Tracking and Controlling of Engineering Deliverables for EPC Projects

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ABSTRACT

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In EPC (Engineering, Procurement and Construction) projects, the engineering/design phase is crucial as it has a direct impact on the delivery of such complex projects. Efficient tracking of engineering deliverables is a key to the successful delivery of these projects. Many studies have been carried out in this domain to develop tracking and control systems, particularly for A/E firms. The engineering deliverables in the Engineering/Design phase in EPC projects should be controlled individually and should be integrated with the project schedule.

The aim of this research is to study current practice in the management area referred above and present a methodology that enhances tracking and controlling of engineering deliverables; integrating the cost and schedule functions; forecasting the cost and time at the report date and at completion; and for integrating the engineering deliverables with the project schedule to demonstrate their effects on the delivery of such projects. To demonstrate the use and essential features of the proposed methodology, a computerized system has been developed in the Microsoft® Windows XP environment using Excel sheet 2003. The developed system operates at three levels in EPC projects: 1) the deliverables level; 2) the activities level; and at 3) the project level. It is a

stand alone system that can be used as an independent add-on utility to the project management software of the industrial partner "PM+". The developed system can be used to assist the project management teams on making decisions to improve the delivery of the EPC projects considering the impact of engineering deliverables. A training set of data developed by an industrial partner, SNC-LAVALIN, from of their EPCM projects, is utilized to validate the accuracy and functionality of the developed system.

ACKNOWLEDGEMENTS

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NOMENCLATURE

% Complete	= Percent complete of the net internal work hour package
%Cumulative@ P.s	= Cumulative earning percentage at the Pervious control point
%Cumulative@ R.s	= Cumulative earning percentage at the Report stage
ACWP	= Actual Cost of Work Preformed
BAC	= Budgeted hour At Completion of a control point
$BAC_{(activity)}$	= Budgeted hour/cost At Completion of an activity
$BAC_{(Dis)}$	= Budgeted hour At Completion of a discipline
$BAC_{(Phase)}$	= Budgeted hour At Completion of a phase
$BAC_{(Proj)}$	= Budgeted hour At Completion of the project
$BAC_{(WP)}$	= Budgeted hour At Completion of a work package
BCWP	= Budgeted Cost of Work Preformed
BCWS	= Budgeted Cost of Work Schedule
Beta (β)	= Ratio of progress period in days of an activity to its original duration in days during reporting period
CPI	= Cost Performance Index
$CPI_{(activity)}$	= Cost Performance Index of an activity
$CPI_{(Dis)}$	= Cost Performance Index of a discipline
$CPI_{(Phase)}$	= Cost Performance Index of a phase
$CPI_{(Proj)}$	= Cost Performance Index of the project
$CPI_{(WP)}$	= Cost Performance Index of a work package
$CV_{(activity)}$	= Cost Variance of an activity

d	= Number of disciplines in a phase
$DOC_{(activity)}$	= Date Of Completion of an activity
Earned Hour@ R.s	= Earned Hours at report stage
FTC	= Forecasted hours To Complete a control point
$FTC_{(activity)}$	= Forecasted cost/hours To Complete an activity
$FTC_{(Dis)}$	= Forecasted cost/hours To Complete a discipline
$FTC_{(Phase)}$	= Forecasted cost/hours To Complete a phase
$FTC_{(Proj)}$	= Forecasted cost/hours To Complete the project
$FTC_{(WP)}$	= Forecasted cost/hours To Complete a work package
FTS	= Forecasted days To Complete an activity
i	= Number of the deliverables in a work package
iwp	= net internal work hours package for a deliverable at report date
IWP	=Internal Work hours Package of all deliverables at report date
IWP-Total	= Internal Work hours Package of a work package
m	= Number of work packages in a discipline
n	= Number of activities in a work package.
OD	= Original Duration of an activity
p	=Number of phases in the project
R	= Report date
R.D	= Remaining Duration to complete an activity
$R.H_{(activity)}$	= Remaining Hours/Cost to complete an activity
$R.H_{(deliverable)}$	= Remaining Hours to complete a deliverable

$R.H_{(Dis)}$	= Remaining Hours to complete a discipline
$R.H_{(Phase)}$	= Remaining Hours to complete a phase
$R.H_{(Proj)}$	= Remaining Hours to complete the project
$R.H_{(WP)}$	= Remaining Hours to complete a work package
Spent Hour	= Spent Hours during reporting period
$SPI_{(activity)}$	= Schedule Performance Index of an activity
$SPI_{(Dis)}$	= Schedule Performance Index of a discipline
$SPI_{(Phase)}$	= Schedule Performance Index of a phase
$SPI_{(Proj)}$	= Schedule Performance Index of a project
$SPI_{(WP)}$	= Schedule Performance Index of a work package
$SV_{(activity)}$	= Schedule Variance of an activity
$T.V_{(activity)}$	= Total Variance in dollar ($) of an activity
$VAC_{(deliverable)}$	= Variance in hours At Completion of a control point
$VAC_{(Dis)}$	= Variance At Completion in hours of the discipline
$VAC_{(Phase)}$	= Variance At Completion in hours of the phase
$VAC_{(Proj)}$	= Variance At Completion in hours of the project
$VAC_{(WP)}$	= Variance At Completion in hours of the work package
WD	= Working Days of the activity

Chapter I -Introduction

1.1 General

During the past decade, researchers have devoted their attention to integrating the cost and time management functions for construction projects, particularly in the construction phase rather than in the engineering phase. The reason, perhaps, is that the cost associated with the engineering phase of a wide range of projects is only 3-10% of the total project cost (Eldin 1991). Although this percentage may be considered a low portion of the overall cost of constructed facilities, engineering have a great impact on the successful delivery of these facilities (Georgy et al. 2005). Moreover, when projects are fast-tracked on a tight schedule, the need to assure satisfactory productivity of engineers assumes even greater importance (Thomas et al. 1999). Georgy (2000) conducted a study based on a substantial set of industrial project data collected by the CII Benchmarking and Metrics Committee over the years 1996, 1997 and 1998. He stated that the detailed design phase caused schedule delays with an average of approximately 18%.

However, a number of studies have been carried out to measure the engineers' performances specifically in Architecture/Engineering firms. These studies employed methods such as work-hour input, cost accounting, schedule milestones, conversion factors and utility theory to measure the performance of engineers. Measuring engineers' performance often depends on establishing the differences between the output documents and their associated actual charged hours regardless of the time frame of the planned work. These methods might not provide realistic control systems for the cost and schedule because of the lack of integration between cost and time. In addition, the effect of the engineers' works (deliverables) on the project schedule is not readily accounted for. Thus, it is vital to have an integrated control system that assures full monitoring of engineering deliverables; the integrating of these deliverables with the project schedule, so as to demonstrate the impact of the engineering deliverables on the entire project's time and cost.

1.2 Engineering Deliverables

For successful delivery of a construction project, a set of deliverables should be identified and established at an early stage. A "deliverable" is a tangible, verifiable work product in the contract that an engineering firm, a construction firm, a vendor or a supplier has committed to deliver to the client. For instance, the expression "engineering deliverables" refers to studies, specifications, designs, drawings, cost estimates, project schedules, data sheets, and test results. Each class of deliverables requires a specific method of planning and control (Barry and Albert 2003). In engineering/design phase, engineers usually produce four types of documents: drawings, specifications, material documents, and manuals. The expression "material documents" refers to the date sheet, purchase orders (POs), purchase requisition (PRs) and material take-off. The expression "manuals" refers to the operation and maintenance manuals, welding procedures, piling procedure, and other similar items (Huff 1987, Eldin 1991, CSI

2004). Therefore, it is essential to establish these deliverables in the planning phase, to identify when they are due, and who has the prime responsibility for their respective delivery. Creating a table that encompasses all deliverables included in a contract is usually a good communication vehicle among all parties in the project (Barry and Albert 2003).

1.3 Characteristics of Project Control

To construct an effective control system that has the capability of integrating the project schedule, budget and progress measurements, a number of characteristics should be established: 1) defining a control budget based on WBS of a project; 2) referencing engineering deliverables on project schedule; and 3) measuring the progress based on a quantitative method (Eldin 1991). By achieving the previous points, tracking and control project cost, schedule and accomplishment during the project's lifecycle can be achieved. Then, a comparison between the actual and the planned work can give a clear picture of the project status. The result derived from this comparison should be in a simple and understandable format to provide a good communication vehicle among the project's team members. According to the results derived from this comparison, one of the following conclusions can be drawn (Robinson 1997):

1- Project on target, as the planned work equals the accomplished work.
2- Project with unacceptable performance, so corrective action is required.
3- Significant deviation between planned and actual work, so the baseline should be considered.

1.4 Scope and Objectives

This research work is a part of a collaborative research project being carried out with an industry partner on management of EPCM projects on remote sites. The work described in this thesis focuses only on management of the engineering phase. The main objective of this research is to study current industry practice as it relates to tracking, controlling and progress reporting on engineering deliverables in EPC projects (Engineering, Procurement and Construction). And to introduce improvement in targeted areas to support these management functions. The research work is carried out from EPC consultants' view point. The following are sub-objectives of this research:

1- Carry out a field study and extensive literature review to develop understanding as well as appreciation of the status of current practice in the stated management functions.

2- Identify jointly with industry partner area that likely to improve execution of the management functions referred to above.

3- Develop algorithms to support the generation of performance indicators, to assist in forecasting cost and time at targeted milestones and to demonstrate the impact of the engineering deliverables on other phases of EPC projects.

4- Develop software to demonstrate the uses and capabilities of developed algorithms.

1.5 Organization of the Thesis

The present thesis consists of six chapters. The second chapter presents a review of the literature focusing on tracking and controlling of engineering deliverables for EPC projects. Chapter Three is devoted to describing the proposed methodology and the developed computerized system. Chapter Four describes the development of the proposed system and its embedded modules. It also depicts screens of the developed system. Chapter Five presents a case study adopted an actual project undertaken by the industrial partner to validate and demonstrate the use of the developed system. Chapter Six includes the concluding remarks and recommendations for future work.

Chapter II – Literature Review

2.1 General

For successful implementation of construction projects, particularly engineering, procurement and construction projects (EPC), an effective tracking and control system should be established at an early stage. Fig.2.1 illustrates the life cycle of a construction project. The key to successful achievement of project objectives lies in establishing effective control parameters for cost, time, and performance (Stevens 1986, PMI 2004). To construct such a system, it is necessary to define the suitable work breakdown structure, organizational breakdown structure, and methods for measuring progress.

For the construction phase, many control systems have been developed. Among them are the models developed by Alshaibani (1999), Hassanein (2003) and Li (2004). By contrast, a limited number of control systems have been developed for the engineering phase. The majority of these control systems depend on different techniques such as work-hours input, time distribution and earned value. However, measuring performance in the engineering phase usually depends on a traditional cost accounting system used by construction companies.The following sections describe the required elements for establishing tracking and control systems for construction projects. Subsequently, a number of current control systems and their advantages and limitations are discussed.

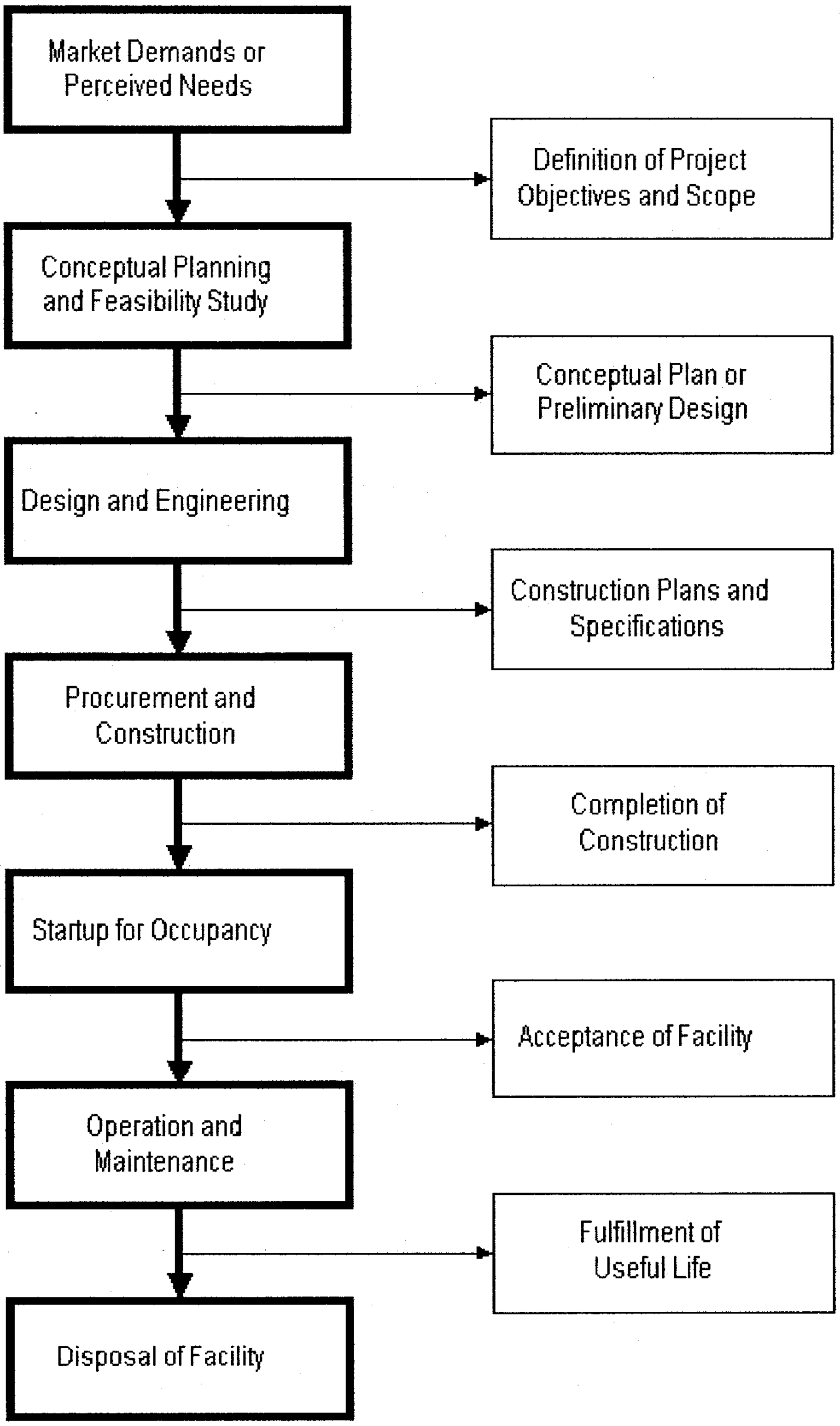


Fig.2. 1 Project Life Cycle of a Constructed Facility (Hendrickson 1999)

2.2 Planning and Scheduling

Planning is the most crucial, knowledge-intensive, ill-structured, and challenging phase in the project development cycle (Kibler 1992, Moselhi 1993). According to AIA (American Institute of Architects) Document B141, design professional services occur in five phases. The first phase is the schematic design phase. In this phase, the architect implements the schematic design and drawings that represent the scale and the relations of the project components. The second phase is the design development phase. The output of this phase is the design documents and drawings that specify and explain the size and nature of the project. The third phase is the construction document phase. The output of this phase encompasses drawings and specifications that describe in detail the construction requirements of a project. The fourth phase is the bidding phase or the negotiation phase. In this phase, the architect supports the owner to obtain bids or to negotiate proposals and to assist in awarding and preparing the construction contracts. The last phase is the construction or contract administration phase. In this phase, the design professional controls the project on behalf of the owner. By identifying the previous phases, the engineering works can be well planned, and the realistic estimation of their time can be determined accurately in the early stage of a constructed facility.

