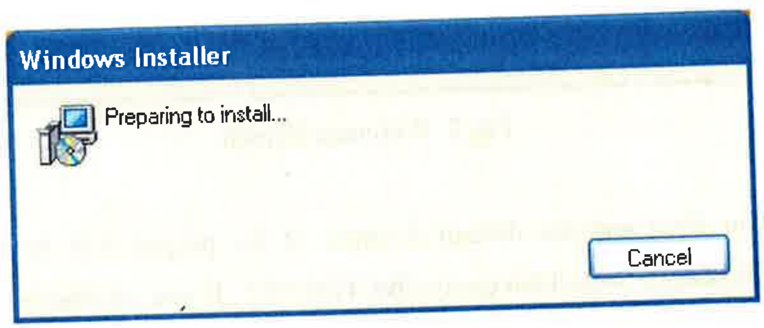


Fig 1: Startup Screen

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

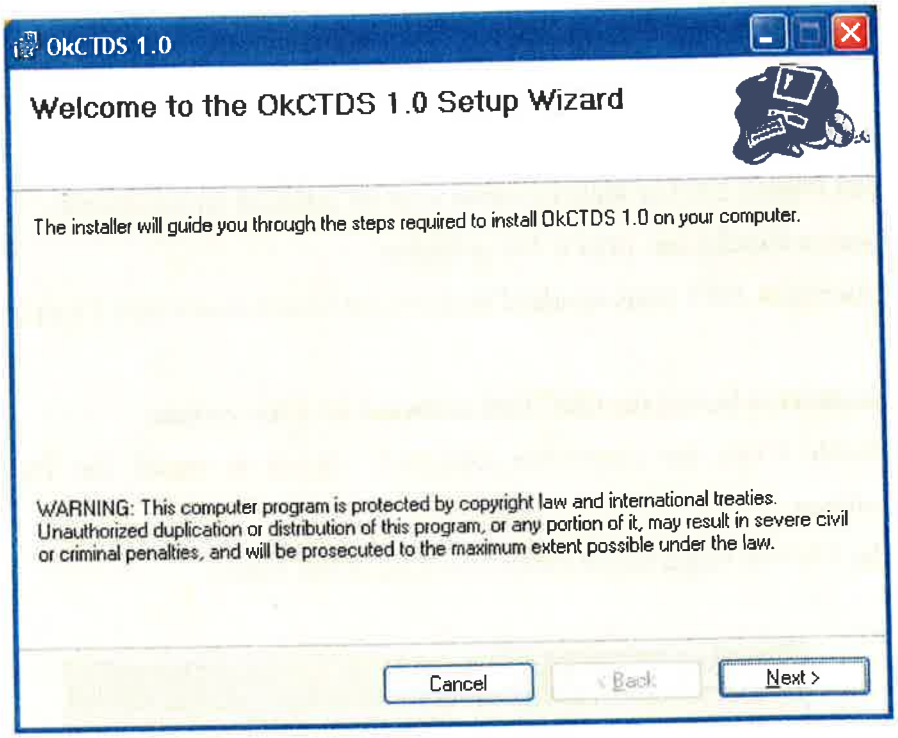


Fig 2: Welcome Screen

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.

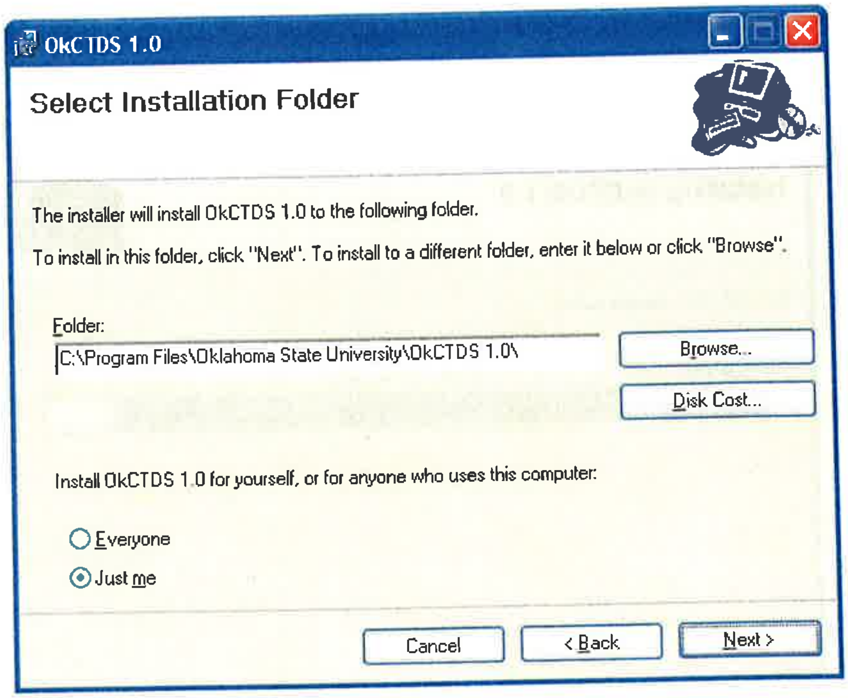


Fig 3: Installation - Folder Selection Screen

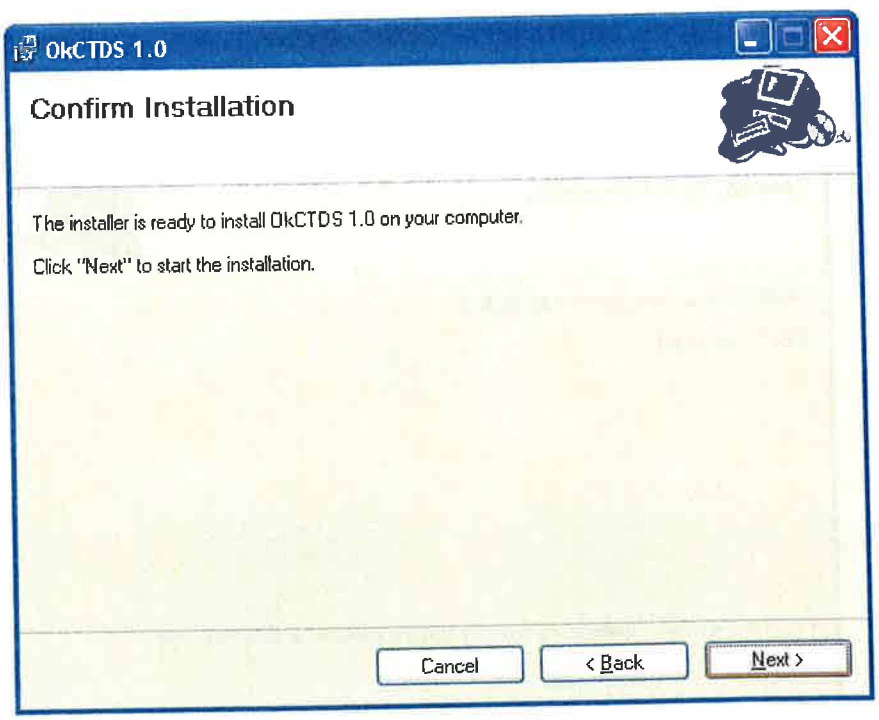


Fig 4: Confirmation Screen

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.

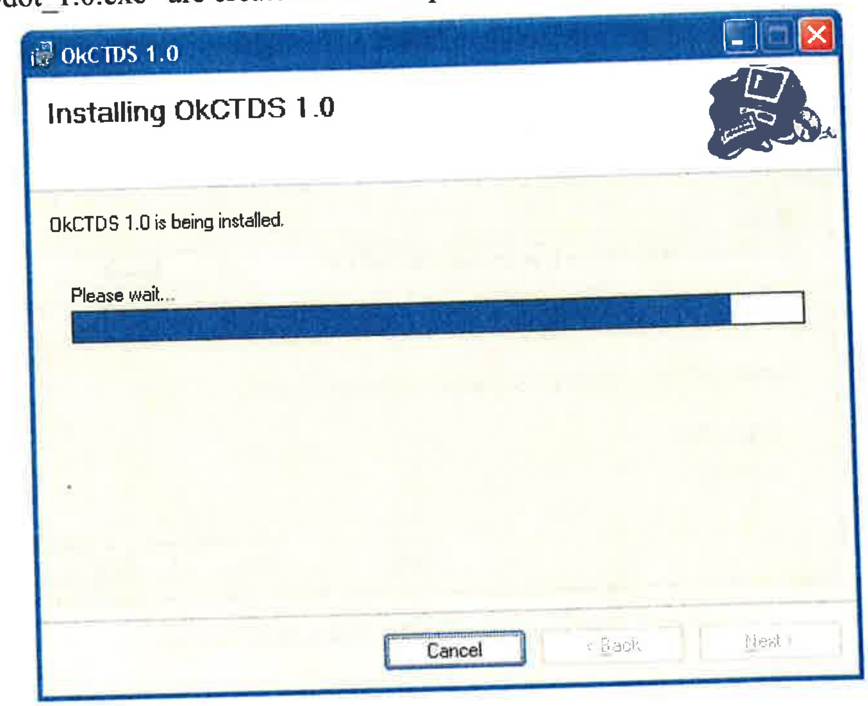


Fig 5: Installation Screen

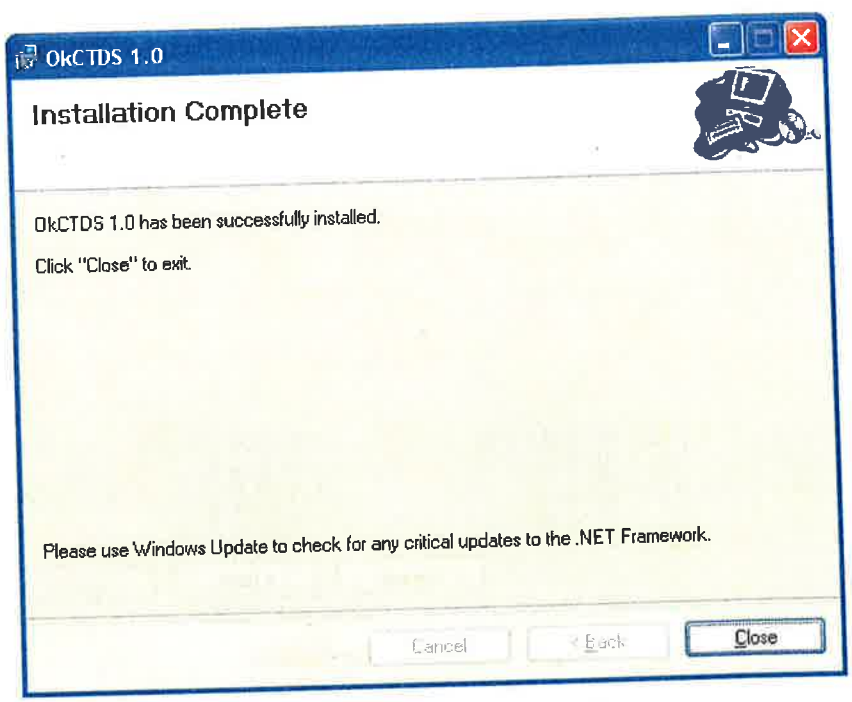


Fig 6: Installation Completion Screen

3 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".