Scheduling aims at depicting the relations among activities, demonstrating the critical path, establishing the duration for each activity, and calculating the float. The schedule is often produced for diverse purposes and is implemented at different stages according to the project's WBS (Kibler 1992, Moselhi 1993, Davey 2004). Scheduling the engineering activities is one of the most difficult tasks because the sequence of their works may not follow typical logic. It comes down to priority, preferences, and discipline (Kerridge and Vervalin 1986).

2.3 Work Breakdown Structure (WBS)

WBS is the sequential division of a large and complex project into smaller and simpler elements, called work packages, which completely define the project (Moselhi 1993). The work breakdown structure has been the subject of many publications, most remarkably those produced by the U.S.A. Department of Defence (DOD), Department of Energy (DOE) and National Aeronautics and Space Agency (NASA) (Moselhi 1993, Thomas et al. 1999). WBS organizes the physical work into levels that can be developed into a summary (DOE 1981). It can be developed in several ways. Subdivisions can consist of the construction site areas, departments, disciplines, process components, building elements, or process system (Moselhi and Ho 1994, NASA 1994, Rad 1999). Fig.2.2 depicts an example of a work breakdown structure.

NASA has developed the WBS to include two types of WBS: Program/Project WBS (PWBS) and Contract WBS (CWBS). The Project Work Breakdown Structure (PWBS) is the structure that consists of the entire project or program; it usually includes three levels as follows: 1) entire project/program, 2) major elements of the subsections, and 3) definable components of subset 2. NASA often controls the three top levels in the PWBS while the lower-levels of the PWBS are often controlled by contractors because coding systems vary from contractor to contractor. The Contract Work Breakdown Structure (CWBS) is a complete WBS for a specific contract that describes all the components of the contract at the lower-level according to the contract statement (DOE 1981). Fig.2.3 illustrates the relations between the PWS and the CWBS. The breakdown is often performed along two axes; the physical components of the project are defined through the vertical axis, while the horizontal axis defines the project in terms of its organizational structure (Moselhi 1993). In addition to these two axes a third axis can be added to represent the resource (DOE 1981, Moselhi1993). WBS can be used for planning, cost estimation, scheduling and integrated cost and schedule control. This technique is usually referred to as cost or control account (Moselhi 1993). The WBS has to integrate with the Organizational Breakdown Structure (OBS) to correlate with tracking and control functions (Li 2004). OBS defines the organizational relationships; it is used as a framework for assigning the work responsibilities (High Bridge Associate, Inc.). It should be established at the early stage of the project to define the responsibilities and resources needed to accomplish the project. Fig. 2.4 gives an example of the OBS. By integrating the WBS and the OBS, the project is well defined in terms of the work frame and responsibility.

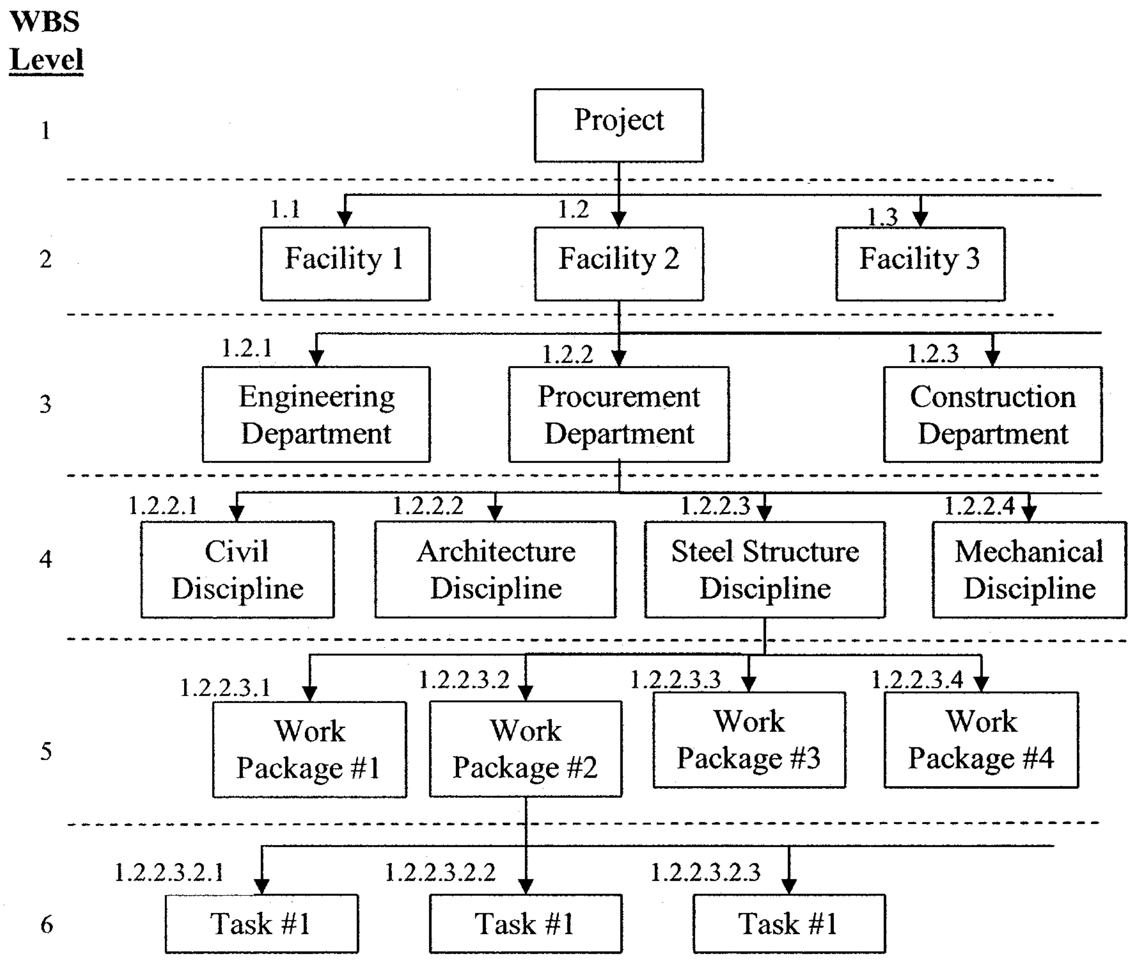


Fig.2. 2 Work Breakdown Structure

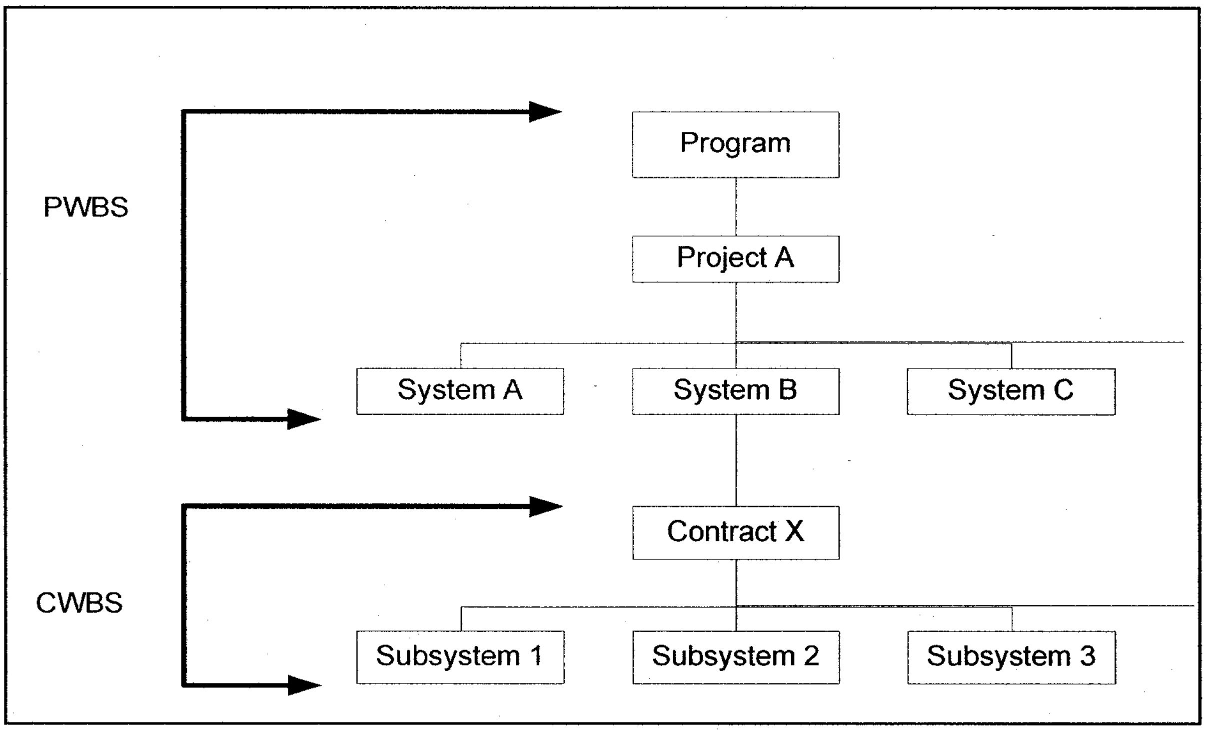


Fig.2. 3 PWBS and CWBS Relationship (NASA 1994)

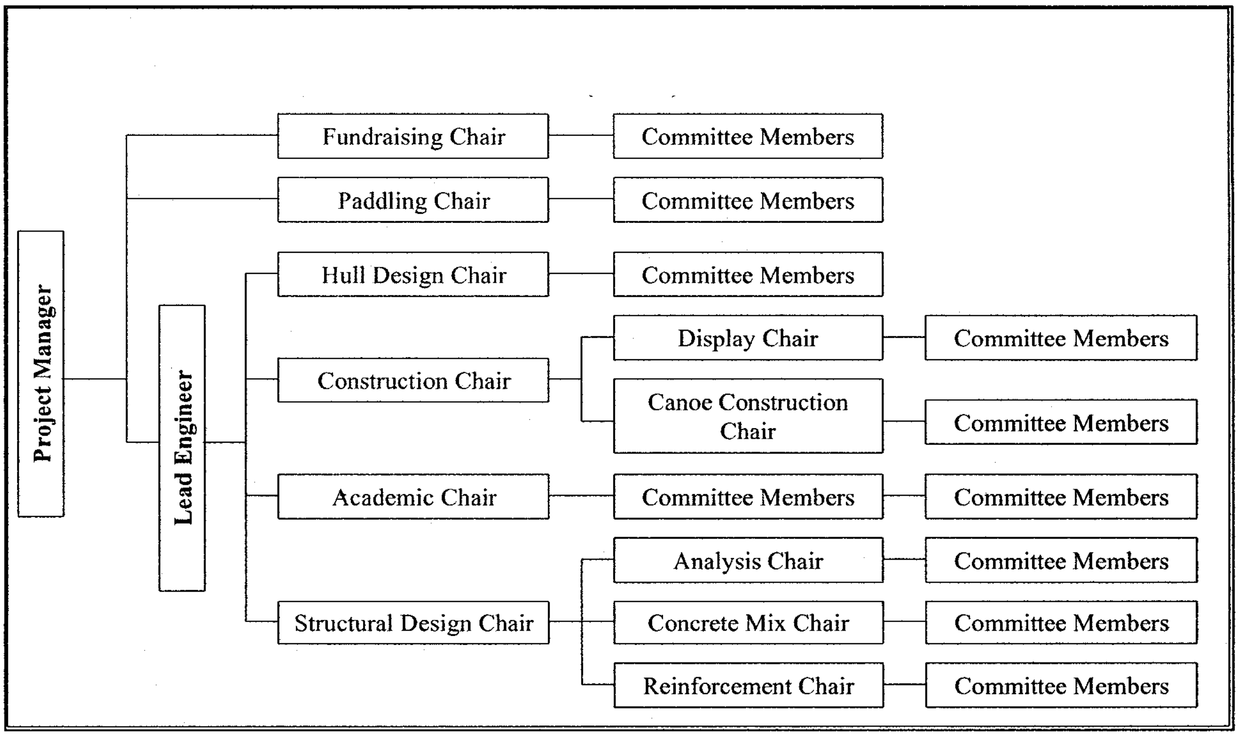


Fig.2. 4 Organizational Breakdown Structure (DOE 1981)

2.4 Work Package

A work package may be generally defined as an item of work that is well described. This item might consist of goods or products. A work package is a cost center, and it is also an activity for scheduling. Each work package must be a measurable and controllable unit of work to be carried out. It is often a functional division of an element at the lowest level in WBS. A work package may vary in size and duration; however, it is usually designed to have a small duration less than a month. It must be identified in the numerical accounting system to allow estimating, monitoring, and measuring performances (Moselhi 1993). In the survey conducted by Moselhi (1993) in the Montreal area, it was found that a work package may have a value of cost accounting of approximately $300,000. The study also provides a guide line for using around 180 work packages for 50$ million contracts, 320 for $100 million, and 460 for $150 million. However, each project is unique, and the design of its control system should account for the project environment and should satisfy its objective. Fig 2.5 gives an example of planning a work package.

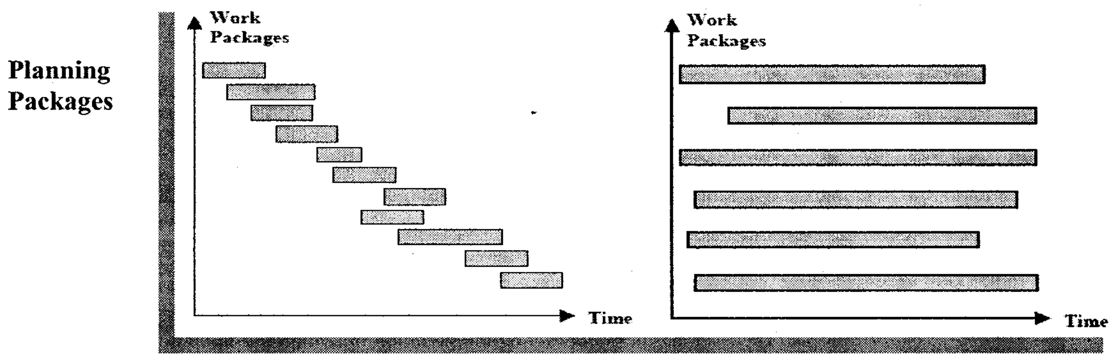


Fig.2. 5 Work packages

After performing WBS and OBS for a construction project, a cost count should be introduced. A cost account is a management control point at which the actual costs can be accumulated and compared to the budgeted cost for the work performed (NASA 1994). It is used for the purpose of planning, monitoring and reporting the cost and schedule; it should be established at an early stage of a project. Each work package in the project system must have a cost account. By integrating the cost account with the WBS and OBS, an integrated control system for the cost and schedule functions such as the Earned Value can be applied. Fig. 2.6 and Fig. 2.7 show the relation of the cost account, work breakdown structure and organizational breakdown structure.