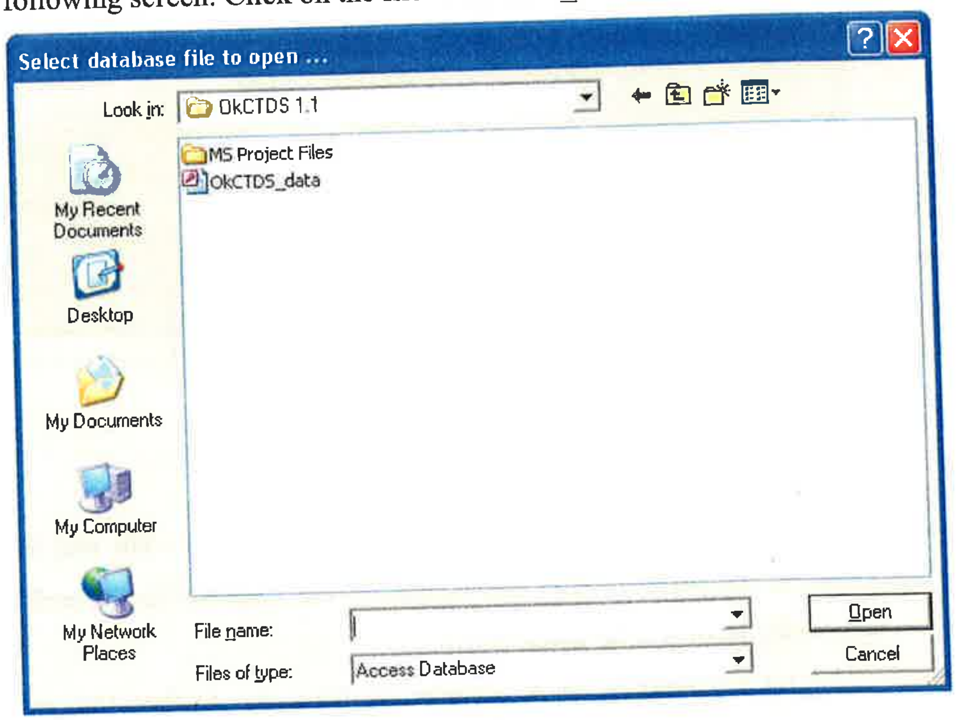


Fig 7: Database File Selection Screen

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

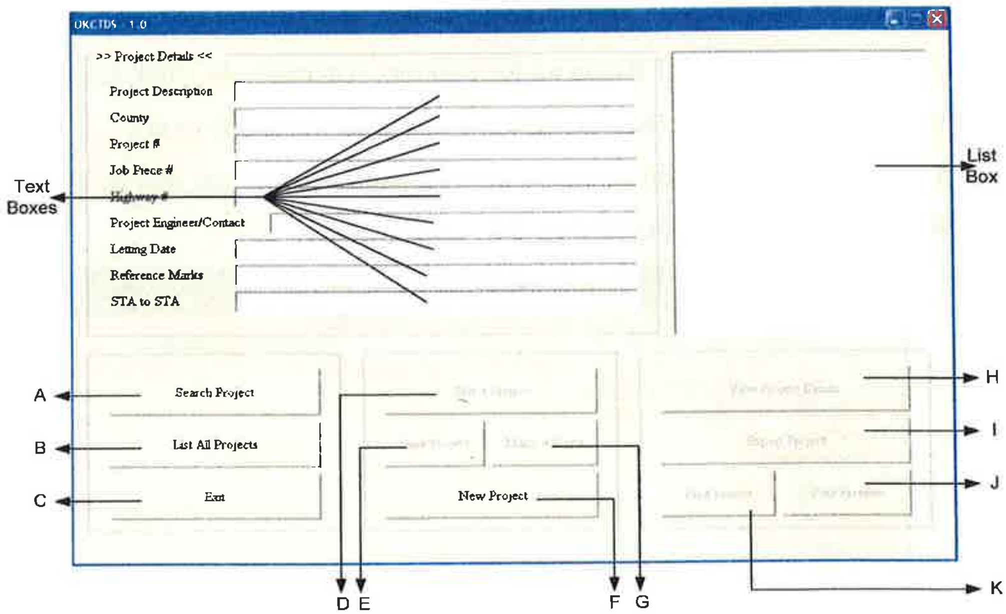


Fig 8: Project Header Form

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 8).

B. List All Projects: When this function is activated, all the existing projects are retrieved and are displayed in the list box (see Fig 8).

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 8).

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.