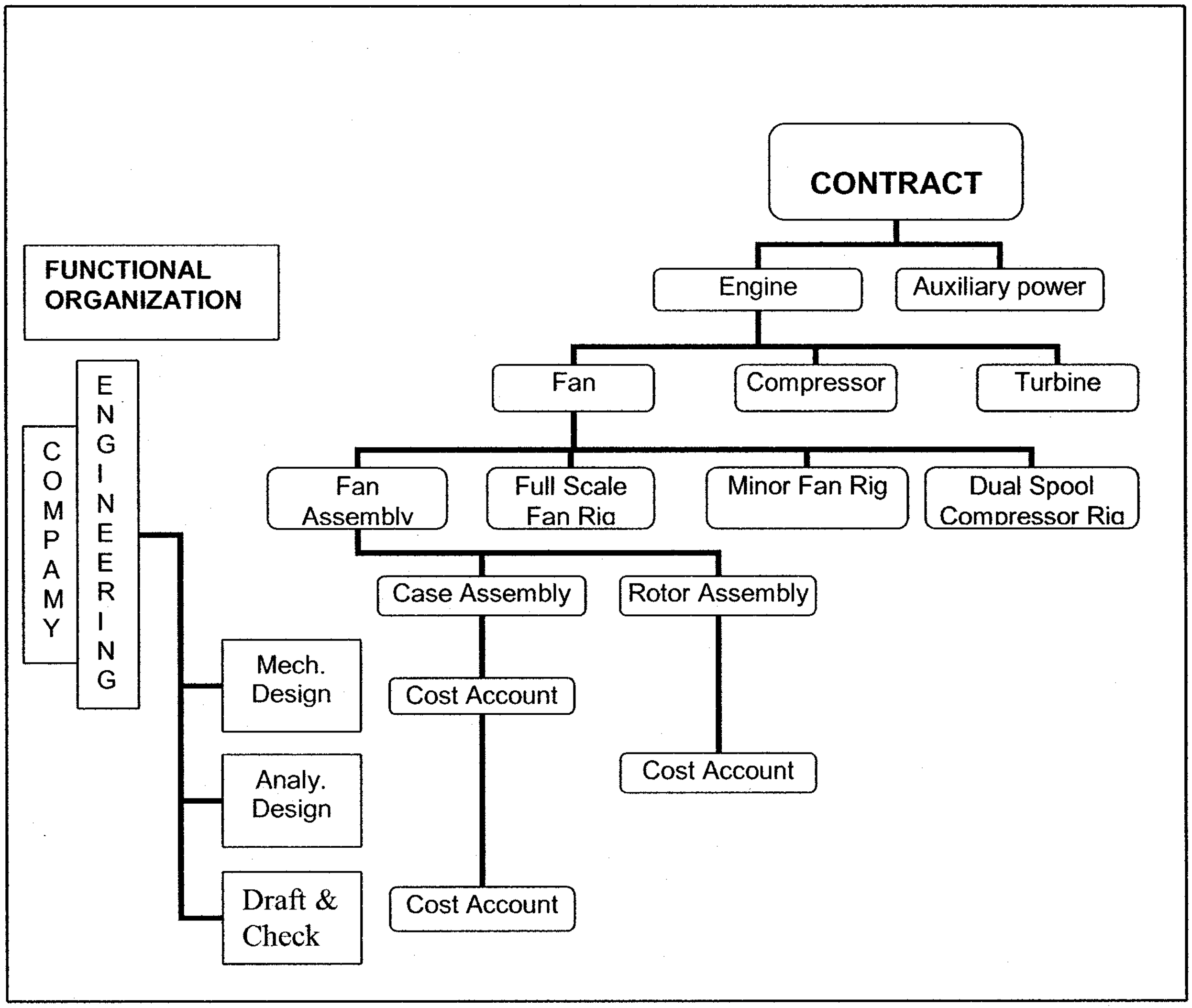


Fig.2. 6 Cost Account (NASA 1994)

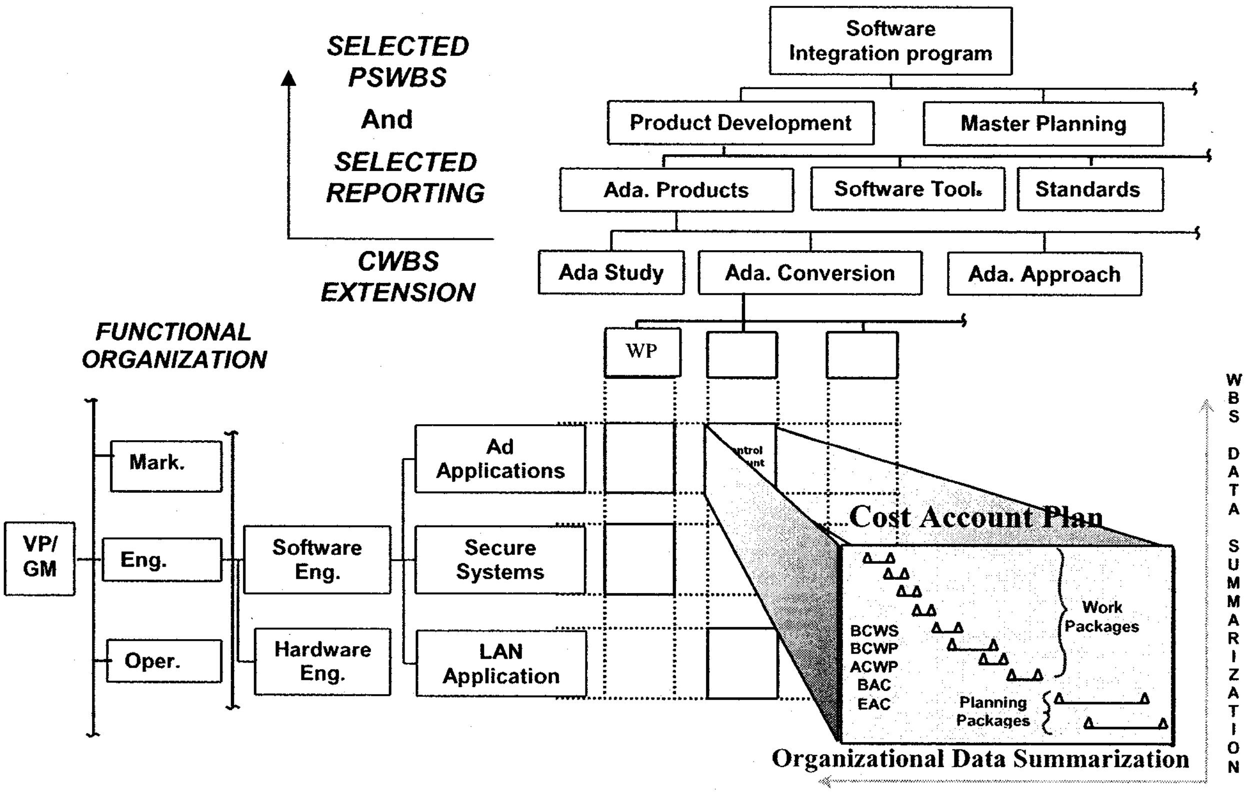


Fig.2. 7 Integration between PWBS& CWBS (DOE 1981)

2.5 Coding Structure

It is a code used to identify every element in the WBS of a project. This code is usually a simple decimal number or an alphanumeric coding system. This coding system is applied in a logical way to indicate the level of every element in the WBS, and to relate the lower-level supporting elements to their parent upper level elements in the WBS. As a result, all elements in the WBS are related to each other (DOE 1979, DOE 1981, NASA 1994). See Fig. 2.2 for an example of a coding system that is extended to 6 levels.

2.6 Current Practice

Considerable research efforts have been carried out in the tracking and control of EPCM projects. This section presents a field study carried out in collaboration with an industrial partner of EPCM projects on remote sits and a comprehensive review of the work conducted by others in this domain.

The field study has been carried out for a span of 10 months period in collaboration with SNC-LAVALIN (industrial partner). The study focused primarily on management of engineering phase of an EPCM project on east of Montreal. Issues related to project configuration, tracking and control of engineering deliverables are presented later. The experience gained from this study confirmed that the execution of the EPC as well as EPCM projects through a number of commitment packages is an efficient strategy not only for planning, but also for tracking and control.

The study demonstrated that SNC-LAVALIN has adopted the commitment package strategy (CMS) to plan, track and control EPC as well as EPCM projects. It should be mentioned that the definition and structure of the commitment package are presented in chapter 5, section 5.4. To apply CMS, three techniques are used: Work Breakdown Structure (WBS), Progress Template (PT), Schedule Template (ST) and Earned Value (EV). WBS is used to subdivide projects into three phases (engineering, procurement and construction); a number of disciplines (civil, concrete, steel structure, etc.); and a number of commitment packages that describe the work in detail. While PT is used to measure progress of each deliverable, ST is used to track and control commitment package schedule, and EV is used to determine performance of each commitment package.

SNC-LAVALIN has developed an integrated management tool, Project Management Plus (**PM+**), which covers most aspects of project management and provides the users with on-line information. The system consists of ten modules such as the Estimating Module, the Document Control Module, and the Procurement Module. The Internal Mandate Module, which is designed to plan, track and control engineering deliverables, is one of these modules. It should be mentioned that the Internal Mandate Module is designed to integrate with the Document Control Module, which is used to generate all types of documents (technical, administrative and vendor) related to the project. Throughout the Internal Mandate Module, users are capable to plan, track and control engineering deliverables by commitment package, observe different types of reports, and monitor scope change of the work. Fig.2.9 illustrates the work follow in the Internal Mandate Module.

In the planning phase, WBS is used to subdivide projects into three phases (engineering, procurement and construction); a number of disciplines (civil, concrete, steel structure, etc.); and a number of commitment packages that describe the work in detail. In the engineering phase, every commitment package is broken down into a set of tasks that are usually associated with a document(s); and a number of activities in the project schedule. While the tasks are planned in terms of the needed man-hour, the activities are planned in terms of time frame (start and finish dates and original duration) and interdependence relationships (start to start, finish to start, etc.). The progress templates, which encompass a set of distinct events with associated cumulative earning percentages, are assigned to tasks for measuring progress purpose. The schedule template is assigned to entire commitment package for tracking purpose. It should be mentioned that one progress template can serve one or more tasks.

In the execution phase, the actual expenditure hours are recorded for the entire commitment package while determining progress for each deliverable is computed by selecting an appropriate earning percentage from a progress template. It should be mentioned that progressing tasks associated with document(s) can be preformed by issuing transmittals in the Document Control module. The forecast hours to complete every task in a commitment package are estimated by members of engineering teams. The engineering teams also estimate the forecast date of completion of each commitment package.

Finally, The Earned Value is used to determine the performance of each commitment package, discipline, and phase. It should be mentioned that the uses of the progress templates and earned value in engineering/design phase are presented later.

The results derived form this study indicated that PM+ is a powerful management tool. One strength of PM+ is its integration between its embedded modules, so evaluating the performance of project's phases can be obtained. The study also indicated that PM+ can accommodate different type of Work Breakdown Structure based on client's preference. The WBS can be developed to serve projects by area, facility, document type (drawings, data sheet, etc.) and by department.

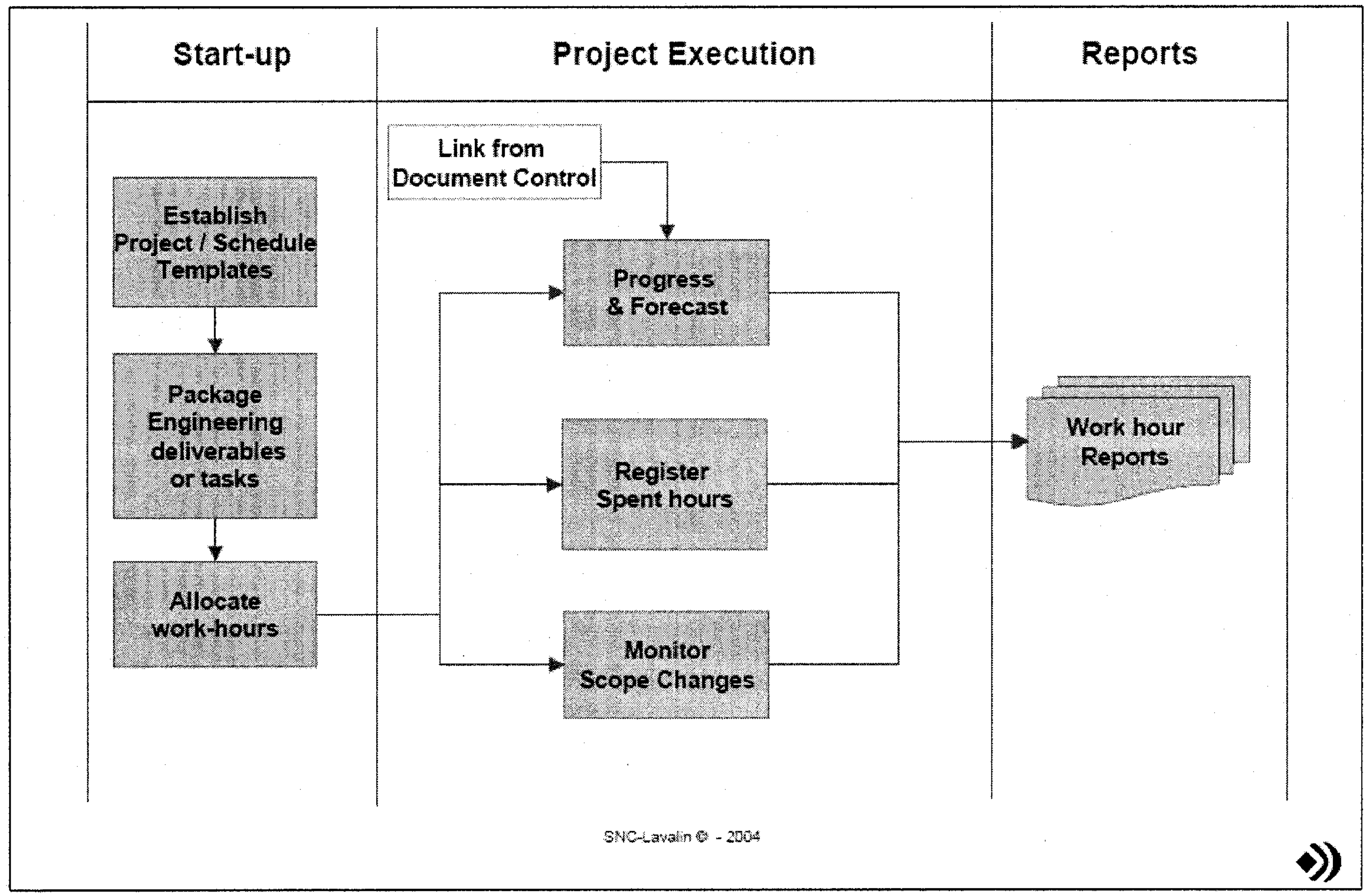


Fig.2. 8 Work Flow in the Internal Mandate Module (Bebawi 2006)

In addition, considerable research work has been carried out in the area of tracking and control engineering works. The majority of these research works focused on measuring engineers' performance rather than on defining the status of the engineering deliverables. Indeed, a method should be developed to enable controlling and managing different document versions (Caldas et al. 2005).The following section describes some of those studies and demonstrates their advantages and limitations.

Earned Value concept is an essential management tool of the cost and schedule (Eldin 1991, Moselhi 1993). Its concept related to the performance measurement of a project in order to evaluate what we actually got with respect to what we spent and what we planned to spend. The earned value technique has received wide attention since 1967 when the U.S Department of Defense introduced cost and schedule control system criteria (C/SCSC). According to this concept, three S-Curves are implemented: 1) the Budgeted Cost of Work Scheduled (BCWS); 2) the Actual Cost of Work Performed (ACWP); and 3) the Budgeted Cost of Work Performed (BCWP). These S-Curves can be created for materials, equipment, subcontractor costs, direct and indirect costs and multiple combinations of the above or the total cost (Moselhi 1993). Fig. 2.8 illustrates the S-Curves where the BCWS curve represents the baseline; the ACWP represents the actual expenditure to perform the work; and the BCWP (earned value) represents the value of the actual work performed. The BCWS and ACWP can be easily created whereas representing the BCWP is difficult maybe because of the lack of a standard, fair and equitable (Moselhi 1993). Then, a set of indicators can be carried out to determine the project status as follows:

Cost or Spending Variance = ACWP – BCWP.....................................2.1

Schedule Variance = BCWP – BCWS..2.2

Accounting Variance = ACWP- BCW...2.3

Cost Performance Index (CPI) = BCWP/ ACWP....................................2.4

Schedule Performance Index (SPI) = BCWP/ BCWS..............................2.5

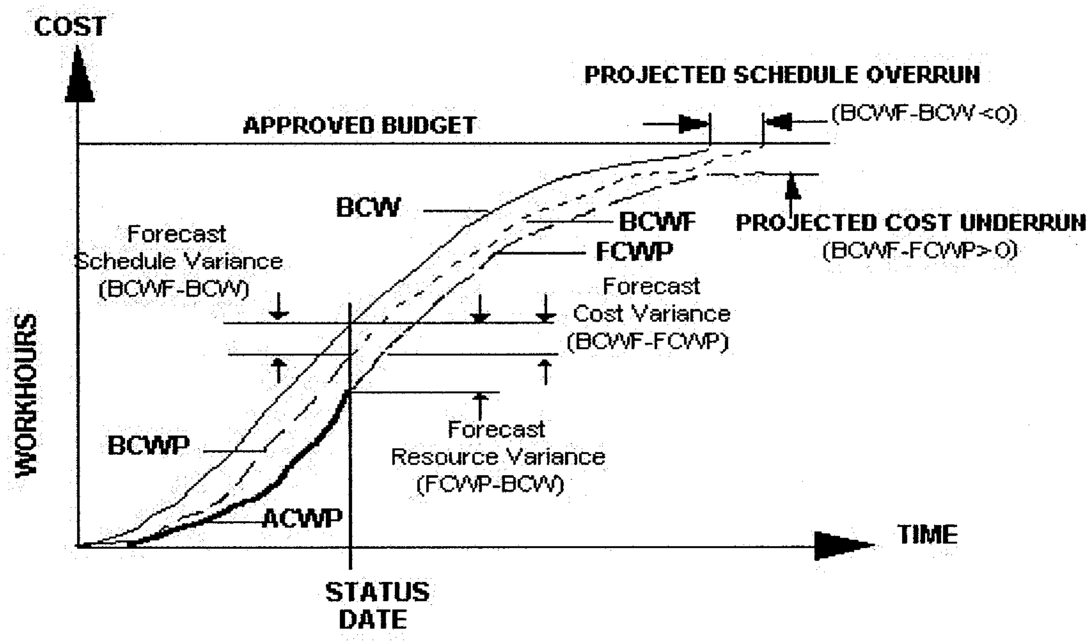


Fig.2. 9 Earned value (SNC-LAVALIN 2006)

The earned value concept has been successfully applied in the construction phase. In the engineering/design phase, engineering deliverables are the key for managing the cost and schedule of a project (Davey, 2004). A few studies have employed the earned value technique to measure the engineers' performance by comparing the actual expenditure hours to the output products (document, drawing, etc) regardless of the time frame of the products. According to Eldin (1991), "the earned value concept can be successfully implemented in the engineering/design phase by identifying distinguishable events (control points) throughout the life cycle of engineering documents and by developing earning rules for reaching these events." These control points can be grouped in tabular format called "Progress Templates". However, there are two types of the progress templates. The first type is for monitoring the schedule only. This type of template involves defining the standard duration for processes to reach specific milestones that we wish to monitor; the second type is the progress template that shows the typical percentages that are gained when specific stages are reached in the production of a task. These stages are used as points of control for the progress of tasks (Moselhi 1993, SNC-LAVALIN 2006). Table 2.1 demonstrates a sample of a progress template for a civil discipline (SNC-LAVALIN 2006). It should be mentioned that the progress templates are established at early stage of a project or process through a management round table among project's parties. By developing these progress templates, the earned value can be correctly applied.

Table 2. 1 Progress Template for Civil Work (PM+, SNC-Lavalin)

CIVIL TEMPLATES		
%Cumulative	**Milestone Description**	**Template Code& Description**
0,00	Initiate Design	**41DD U/G Piping & Site work Drawings**
20,00	Start Engineering	
60,00	Issued for Client Review	
61,00	Client Comments	
90,00	Released for Tender	
95,00	Released for construction	
100,00	As-Built received &Filed	
0,00	Initiate Design	**41EC Design Criteria-site work &U/G Piping**
15,00	Start Documents	
60,00	Coordination Start	
61,00	Issued for client Review	
100,00	Issued for detailed Design	
0,00	Initiate Design	**42EF Installation Specifications**
15,00	Start Documents	
60,00	Coordination Start	
61,00	Issued for client Review	
100,00	Issued for detailed Design	

Armentrout (1986) explained a commitment management concept to measure the performance of the engineers in A/E firms. A commitment is a promise or pledge to the client to provide a deliverable product or to accomplish a project milestone by a specific date. By tracking these commitments periodically, the performance of the engineering organization can be measured by answering the question: "How well are the commitments met?" Then, if the comparison shows that a significant number of commitments are not being met, reviewing the performance at the lowest level can explain where the problems came from. The system is based on paying attention at all levels to ensure that the commitments are met. Although the system is defined by how well the organization does, it is not suitable for integrating cost and schedule, and there is no clear understanding of whether the system is suitable for EPC projects. The system focuses only on schedule milestones.

Eldin (1991) has developed a model to measure the engineering performance in A/E firms. He developed a control budget, project schedule and a progress measurement process. In his model, the project schedule was developed based on the American Institute of Architecture (AIA) documentation of the engineering works in the engineering phase. The work break down structure is used to divide the project into a set of documents that define the scope of work in every discipline in every facility. By carrying out the pervious step, a definitive estimate of the man-hour needed to deliver each document can be determined. These documents, then, are assigned unique numerical codes and are grouped in work packages that are referenced in the project schedule according to their logical executions. Fig 2.10 and Fig 2.11 illustrate the grouped documents under work packages and the logical order of these work packages in the schedule, respectively. Thus, the control budget of each work package is derived from summing up the total man-hour of its documents (direct cost) and other budgets such as those related to supervision and supporting services (indirect cost).

In the execution phase, the earning rule is used to measure the progress of the documents at pre-defined points. Each point is assigned an earning value that can be expressed as a percentage of the document's budget, duration, or another arbitrary work unit. Thus, earned values can be calculated as the percent complete of these earning points while actual spent work unit is recorded for each document. As a result, the Performance Index (PI) for every document, every work package, every discipline and project can be obtained by applying the Earned Value concept. It is obvious that the system is valid only for A/E firms and the impact of engineering deliverables on other project phases (construction and procurement) is not presented.

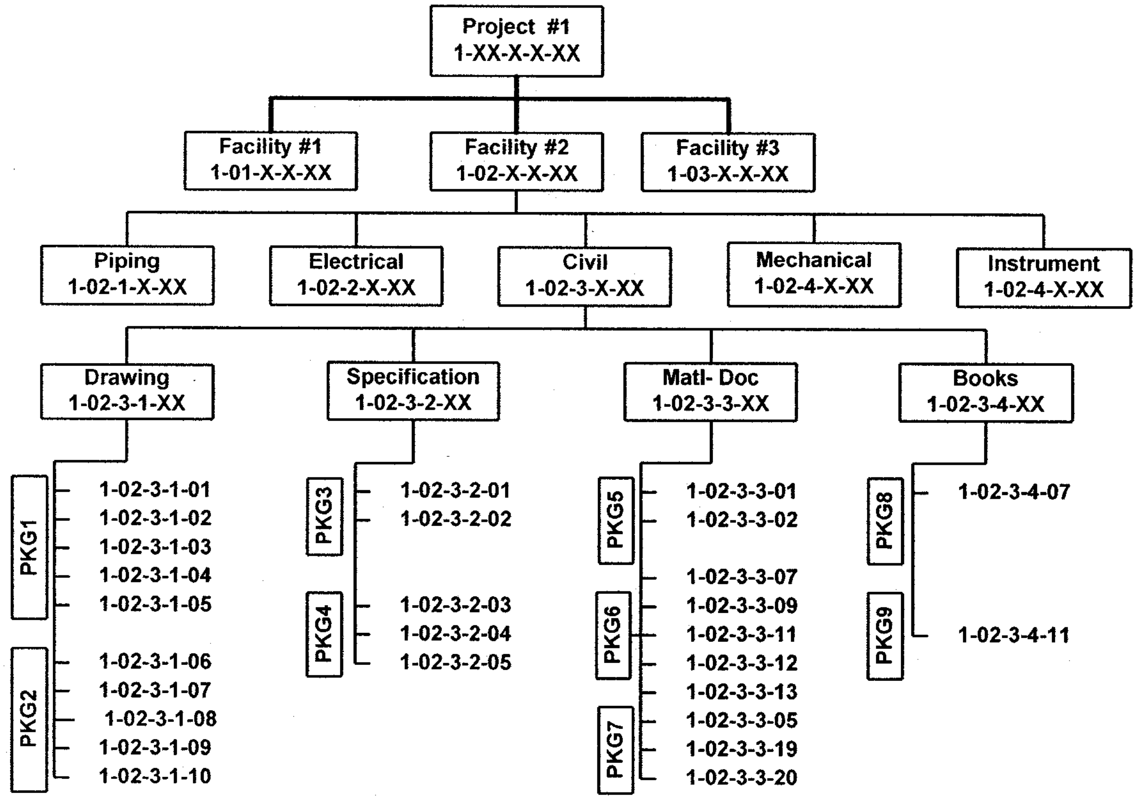


Fig.2. 10 Identification of Eng. Documents on WBS (Eldin 1991)

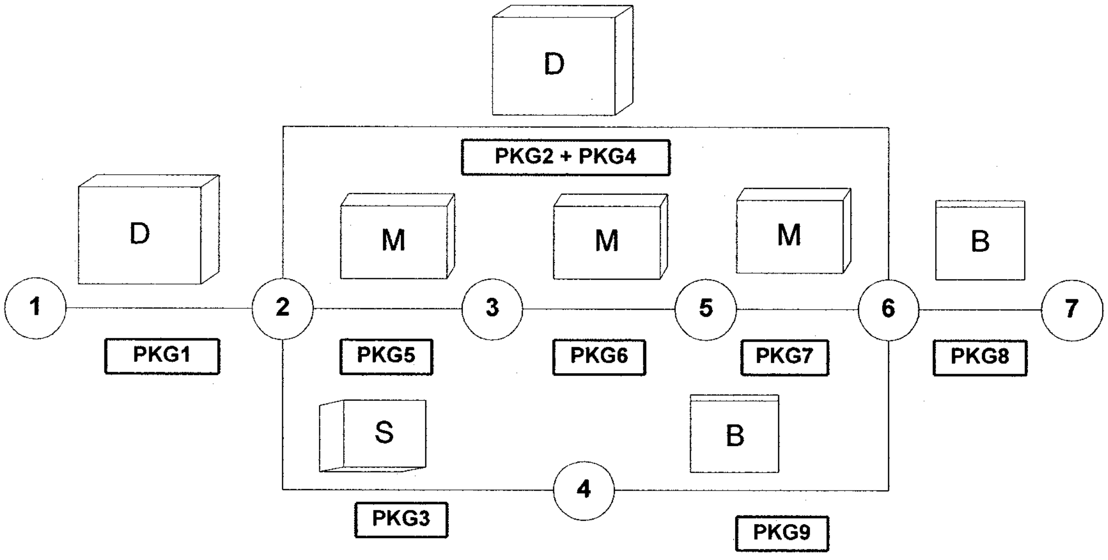


Fig.2. 11 Reference Eng. Documents on the project Schedule (Eldin 1991)

Thomas et al. (1999) has developed a conceptual model to measure the productivity of the engineers in A/E firms for specific types of projects (secondary schools). The first step in this model is to develop a conversion factor that is based on defining a standard drawing or specification division. According to the authors, standard is usually selected as an output document that occurs frequently. The unit rate (work hour/sheet) for the architectural detailed drawings was used as the standard. Secondly, rules of credit are used in the system. Rules of credit require defining the incremental percentage of the earning value at each milestone. Throughout a survey conducted by the authors, it is found that four milestones were applied during the design phase: 1) first draft; 2) second draft reviewed; 3) review and revision; and 4) quality control review. After calculating the conversion factors and establishing the rules of credit for each document, the equivalent quantities of the output are calculated by multiplying the conversion factor and the credited quantities. Thus, the productivity can be achieved by comparing the output units to the input hours. It is apparent that the system does not have the capability to integrate the cost and time. And it is also limited to a specific type of projects (secondary schools).

Chang (2001) have developed a Work-Time Model to arrange engineers' work mechanisms and time on tasks. In his model, the Information Processing (IP) technique, which is used among parties in an organization to reduce the Uncertainty and Equivocation (U&E) associated with tasks, was utilized. To achieve effective performance, a fit should be obtained between IP requirements and capacity (see Fig.2.12). To obtain the IP requirements of each task, the weights of the Uncertainty and Equivocation (U&E) associated with tasks are computed based on analyzing the sources of the U&E. He stated that the sources of the U&E are the task characteristics, task interdependence, human characteristics, task environment and task-possessed information. To determine the weight value for each source, a questionnaire composed of four questions with answers scored from 1 to 5 is used. Engineers consume time through work mechanisms that include: Internal Work (IW), External Communication (EC) and Internal Communication (IC). Therefore, a time unit (work hour) is used to estimate the required work hours to accomplish each task.

In the planning phase, the scores derived from the questionnaire are used to spread engineers' time along the EC, IC and IW. It is assumed that the EC receives a score from the equivocality of the task environment, the IC receives a score from the equivocality of other four sources and the IW receives scores from the uncertainty of the five sources. In the execution phase, the project time sheets recorded hours on tasks. To compute the actual EC, IC and IW, interviews with the project managers are carried out to obtain the ratios between the EC, IC and IW. After performing the previous steps, the overall fit can be determined by computing the differences between the planned and actual hours., Shing and Chang stated that the smaller the value of the fit the higher the performance is. They also used the cost ratio to determine the performance of each task. Although the system was developed to plan and track all engineering activities, its difficulty resides in defining the U&E associated with tasks and on spreading the time between the EC, IC, and IW. Moreover, the impact of engineering deliverable on project phases is not demonstrated.