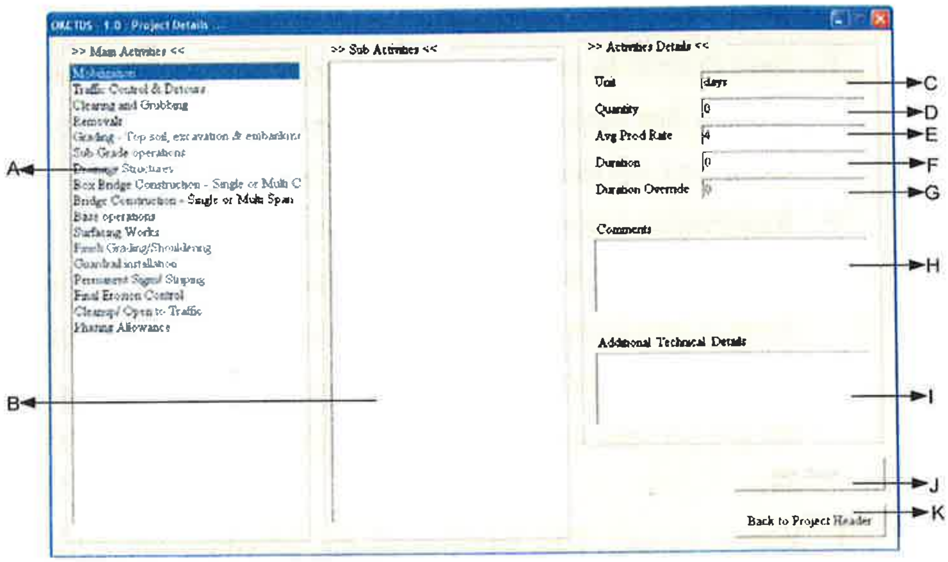


Fig 9: Project Details Form

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:

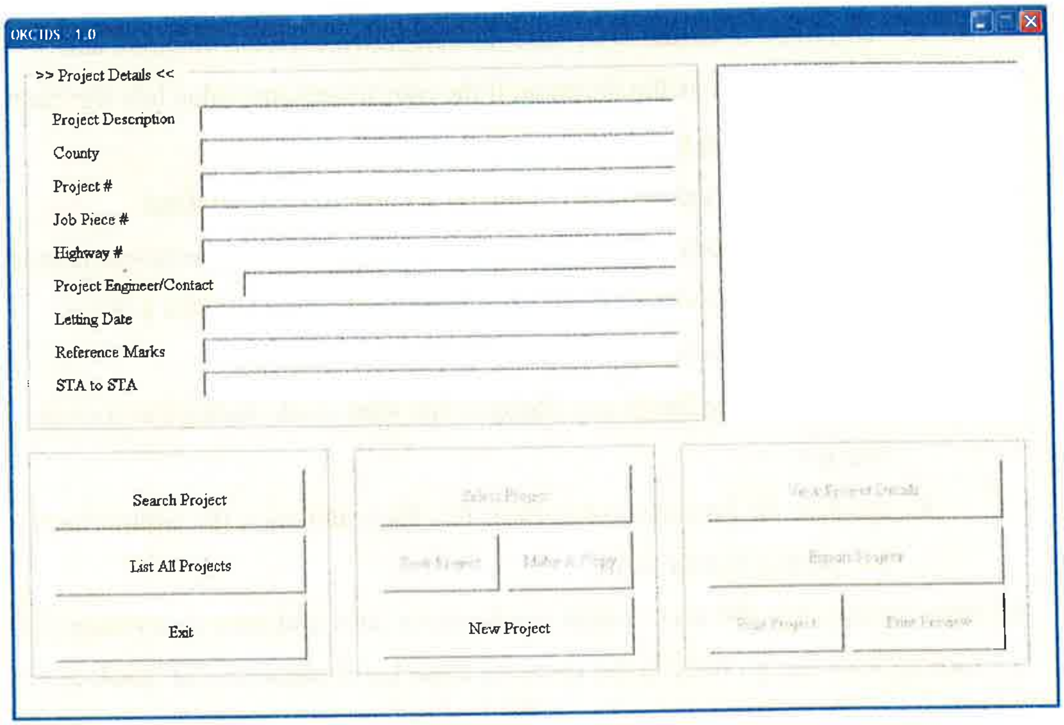


Fig 10: Project Header Form – Default Screen

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

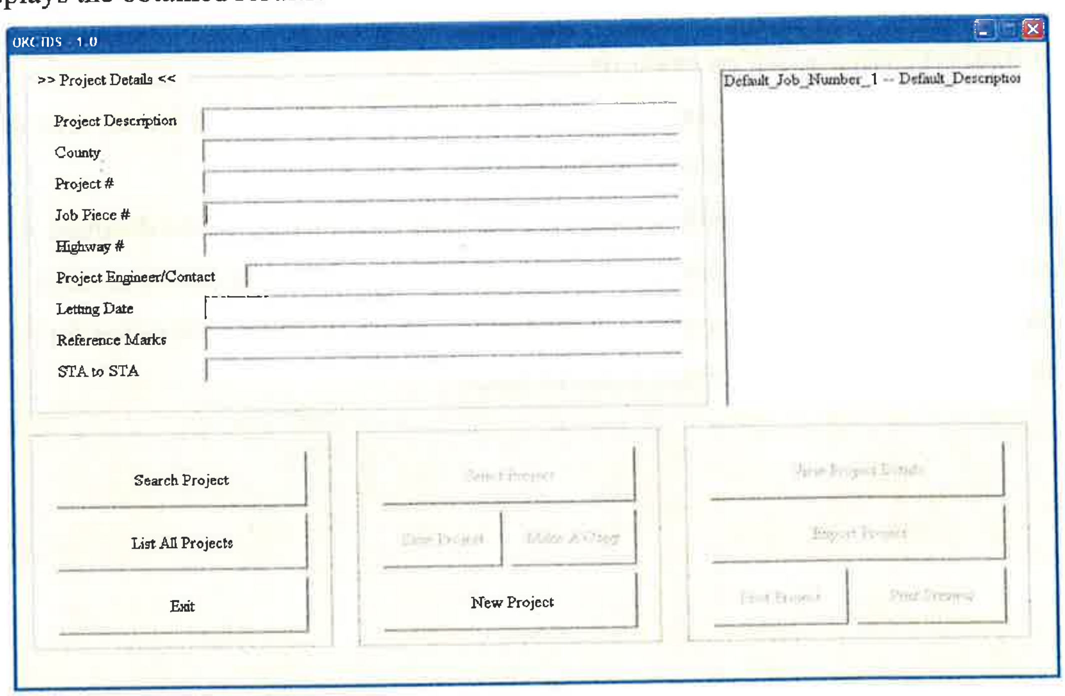


Fig 11: Search Option - Project Header Form

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.