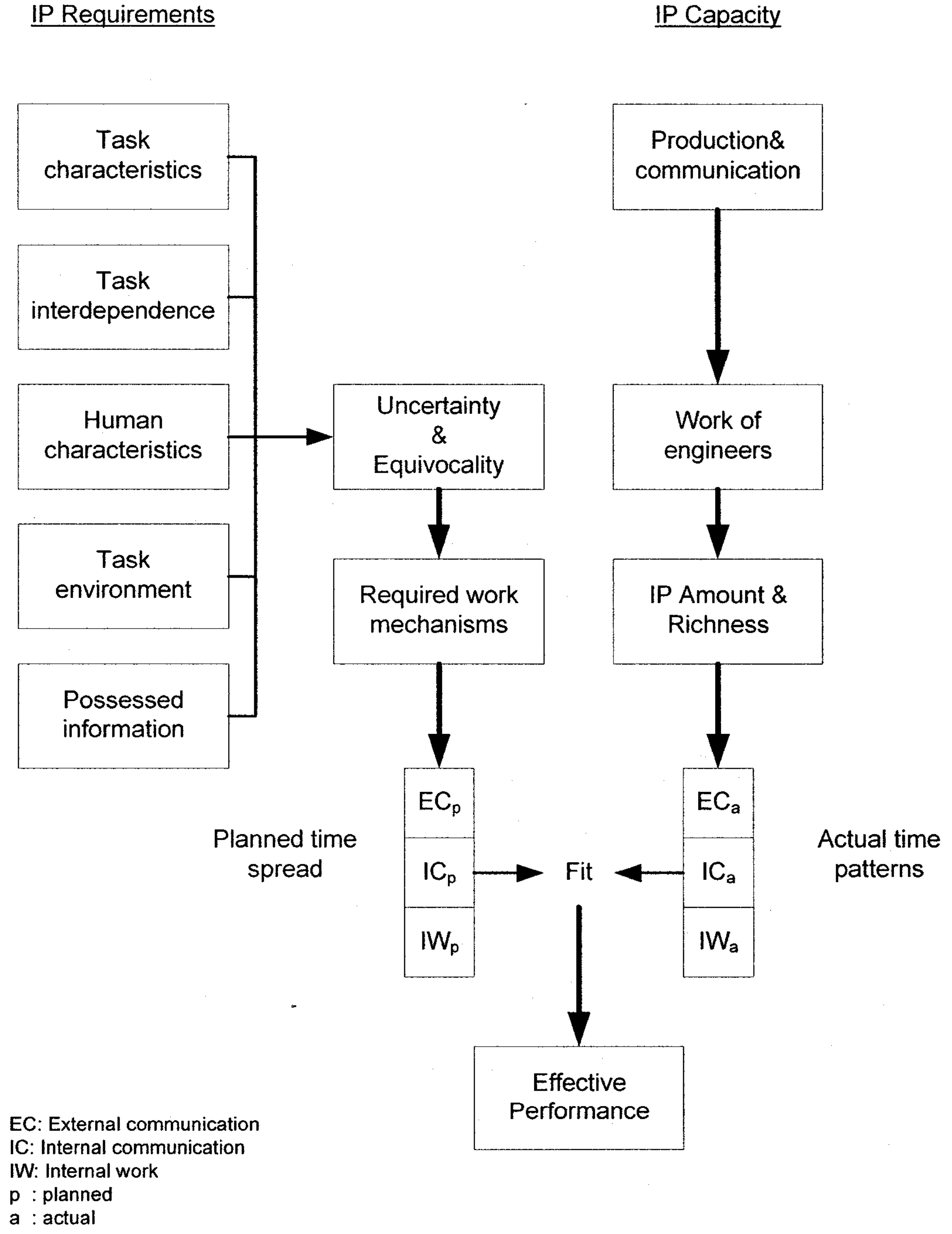


Fig.2. 12 Model of IP Mechanisms and Time (Chang 2001)

Georgy et al. (2005) has developed a model based on a multiple attribute utility function method. In this model, the utility function is utilized to determine the overall performance of engineers who usually provide three basic values: 1) Detailed design values; 2) Fabrication and construction values; and 3) Start-up and commissioning values. Each value includes a set of performance measurements that can be maximized and minimized to obtain optimal engineering performance (Fig. 2.11). The multiple attribute utility function theory was developed based on two main steps.

The first step is to identify a single attribute function $U_i\ (y_i)$ associated with the various engineering performance measures. This is done by examining each performance measurement through questionnaires and interviews with experts in the construction industry. For instance, values of measurements can range between 0 and 1 (U_L, U_H). The second step is to develop a preference structure among these measurements to obtain their relative importance. Then, pair-wise comparisons were performed at the phase level and at the upper level in the project hierarchy. Fig. 2.13 illustrates the two levels of the pair-wise comparison and the ten measurements.

Having performed the previous point, the weight values of the different measurements can be extracted from the phase level. Then, the global (project hierarchical) level is established by multiplying the weighted vector with its component in the upper level. As a result, the overall performance can be achieved using the over-all utility function ($U_t = \sum U_i (y_i)$). Then, engineering performance is evaluated according to U_t value, which is a range between 0 and 1. The authors stated that the bigger the value the better the performance of the engineering. By applying this method to several construction projects that did not follow the statistical method, a value of 0.86 was considered as an optimal engineering performance. Thus, the performance of the engineering can be determined by its relative ratio ($U_r = U_t/0.86$). The higher the value of U_r the better the performance of the project is.

The main limitation in this model as the authors stated is the difficulty associated with acquiring the data for a preference project. Besides, the model was developed based on an assumption that the evaluators had a risk-natural attitude. It is obvious that capturing a single deliverable or a set of deliverables that might cause the problem is not identified in the system. The system also does not include the integrating of the cost and time.

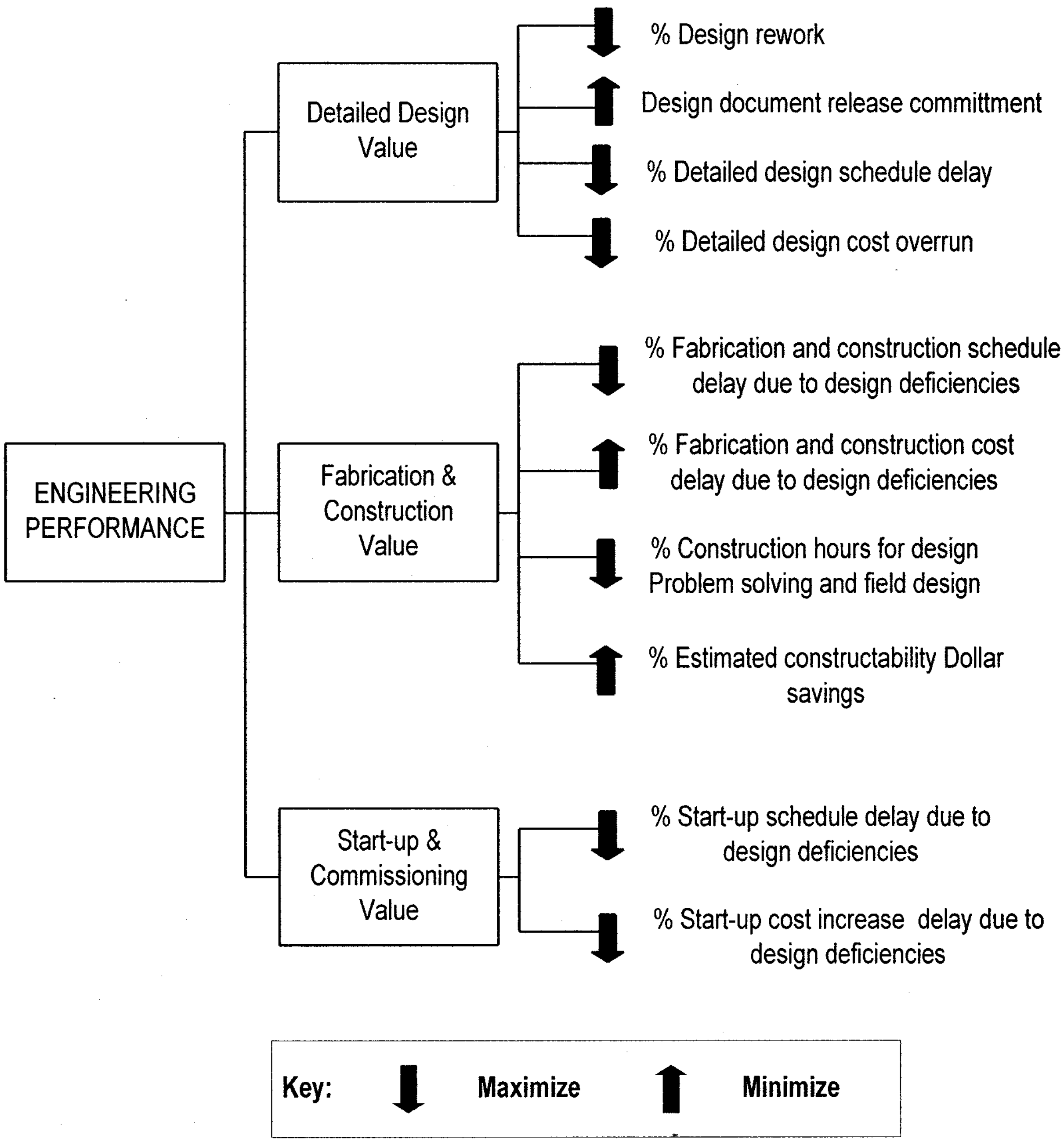


Fig.2. 13 Measures of Engineering Performance (Georgy et al. 2005)

2.7 Desired characteristics of control systems

After recognizing the limitations of the previous control systems, an integrated system for tracking and controlling engineering deliverables for EPC projects should be developed to overcome certain limitations. Therefore, it is essential to identify the characteristics of such a system. They can be summarized as follows:

1- The system must operate at three levels (deliverables, activity and project).

2- The system must integrate engineering deliverables with the project schedule.

3- The system must be capable of manipulating and retrieving complex data in an easy and automated way.

4- The system must have the capability of identifying the reasons behind unacceptable performance, if any, at any level.

5- The system must be capable of working as standalone software and/or to integrate with scheduling software (P3).

6- The system must have a friendly interface and must be easy to use.

7- The system must integrate the cost and schedule functions (Alshaibani 1999).

8- The system must have its embedded database (Progress Templates).

9- The system must demonstrate the effect of the engineering deliverables on other phases of EPC projects.

10-The system must report project status timely and effectively.

2.8 Summary

This chapter has introduced an intensive literature review of the tracking and control method. It introduces the elements for tracking and controlling construction projects. This chapter has also introduced the current practice in the area of tracking and controlling engineering deliverables, including a filed study. The field study that was carried out in collaboration with SNC-LAVALIN, industrial partner, for an EPCM project on the east of Montreal was introduced. The current control systems that have been implemented by others were discussed. The advantages and limitations of those controls have been demonstrated. Finally, the characteristics of a desired integrated control system have been pointed out.

Chapter III –Proposed System

3.1 Methodology

For tracking and controlling engineering deliverables in EPC projects in an effective way, a set of considerations should be taken into account. They should be identified and established at the project startup to provide the project management team with meaningful information that assists them in defining the project status accurately during the execution phase. These considerations include: 1) defining the level at which the measuring will take place; 2) establishing the basis and rule for measuring performances; 3) integrating engineering deliverables into the project schedule; and 4) demonstrating the effects of engineering deliverables performances on the entire project schedule. Thus, the proposed methodology in this research relies on three main techniques: 1) Work Breakdown Structure (WBS); 2) Earned Value (EV); and 3) Progress Template (PT).

First, defining the level at which the measurement will take place in the project hierarchy system can be accomplished by using the WBS technique. As stated earlier, WBS is used to break down large complex projects into a number of well-defined items called work packages. WBS can be developed to break down EPC projects into different levels such as phase (Engineering, Procurement and Construction), discipline (Civil, Architecture, etc.), work package, and activity levels. Fig.3.1 depicts WBS technique in the proposed methodology. In the engineering phase, every work package can be broken down into a number of activities on the project schedule (Fig.3.2); and a number of deliverables. The activities represent tangible and intangible efforts undertaken by engineers to produce deliverables. The expression “tangible efforts” refers to direct products that are deliverables while the expression “intangible efforts” refers to indirect products such as internal coordination among project’s members and external communication with the client. The deliverables represent direct products (drawings, data sheets, specifications, etc.). **SNC-LAVALIN** utilizes this concept to break down projects and to develop their respective WBSs (see Fig. 3.3). In the proposed methodology, measuring the project performance is achieved at three levels: deliverables, activities and the entire project levels. It should be mentioned that the entire project level may include three or more sub-levels based on the WBS of the project. In the proposed methodology, the deliverable level is the lowest tracking level in the engineering phase, whereas the activity level is the lowest level in the project schedule. The activity level is used to integrate the deliverables level with other levels in the project hierarchy system.

The second consideration is to define the basis for measuring the performance. The Earned Value concept is used in the proposed methodology to measure project performance, to forecast cost and time and to integrate cost and schedule functions (Eldin 1991, Moselhi 1993, Fleming and Koppelman 2000). Applying the earned value concept requires defining its components (BCWS, BCWP and

ACWP) and identifying how it will be applied and when it will be established (Eldin 1989, Moselhi 1993).

In the engineering/design phase, the document's budget can be determined by estimating the needed man-hour (tangible and intangible efforts) to produce each document (deliverable) in each work package in every discipline (Song and AbouRizk 2005, SNC-LAVALIN 2006). As a result, the BWCS represents the document's budget (man-hour) and the ACWP represents the actual hours spent to produce a document. While the values of BCWS and ACWP are straight forward, BCWP (earned value) is not. To determine the value of BCWP (earned value), the earning rules can be utilized. According to Eldin (1991), the earning values can be determined as the percentages of the documents' budget (man-hour). The earning rules should be applied at distinct events (control points) throughout the lifecycle of a document. These control points associated with earning percentages should be established at the project early stage for each deliverable (Eldin 1991, Moselhi 1993, SNC-LAVALIN 2006). It should be mentioned that the number of control points with their associated earning values can be varied from document to document. To facilitate using these control points, they can be organized in tabular formats, namely Progress Templates. Different progress templates can be grouped in one database to serve one or more disciplines (see Table2.1).

Therefore, measuring the performance of each deliverable can be accomplished by applying the earned value concept at each control point in the progress templates. However, at the activity level, the earned value concept can not be applied because the earned value components (BCWS, BCWP and ACWP) are not identified yet. Thus, engineering deliverables should be integrated with the activities in the project schedule.

The third consideration is to integrate engineering deliverables into project schedule. As stated above, in the engineering/design phase, each work package has been identified in terms of a time frame (activity time frame) and in terms of budget (man-hour for all deliverables). To apply the earned value concept accurately at different levels in the project hierarchy, the man-hour components of all deliverables in a work package must be transferred to the corresponding activities in the same work package. Therefore, in the proposed methodology, two main assumptions should be satisfied: 1) all deliverables in one work package must pass through the same work package's activities in a sequential way; and 2) the number of control points in a progress template for each deliverable in each work package must be equal to the number of activities in the project schedule for the same work package. Having accomplished the pervious points, the man-hour components derived from the deliverables' level can be transferred to the activity level. Fig.3.4 depicts the proposed structure of a work package in the engineering/design phase. As a result, determining the performance, integrating the cost and schedule functions, and forecasting the cost and time can be achieved not only at the activity level but also at all levels in the project hierarchy.

Eventually, the effect of the engineering deliverables on the project schedule must be shown. As stated earlier, the activities in the project schedule are defined in terms of the time frame (start and finish dates, original duration) and are tied together through different types of relationships (finish to start, start to start, etc.). Using these identification functions in addition to schedule performance index (SPI), the effect of the engineering deliverables on the project schedule can be realized. For instance, a set of deliverables in a work package in the engineering phase experiences poor performance at a certain control point; consequently, the performance of the corresponding activity in the same work package has poor performance (SPI<1) too. Thus, the forecast finish date might be greater than the as-planned finished date of this activity. As a result, the activities that have relationships (finish to start) with it might not start on its planned date. In addition, a number of activities in the same phase and/or other phases might experience delays also. Moreover, this impact might be extended to other activities in the project schedule so that slippage in the schedule could take place. It should be noted that the system is limited to a finish-start relationship with or without a lag time.

Therefore, the proposed methodology can be applied to track and control engineering deliverables, to integrate cost and schedule functions, and to forecast cost and time at three levels (the deliverables' level, the activity level and at the project level). In addition, the impact of the unfavorable performance of engineering deliverables on the project schedule can be demonstrated.

To demonstrate the use and essential features of the proposed methodology, a computerized system, **T**racking **E**ngineering **D**eliverable **S**ystem (**TEDS**), has been developed in this research. The following paragraphs describe in detail the development and the uses of the proposed system (**TEDS)**.

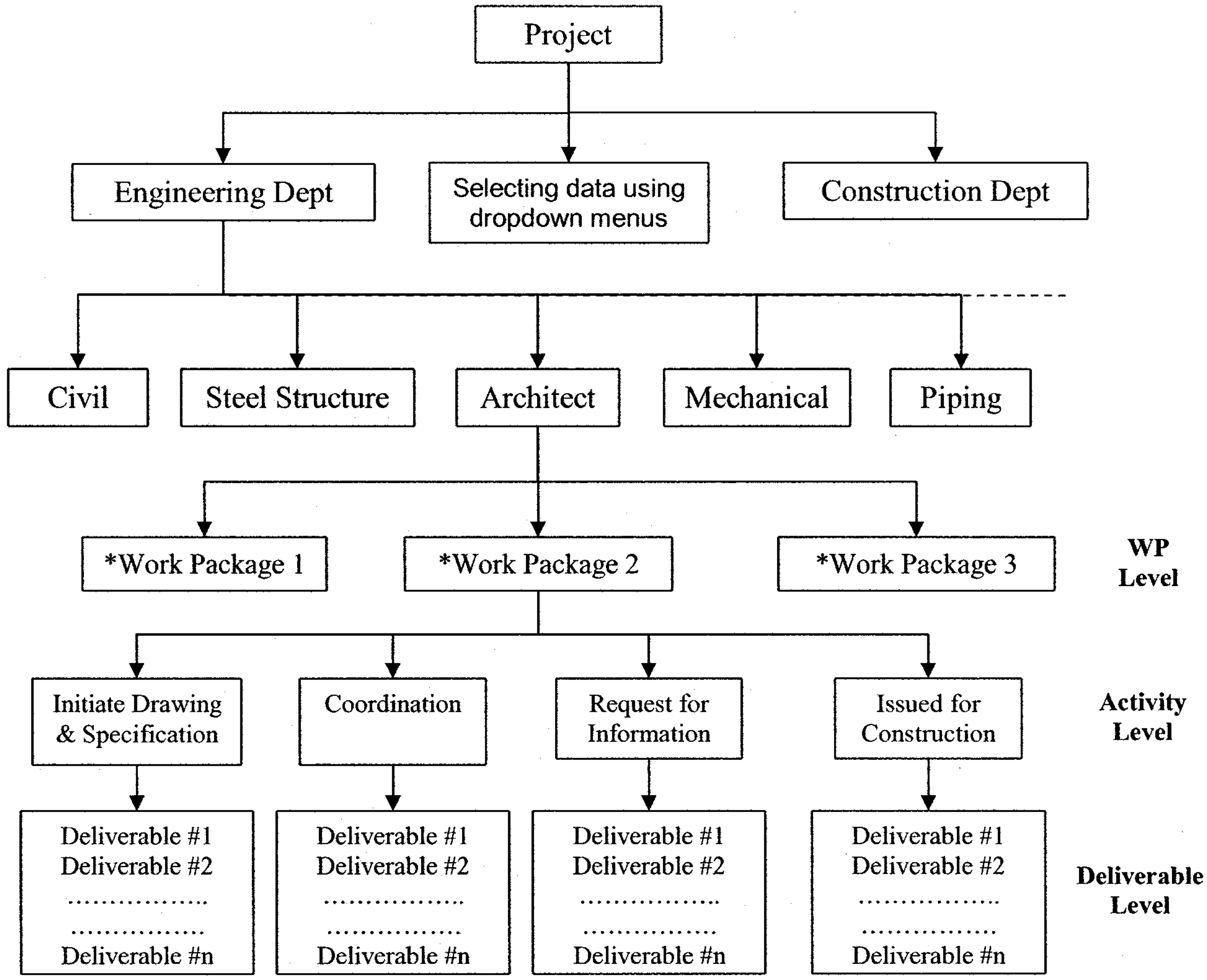


Fig.3. 1 WBS in the Proposed System

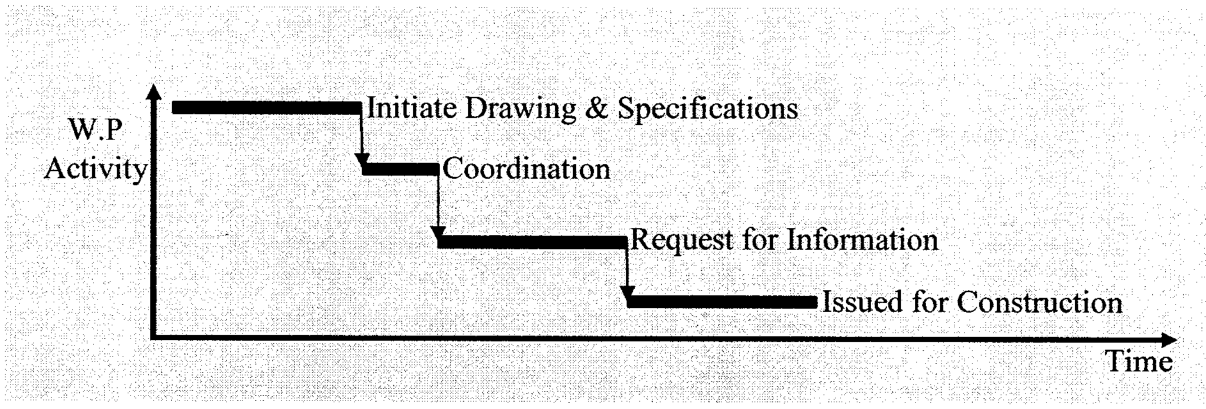
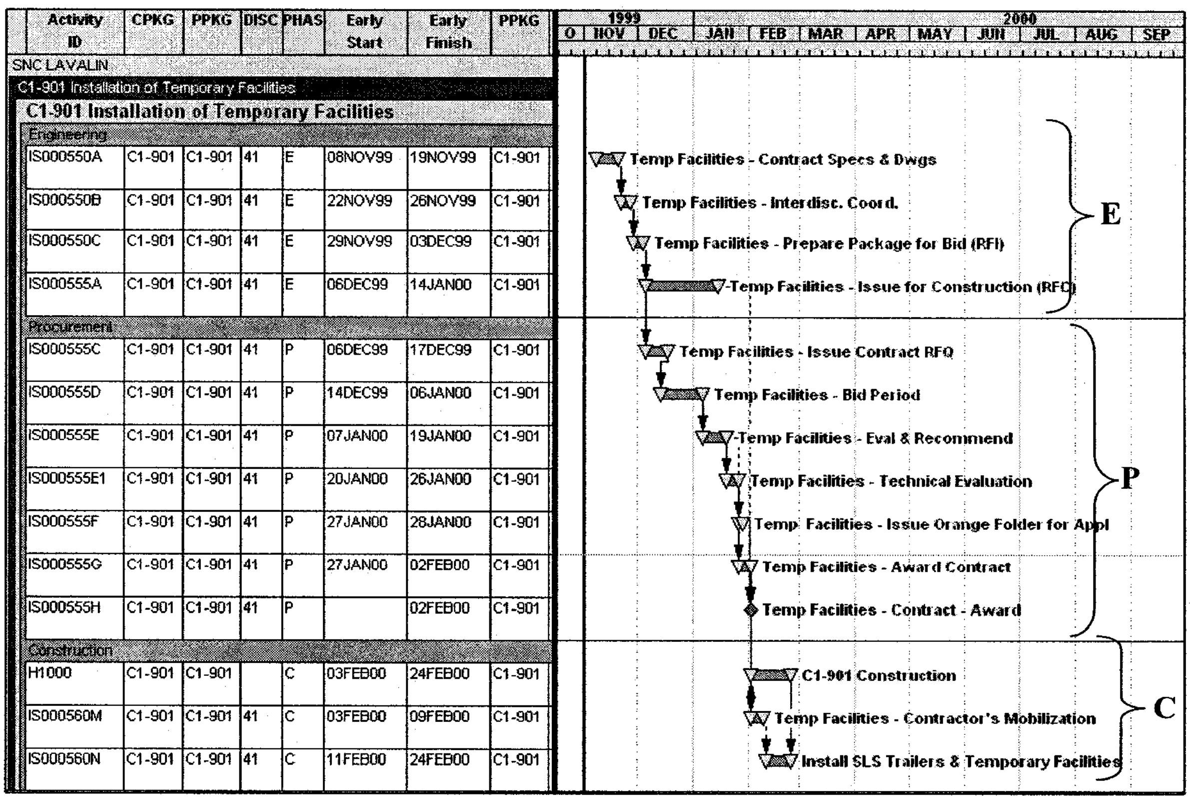


Fig.3. 2 Work Package's Activities in Engineering Phase



Activity ID	CPKG	PPKG	DISC	PHAS	Early Start	Early Finish	PPKG
SNC LAVALIN							
C1-901 Installation of Temporary Facilities							
C1-901 Installation of Temporary Facilities							
Engineering							
IS000550A	C1-901	C1-901	41	E	08NOV99	19NOV99	C1-901
IS000550B	C1-901	C1-901	41	E	22NOV99	26NOV99	C1-901
IS000550C	C1-901	C1-901	41	E	29NOV99	03DEC99	C1-901
IS000555A	C1-901	C1-901	41	E	06DEC99	14JAN00	C1-901
Procurement							
IS000555C	C1-901	C1-901	41	P	06DEC99	17DEC99	C1-901
IS000555D	C1-901	C1-901	41	P	14DEC99	06JAN00	C1-901
IS000555E	C1-901	C1-901	41	P	07JAN00	19JAN00	C1-901
IS000555E1	C1-901	C1-901	41	P	20JAN00	26JAN00	C1-901
IS000555F	C1-901	C1-901	41	P	27JAN00	28JAN00	C1-901
IS000555G	C1-901	C1-901	41	P	27JAN00	02FEB00	C1-901
IS000555H	C1-901	C1-901	41	P		02FEB00	C1-901
Construction							
H1000	C1-901	C1-901		C	03FEB00	24FEB00	C1-901
IS000560M	C1-901	C1-901	41	C	03FEB00	09FEB00	C1-901
IS000560N	C1-901	C1-901	41	C	11FEB00	24FEB00	C1-901

Fig.3. 3 Schedule of an EPCM Training Project (SNC-LAVALIN 2006)

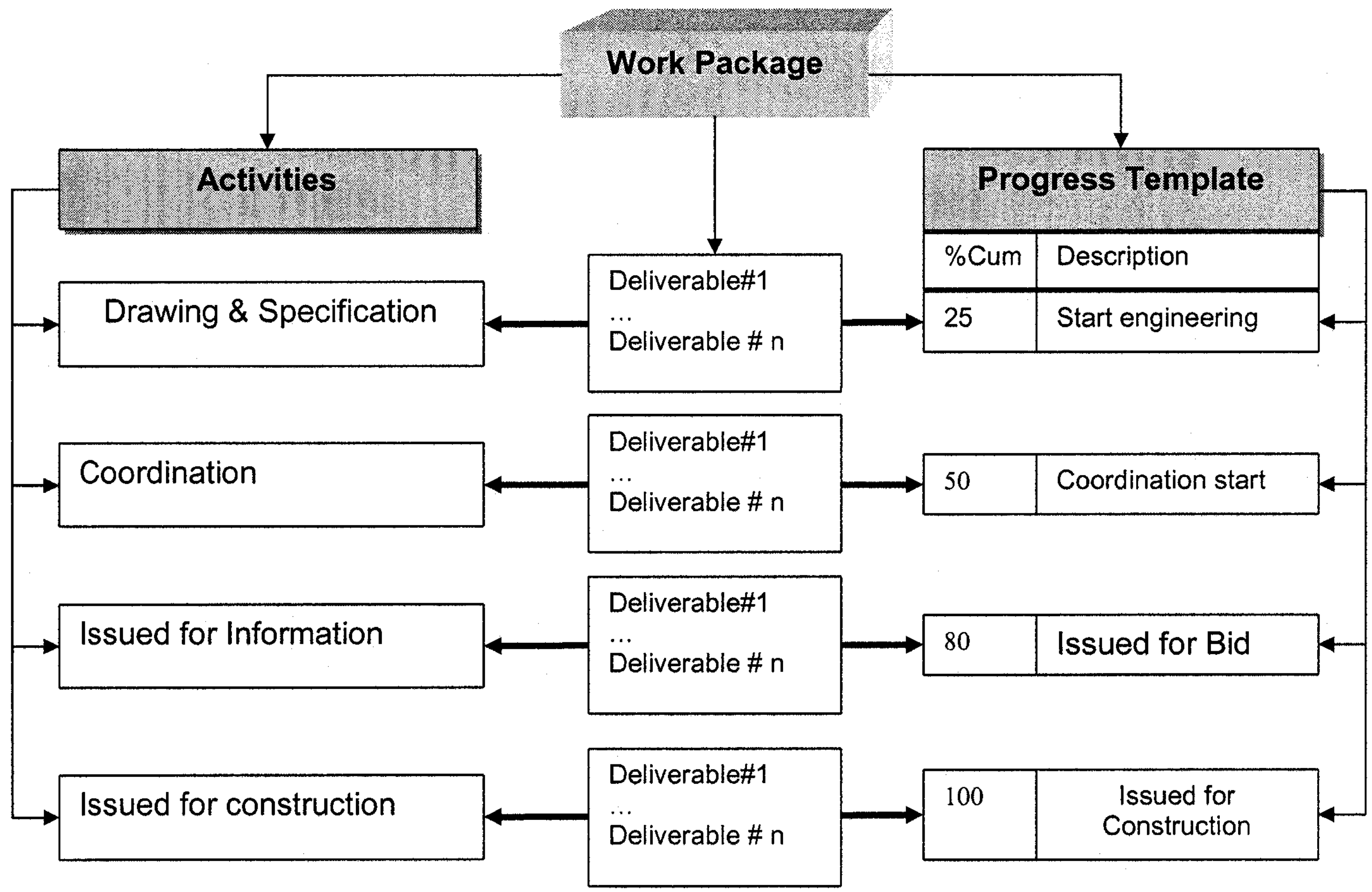


Fig.3. 4 Proposed Work Package Structure

3.2 System Layout

Engineering, Procurement and Construction (EPC) projects usually include a huge number of technical documents that must be produced by engineers. For the purposes of tracking and controlling these documents, an effective computerized system must be designed in such a way that permits manipulation and retrieval of data in an effective manner and that provides the project manager with significant information in easy format. Such a system should be developed to reflect the level of detail based on the nature of a project (Chevallier and Russell 2001). It should be also implemented to overcome any obstacles that might exist in the current project-control software. One of the major drawbacks in controlling systems is that of entering the data and/or re-entry portions of the data in different files. Another problem is the reports of scheduling that rely heavily on the tabular presentation of large quantities of information. Besides, the majority of software systems are standalone, or separated (Rowings 1991). Indeed, the major problem is the lack of integration between all the phases EPC projects.

Therefore, the proposed system, **T**racking **E**ngineering **D**eliverable **S**ystem, has been implemented in Microsoft Windows XP environment using Microsoft Excel sheet 2003. Microsoft Excel sheet has been chosen because it is easy to use, it can integrate with other scheduling software such as Primavera Project Planner (P3), and it has the capability of providing graphical and tabular reports. Visual Basic Application programming language (VBA) and Macros have been utilized in the proposed system (**TEDS**) to develop its embedded algorithms (e.g. Document, Impacted activity) and functions (e.g. calculate progress, transfer data). The main advantages of the proposed system lie in the following: 1) tracking and controlling engineering deliverables individually; 2) integrating cost and schedule functions; 3) forecasting project cost, time and date of completion; and 4) detecting the impact of the performance of the engineering deliverables on the procurement and/or construction phase.

The proposed system has a number of features that demonstrate its superiority over other current control systems:-

1- It is easy to use since it works under Microsoft Excel sheet.
2- It is designed to accommodate different types of work breakdown structure.
3- It can be integrated with Primavera Project Planner (P3), or it can be used as standalone software.
4- It can integrate cost and schedule functions for other phases of the project.
5- The system can detect the impact of the performance of engineering deliverables on other phases in EPC projects.
6- It provides a number of reports at different levels according to the project WBS and user's preference.

The system has been developed using two commercially available software systems:

1- Primavera Project Planner software is used to import the project schedule and interdependence relationships files to the developed Excel sheet. This is carried out by first exporting the data files into a transient directory, which is used later to transfer the data to the developed Excel sheet. It should be noted that no further calculation is done in Primavera Project Planner to avoid any redundancy in carrying out all calculation functions.
2- The developed Excel sheet is used as the medium to integrate engineering deliverables with the project schedule. And it performs all necessary calculations triggered by the algorithms and functions of the developed system.