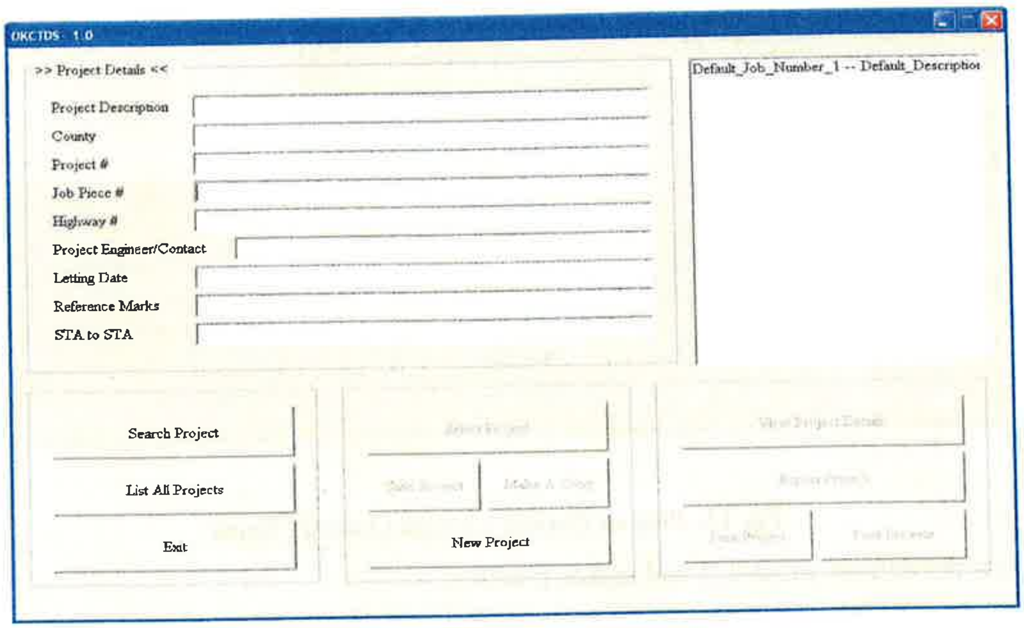


Fig 12: List Option - Project Header Form

4.3 Select Project: Selects the highlighted project and makes it the active project. Highlights the default_project_1:

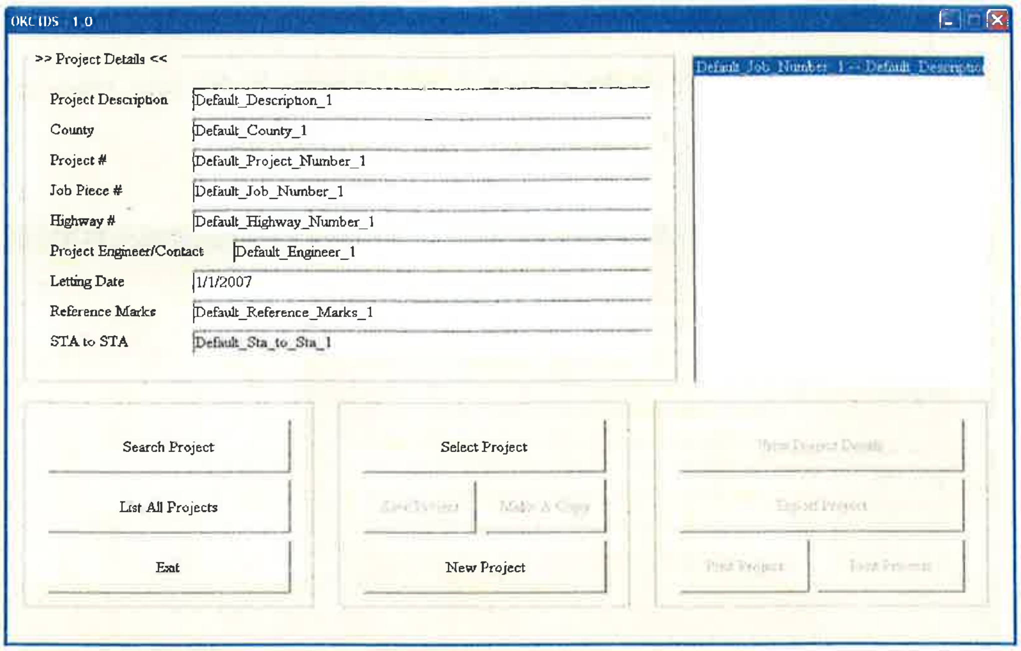


Fig 13: Project Choice – Project Header Form

Selects the default_project_1 and makes it active:

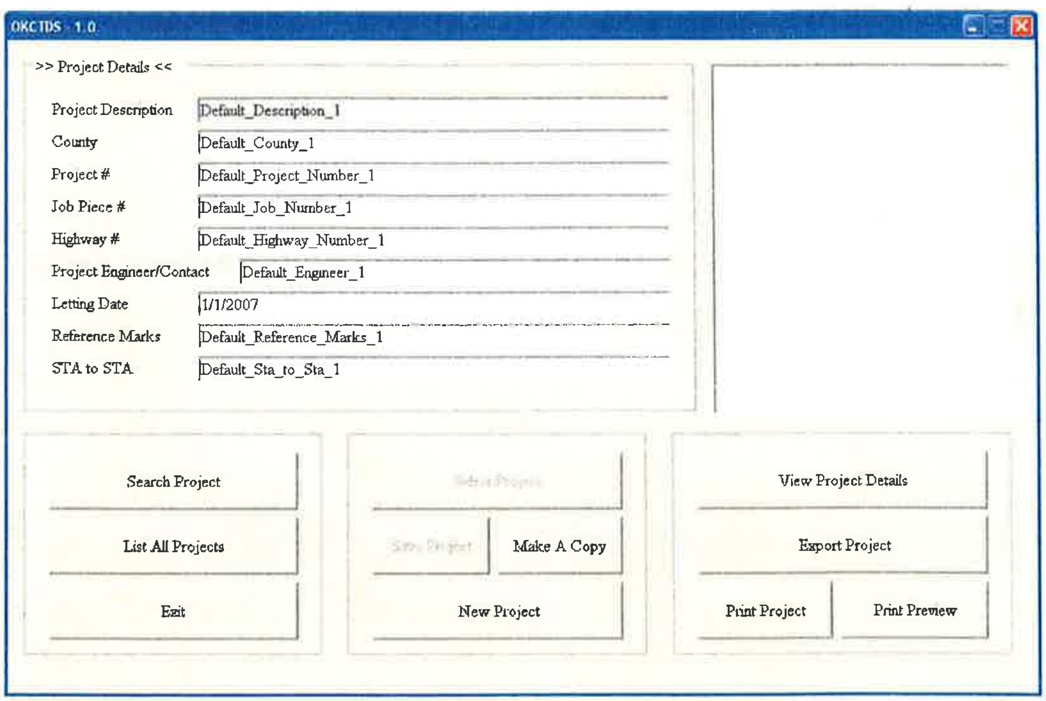


Fig 14: Project Selection – Project Header Form

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.