Fig.3.5 depicts integration between **TEDS** and **P3** in terms of WBS. Fig.3.6 illustrates the general layout of **TEDS** while Fig.3.7 illustrates a detailed layout of **TEDS** and its link to Primavera Project Planner (**P3**). It should be mentioned that **TEDS** can be operated as standalone software on which the user requires to input all project data (see Fig. 3.8).

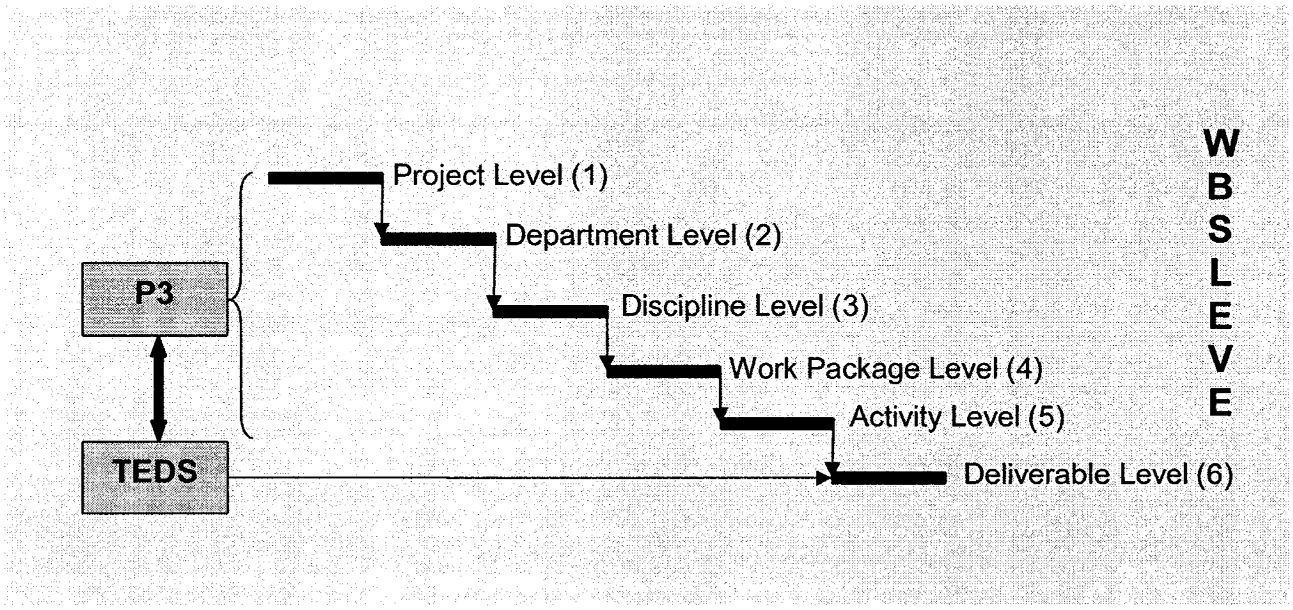


Fig.3. 5 Relation between P3 and TEDS in terms of WBS

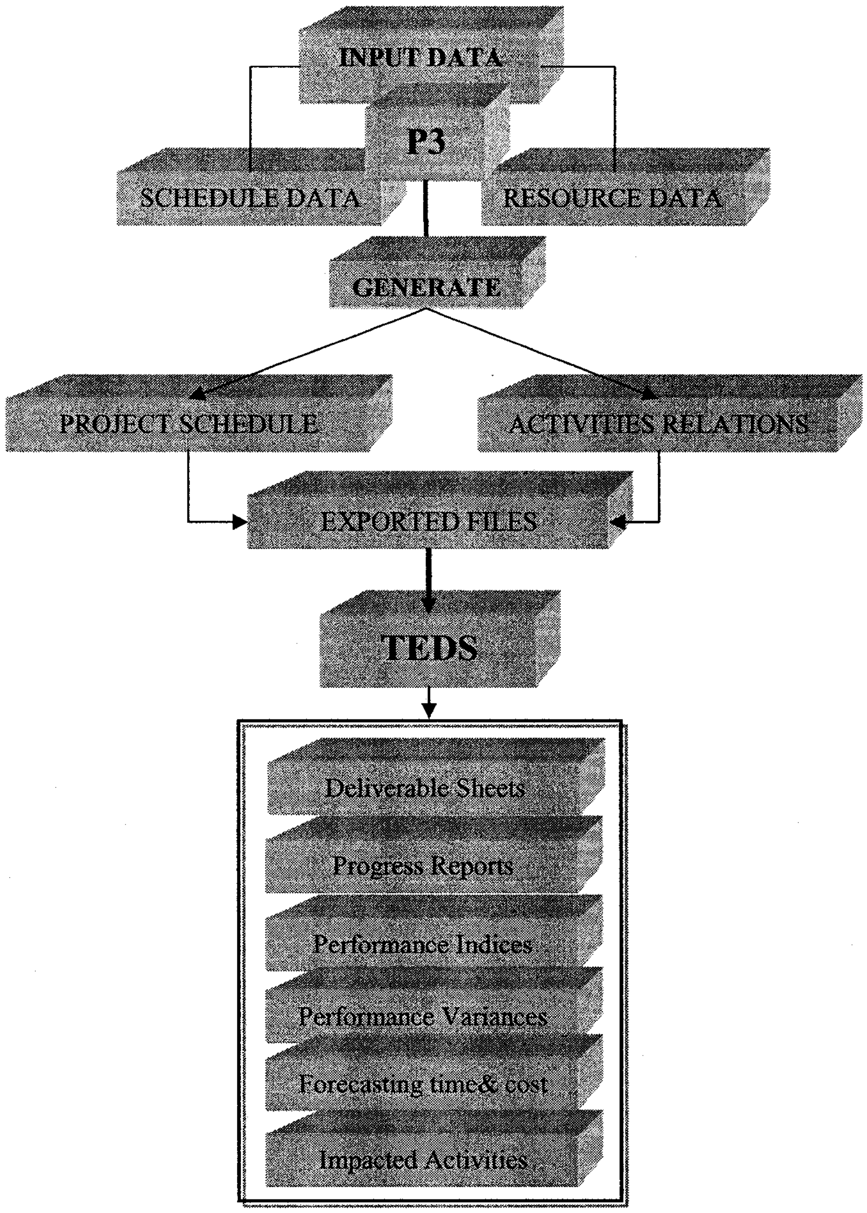


Fig.3. 6 General Layout of the Proposed System (TEDS)

3.3 Data Required

The required data is entered to the developed system in two stages: 1) in Primavera Project Planner (P3); and 2) in TEDS. In the first stage, data is entered into P3 to generate the project schedule and its base line. Then, P3 is used to export two types of database files: 1) the project schedule; 2) the interdependence relationships among the activities files. Tables 3.1 and 3.2 show the exported database files from Primavera Project Planner (P3). In the second stage two steps are required to enter data into the developed system: importing project database files; and creating document sheets for engineering deliverables. The first step is accomplished automatically by the system while in the second step the user is requested to select, interactively, a work package to which a document sheet is linked (see Fig.3.7). It should be mentioned that the generating and linking process of document sheets is done automatically.

In each document sheet, the user is requested to key a set of data for each deliverable such as the description and the needed man-hour and to set up a progress template with its cumulative earning percentage for each deliverable. It should be noted that each document sheet should serve one work package. Table 3.3 shows the needed data for each deliverable. It should be mentioned that the first step in the second stage could be replaced by the direct input of project data files in **TEDS** when used as stand alone software. Fig.3.8 depicts **TEDS** as a stand-alone system.

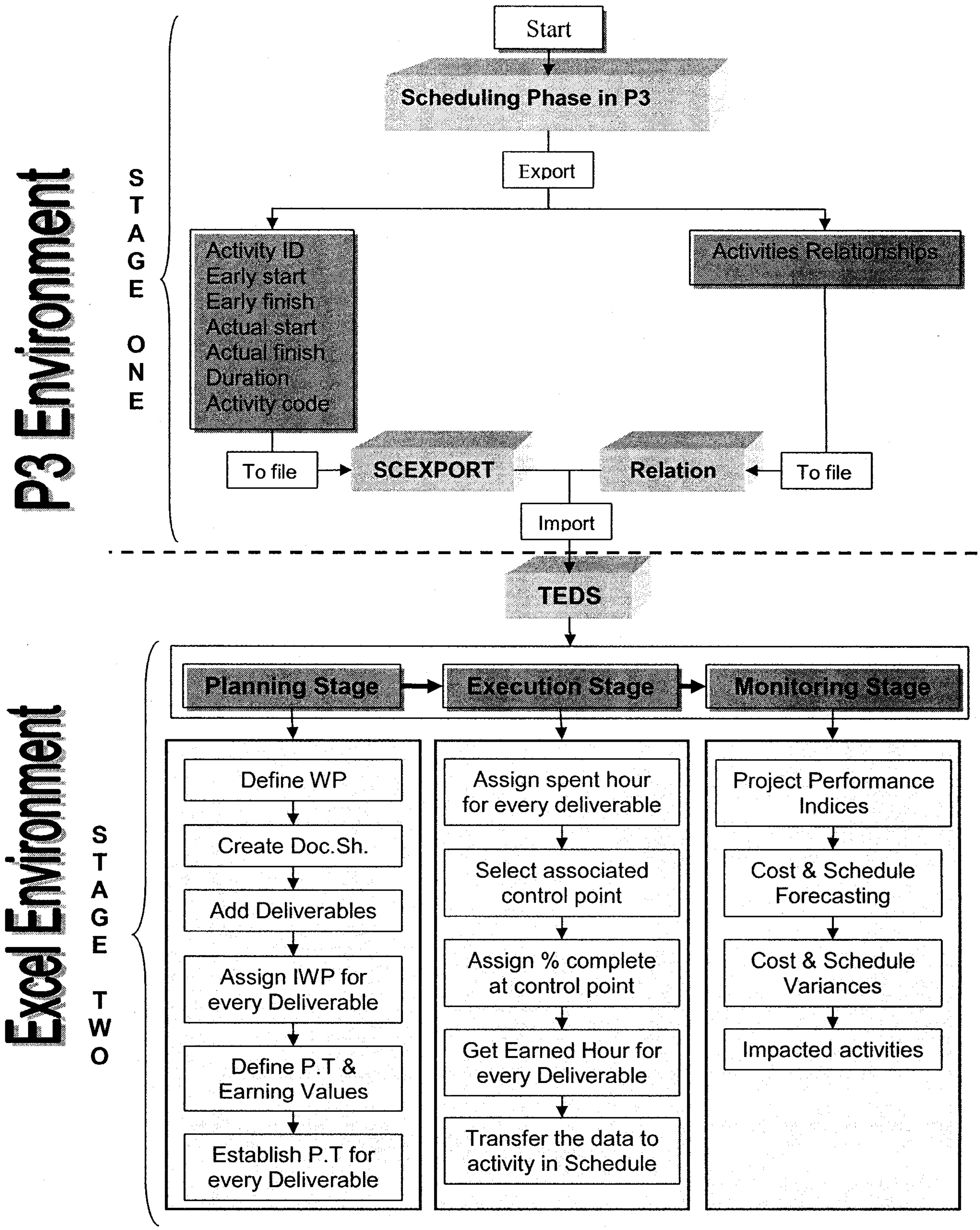


Fig.3. 7 A Detailed Layout of TEDS & P3

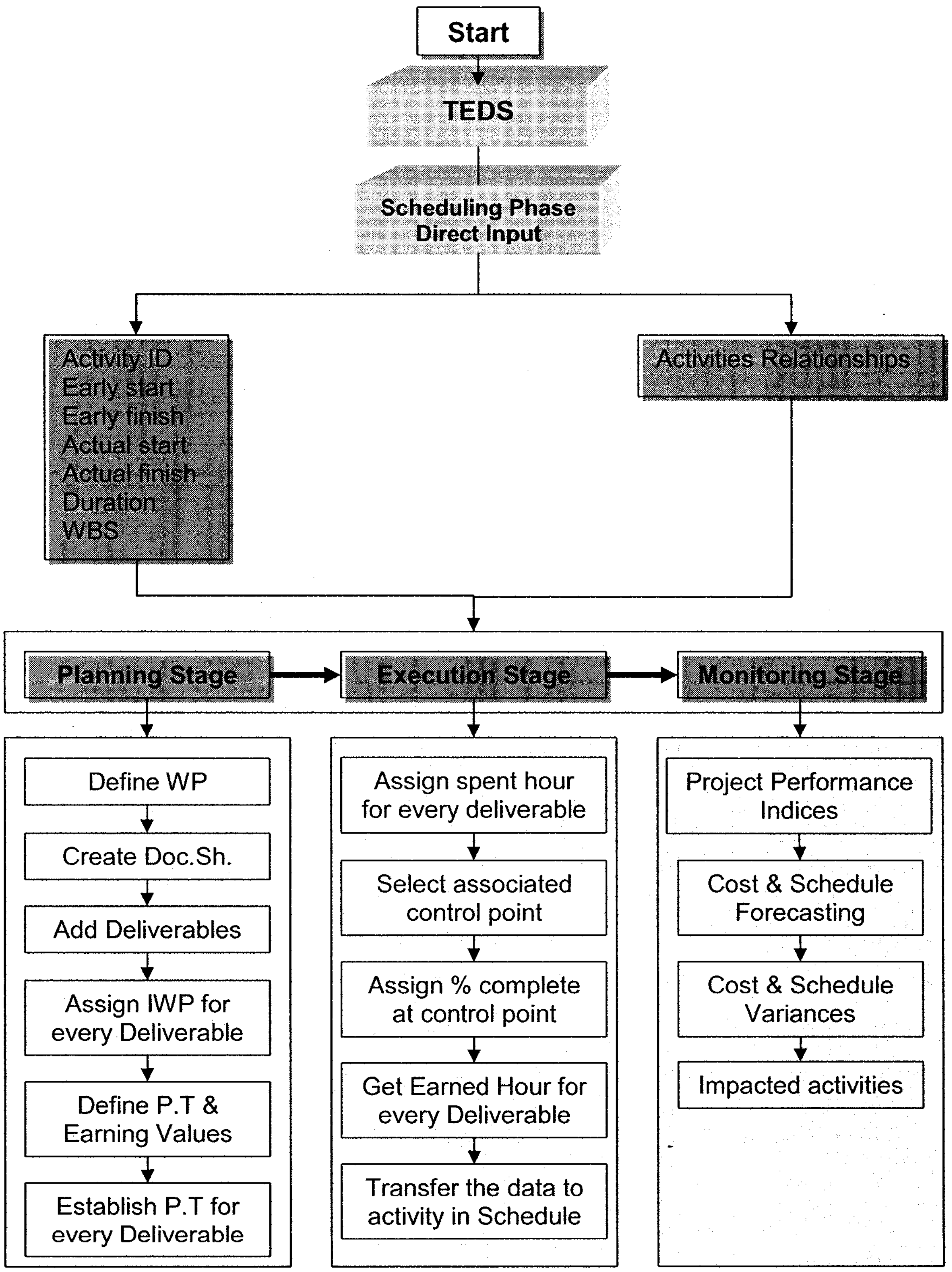


Fig.3. 8 TEDS as Standalone Software

Table 3. 1 Project Schedule File

No	Data Description	Schedule
1	Activity ID	As Planned
2	Activity Description	As Planned
3	Early start	As Planned
4	Actual start	--------------
5	Early finish	As Planned
6	Actual finish	--------------
7	Original Duration	As Planned
8	Activity code (WBS)	As Planned

Table 3. 2 Interdependence Relationships File

No	Data Description	Schedule
1	Activity ID (Predecessor)	As Planned
2	Successor	As Planned
3	Lag	As Planned
4	Relation Type	As Planned

Table 3. 3 Required Data for Deliverables

No	Data Description	Schedule
1	Deliverable's description	As Planned
2	Needed man-hour	As Planned
3	Progress Template (%cumulative earning)	As Planned

3.4 System's Algorithms

3.4.1 General

The proposed system, **T**racking **E**ngineering **D**eliverable **S**ystem (**TEDS**), has been developed utilizing: 1) the Earned Value Concept and the related control points developed by Eldin, 1991; 2) the Progress Templates Technique used by SNC-Lavalin; and 3) the developed Impacted Activity. As stated earlier, project progress is reported at three levels: 1) the deliverable level; 2) the activity level; and 3) the entire project level. It should be mentioned that level three may have three sub-levels or more according to the project work breakdown structure. These three sub-levels could be the following: phase level, discipline level, and work package level. Thus, the following four algorithms are developed to report the project status at the three levels as stated earlier:

1- Performance Algorithms adopted from Earned Value (U.S.A Department of Energy, 1980) and Progress Templates (SNC-LAVALIN).