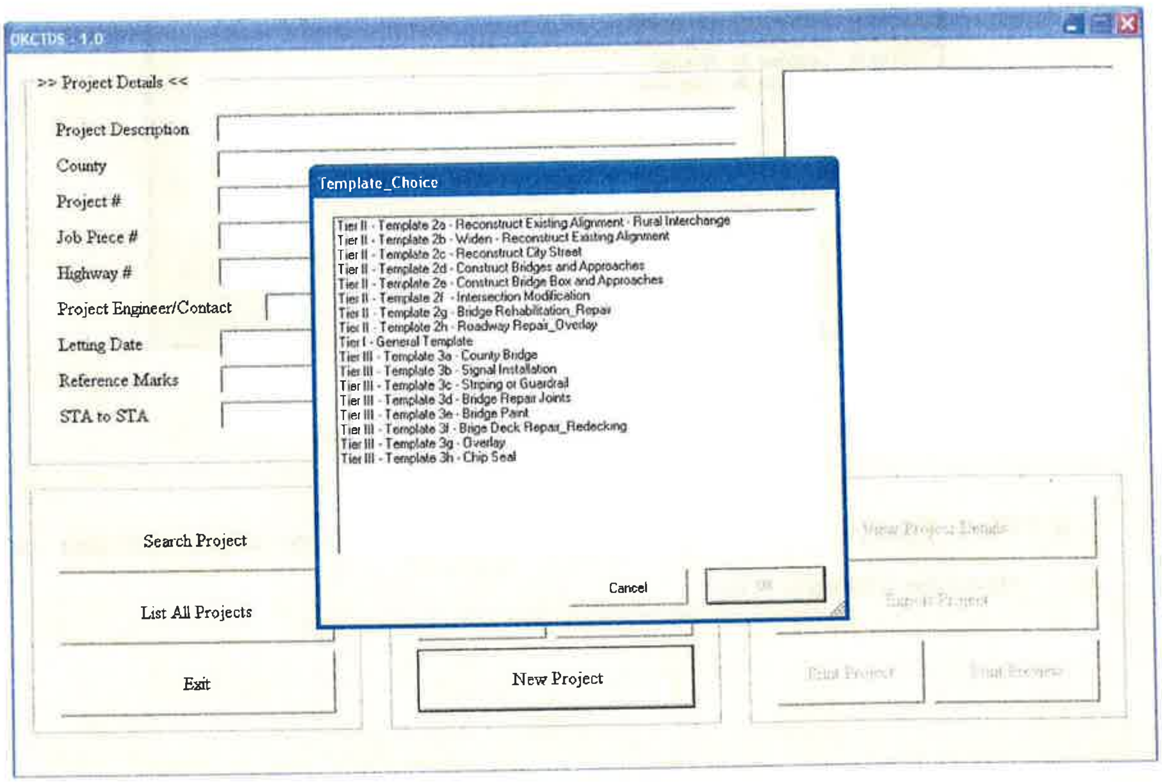


Fig 15: New Template Selection – Project Header Form

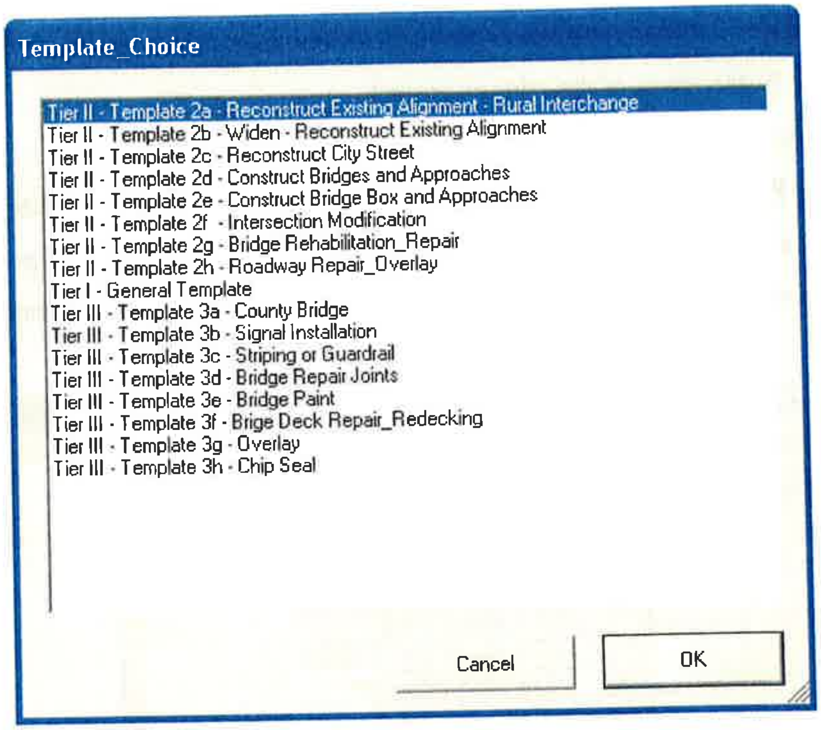


Fig 16: New Template Selection Form

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

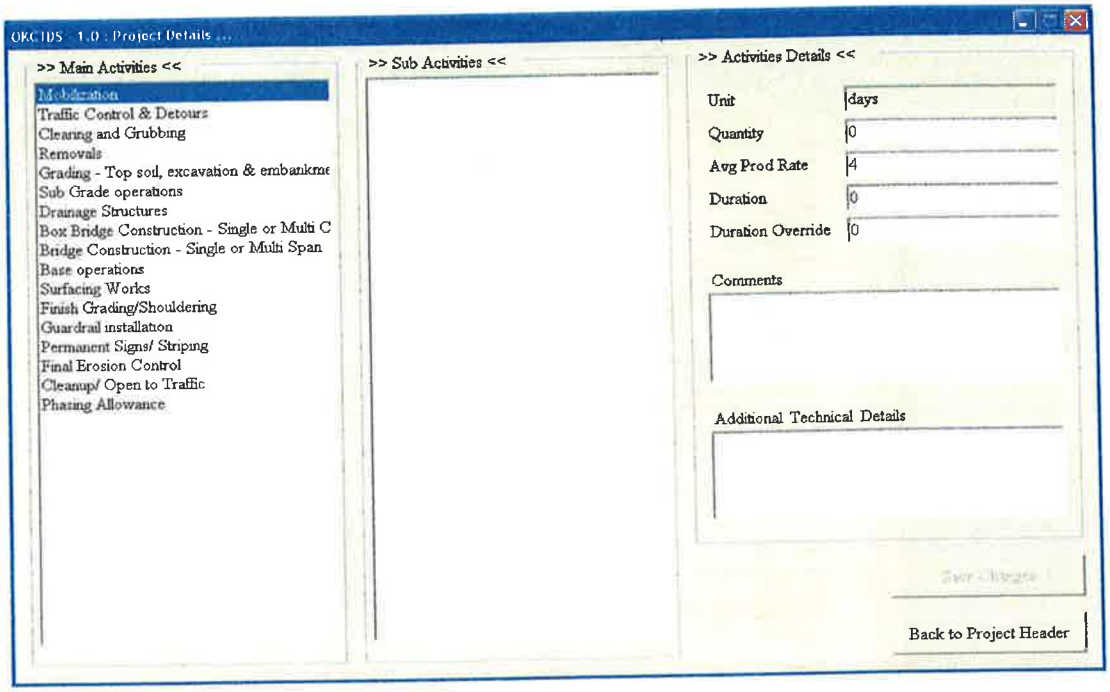


Fig 17: Project Details Form

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.

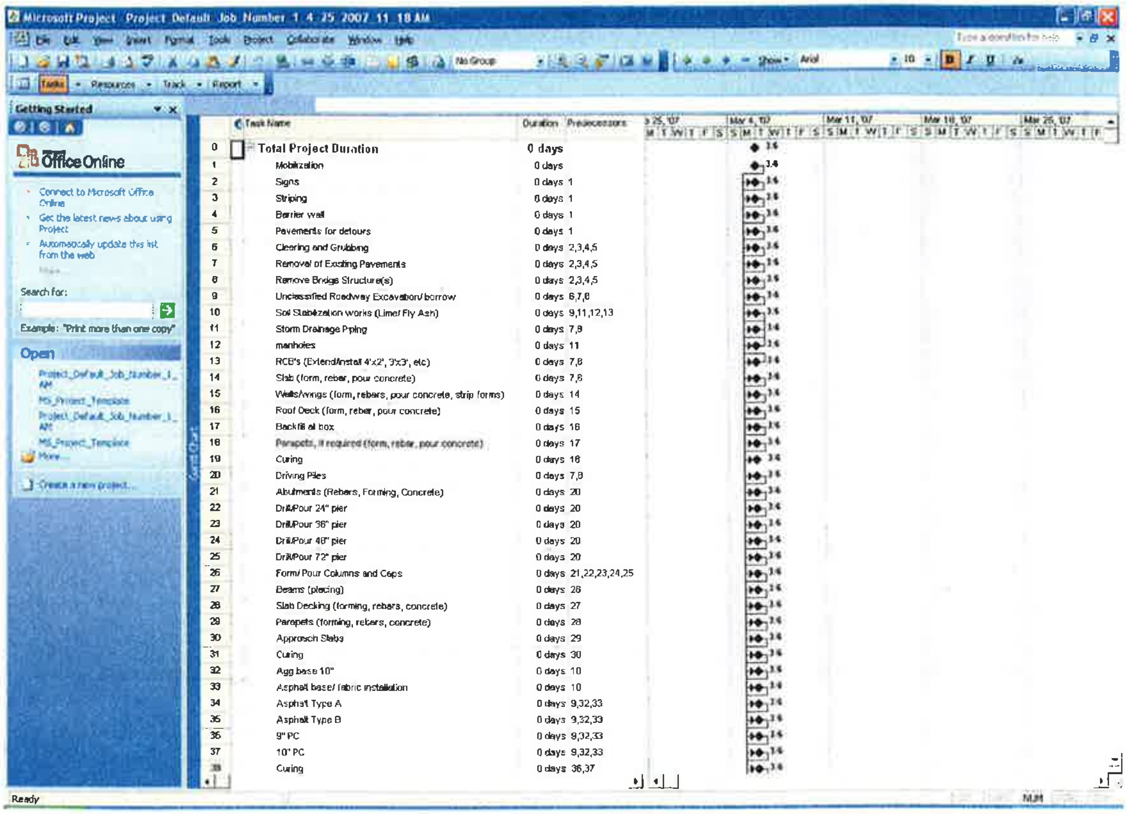
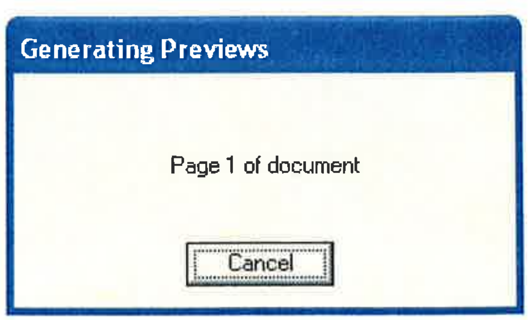
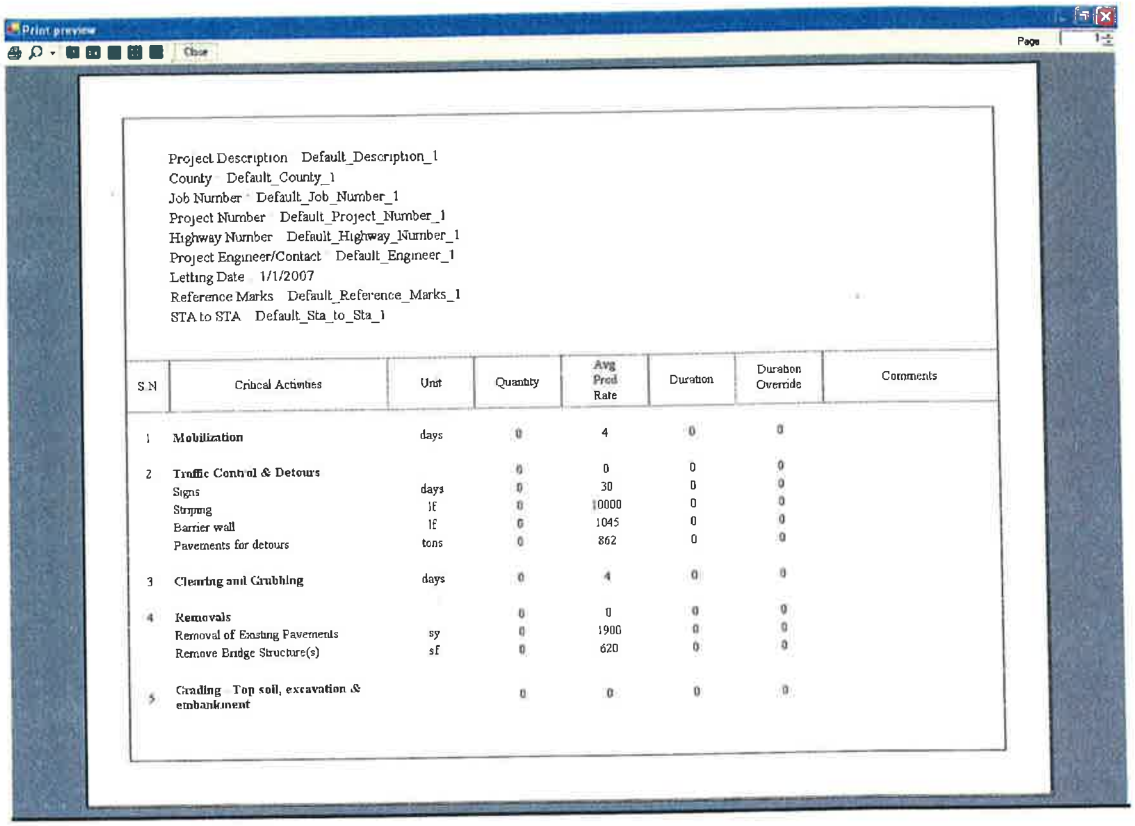


Fig 18: MS Project Screen

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 19: Print Preview Screen

DO NOTS

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.

APPENDIX E

OK-CTDS INSTALLATION CD