2- Performance Forecasting Algorithms developed to forecast cost, time and date of completion.

3- Performance Variances Algorithms adopted from the Earned Value Technique.

4- Impacted Activities Algorithm developed to detect late start activities in the project schedule.

3.4.2 Performance Algorithms

Earned Value concept is used in the proposed system for calculating performance indices of the EPC projects (Fig.3.9). The following equations demonstrate the project performance indices (Moselhi, 1993):

CPI= (BCWP)/ (ACWP)

SPI= (BCWP)/ (BCWS)

In which

ACWP	= Actual Cost or Hours of Work Preformed
BCWS	= Budgeted Cost or Hours of Work Schedule
BCWP	= Budgeted Cost or Hours of Work Preformed
CPI	= Cost Performance Index
SPI	= Schedule Performance Index

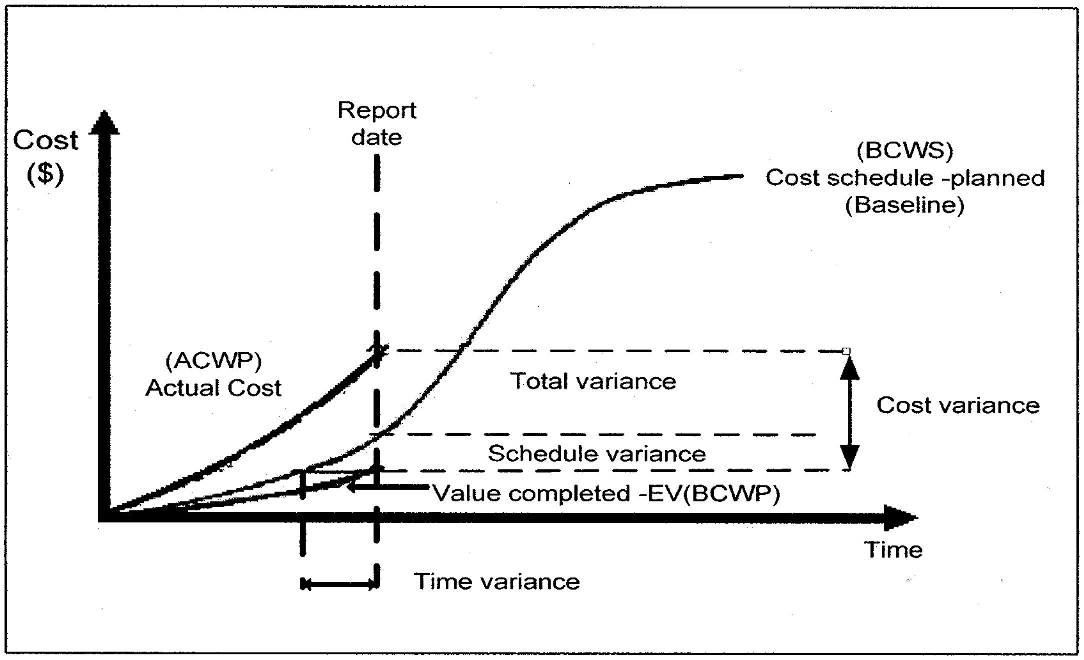


Fig.3. 9 Earned Value Concept (Moselhi 1993)

The status of each deliverable in every work package in the engineering phase of EPC projects can be detected by utilizing the Earned Value concept, which is performed at set of pre-defined control points (progress templates). This can be done by establishing the elements of EV: the Budgeted Cost of Work Schedule (BCWS), the Actual Cost of Work Performed (ACWP); and the Budgeted Cost of Work Performed (BCWP). The previous terms have been modified in **TEDS** to become as follows: the Internal Work Package (IWP) represents BCWS; Spent Hour represents (ACWP); and Earned Hours represents BCWP. TEDS is designed to determine the performance of each deliverable at every control point in the progress template. Since each control point has a cumulative earning percentage, it is essential to obtain the net internal work package (iwp) at every control point in the progress template. To do so, the Internal Work Package (Total-IWP) of the deliverable is multiplied by the value derived from subtracting two consecutive cumulative percentages (report date and previous date) in the progress template. By doing so, the control point at the report date in a progress template has its net budgeted (or planned) hours. Equation 3.1 explains this process.

iwp =IWP * [%Cumulative@ R.s - %Cumulative@ P.s]……..……………………..3.1

In which

IWP = Internal Work hours Package of the deliverable

iwp = Net internal work hours of a deliverable at report date

%Cumulative@ R.s = Cumulative earning percentage at Report stage

%Cumulative@ P.s = Cumulative earning percentage at Pervious stage

In a construction project, reporting the project status is usually performed periodically (weekly, monthly, etc.) regardless of the time frame of the activities in the project schedule. Since there is an interrelationship between the control points in every progress template and their corresponding activities in the project schedule in one work package, it is essential to take into consideration the partial progress of the corresponding activity. In other words, a control point receives its full percentage when its corresponding activity in the project schedule is finished. Therefore, a new factor, Beta (**β**), should be introduced in Equation 3.1 to indicate partial completion of an activity. Beta (**β**) is the ratio of progress period in days of an activity to its original duration in days during reporting period. Thus, **β** can be deduced from Equation 3.2 as follows:

β = WD/OD..3.2

In which

WD = Working Days= Report Date - Actual start Date of an activity

OD = Original Duration of an activity in the project schedule.

Thus, the general equation for establishing the net budgeted hour (iwp) for every deliverable at every control point in the progress templates is as follows:

iwp = IWP * [%Cumulative@ R.s - %Cumulative@ P.s]* **β**......... ....3.3

Having determined the iwp, the Earned Hours can be achieved by examining whether the control point has been accomplished or not. Equation 3.4 expresses this as follows:

Earned Hour@ R.s = iwp * %Complete...3.4

Because the Spent Hours value is a direct input for every deliverable during the reporting period, the cost performance index CPI can be calculated for every deliverable as follows:

CPI= Earned Hours@ R.s/Spent Hours..3.5

In which

CPI	= Cost Performance Index
Earned Hour@ R.s	= Earned hour at report date
Spent Hour	= Actual spent hour at specific period
% complete	= Percent complete of net internal work package hour

After this equation is developed, the CPI can be calculated accurately for each deliverable at each control point in a Progress Template. According to the Earned Value concept, the Cost Performance Index (CPI) is considered good when CPI >=1, which means that the earned hours are equal to or greater than the spent hours; in contrast, if the CPI is less than 1, it means that the performance of the deliverable is lower than as-planned.

By determining the value of the CPI for every deliverable, project managers can examine the performance of every deliverable in every work package; they can also clearly define the reasons behind poor performance, if detected. Indeed, the time and effort taken to identify these reasons would be minimized, and the project managers could devote their efforts to other tasks. Table 3.4 gives an example for determining the Cost Performance Index (CPI) for every deliverable in one work package. It should be mentioned that the value of (**β**) is calculated in the project schedule window of TEDS and is then transferred automatically to the deliverables in the document sheet. In this example, **β**=1 means number of days during progress period of an activity equals to its original duration in days during reporting period. It should be mentioned that value of **β** should not exceed 1.0

Table 3. 4 Performance of the Deliverables

Document Description	Total IWP	Template description	%Re	%Ps	β	iwp	Spent Hour	% Com.	Earned Hour	CPI
Deliver.#1	60	45D2-Studies completed	80	60	1	12	11	100	12	1.09
Deliver.#2	100	45D2-Studies completed	80	60	1	20	20	95	19	0.95
Deliver.#3	85	45D2-Studies completed	80	60	1	17	17	100	17	1.00
Deliver.#4	88	45D2-Studies completed	80	60	1	17.6	17	100	17.6	1.04
∑Total	**333**					**66.6**	**65**	**20**	**65.60**	

Total-IWP = Total internal Work Package hours for each deliverable

Template description = Name and description of each control point in the progress template

%R.s = Cumulative earning percentage at the report date

%P.s = Cumulative earning percentage at the Pervious date

β = Ratio of progress period in days of an activity to its original duration in days during reporting period

iwp = Net internal work hour package of a deliverable at a control point

Spent Hour = Spent hour to at a control point during reporting period

%Com. = Percent complete of net internal work package hour

Earned Hour = Earned hours calculated by the system

CPI = Cost Performance Index

Performance at the Activity level can be determined by transferring the summation of man-hour components that are derived from all deliverables to the corresponding activity in the project schedule. It should be mentioned that transferring man-hour components from the document sheet to the activity in the project schedule is done automatically in **TEDS**. Thus, the performance indices for an activity can be calculated as follows:

$$CPI_{(activity)} = \sum_{1 \to i} EarnedHours / \sum_{1 \to i} SpentHours \quad \text{......} 3.6$$

$$SPI_{(activity)} = \sum_{1 \to i} EarnedHours / \sum_{1 \to i} iwp \quad \text{......} 3.7$$

In which

i = Number of the deliverables in one work package

By applying equations 3.6 and 3.7, the cost and schedule performance indices (CPI and SPI) for every activity in every work package in the engineering/design phase are determined. As a result, project managers can accurately track and control every activity in the engineering/design phase. Table 3.5 demonstrates determining performance indices of the activities based on the data transferred from its corresponding deliverables.

Table 3. 5 Performance Indices of the Activities

W.P Description	Total IWP	Activity Description	IWP	Spent Hours	Earned Hours	Rem. Hours	$/wh	CPI	SPI
Work Package	333	Drawing &Specification	66.60	65	65.60	0	30	1.01	0.98
		coordination							
		Issue for bid							
		Issue for construction							

Total.IWP = Total Internal Work hours Package of one work package
Activity description = Name and description of the activity
IWP = Sum of all iwp derived from the deliverables
Spent Hour = Spent hour at a control point (direct input)
Earned Hour = Earned hours calculated by the system
Rem.Hours = Remaining budgeted hours to complete the activity
$/wh = Cost in dollar per work hour

Performance indices at the project level and its sub-levels can, similarly, be carried out by aggregating man-hour components of its activities. The three sub-levels are as follows: work package level, discipline level, and phase level. By determining performance indices for these sub-levels based on cumulative data, the tendency of the overall performance to be affected by a single performance of an activity is reduced. Determining performance indices at the three sub-levels referred above is described below.

Every work package in engineering phase comprises a number of activities. Since every activity in every work package has received its man-hour components (budgeted hours, earned hours and spent hours) from the document sheet, the work package performance can be performed by aggregating the man-hour components of its activities. Equations 3.8 and 3.9 demonstrate obtaining the performance indices for a work package.

$$CPI_{(WP)} = \sum_{1 \to n} EarnedHours / \sum_{1 \to n} SpentHours \quad \text{..........} 3.8$$

$$SPI_{(WP)} = \sum_{1 \to n} EarnedHours / \sum_{1 \to n} IWP \quad \text{..........} 3.9$$

In which

n = Number of activities in a work package.

IWP = Internal work hour package of the activity

Table 3.6 gives an example of determining the performance indices (CPI and SPI) of a work package. In this example, although some activities experienced poor performance (cost over run, schedule delay), the overall performance of the work package as listed in the table was good (CPI=1, SPI=1). It should be mentioned that the main window of **TEDS** allows users to input the cost ($) per each work hour. This gives high flexibility to the system, so different costs per work hour can be keyed in according to the complexity of each work package. As a result, the project management team can more accurately identify which work package would affect the project delivery.

Table 3. 6 Performance Indices of a Work Package

W.P Description	Total IWP	Activity description	IWP	Spent Hours	Earned Hours	Percent Comp	$/wh	CPI	SPI
Work Package	333	Drawing &Specification	66.60	65	65.60	20	30	1.01	0.98
		coordination	116.55	116	116.55	35	30	1.00	1.00
		Issue for bid	66.6	68	66.6	20	30	0.98	1.00
		Issue for construction	66.6	65	68	20	30	1.05	1.02
∑Total	**333**		**316.35**	**314**	**316.75**	**95**		**1.01**	**1.00**

At the discipline level, detecting the discipline performance is important to define which discipline would have poor performance, and what its impact would be on the other disciplines, on other phases, and/or on the entire project. Each discipline might comprise many work packages. Similarly, the performance of every discipline can be obtained by summing up the man-hour components of its work packages. Thus, equations 3.10 and 3.11 are used for this purpose:

$$CPI_{(Dis)} = \sum_{1\rightarrow n}^{1\rightarrow m} EarnedHours / \sum_{1\rightarrow n}^{1\rightarrow m} SpentHours \quad \text{......} 3.10$$

$$SPI_{(Dis)} = \sum_{1\rightarrow n}^{1\rightarrow m} EarnedHours / \sum_{1\rightarrow n}^{1\rightarrow m} IWP \quad \text{......} 3.11$$

In which

m = Number of work packages in one discipline

Table 3. 7 Performance Indices of the Civil Discipline

Discipline	W. P Description	Total IWP	Activity description	IWP	Spent Hour	Earned Hour	CPI	SPI
Civil	W.Package#1 (Temporary-facility)	333	Drawing &Specification	66.60	65	65.60	1.01	0.98
			coordination	116.55	116	116.55	1.00	1.00
			Issue for bid	66.6	68	66.6	0.98	1.00
			Issue for construction	66.6	65	68	1.05	1.02
	Sub Total #1	**333**		**316.35**	**314**	**316.75**	**1.01**	**1.00**
	W.Package#2 (Fences)	540	Drawing &Specification	135	133	135	1.02	1.00
			coordination	189	187	189	1.01	1.00
			Issue for bid					
			Issue for construction					
	Sub Total #2	**540**		**324**	**320**	**324**	**1.01**	**1.00**
	W.Package#3 (Parking lot)	430	Drawing &Specification	86	88	86	0.98	1.00
			coordination					
			Issue for bid					
			Issue for construction					
	Sub Total #3	**430**		**86**	**88**	**86**	**0.98**	**1.00**
	Total	***1303***		***726.35***	***722***	***726.75***	***1.04***	***1.00***

As shown in Table 3.7, the civil discipline comprises three work packages, namely: Temporary Facility, Fences and Parking Lot. Although the work package" Parking Lot" experienced poor performance (CPI=0.98), the overall performance of the Civil discipline was good (CPI=1.04). Thus, the work package" Parking Lot" has no dominating negative impact on the civil discipline.

At the phase level, EPC projects are broken down into three phases: Engineering, Procurement and Construction phase. Each phase might consist of many disciplines such as civil, mechanical, and electrical, etc. To detect the engineering phase performance, man-hour components of its disciplines should be computed. Because the man-hour components of every discipline in the engineering phase have been achieved at the discipline level, the performance indices of the engineering phase can be obtained using equations 3.12 and 3.13.

$$CPI_{(Phase)} = \sum_{1\to d} \sum_{1\to n}^{1\to m} EarnedHours / \sum_{1\to d} \sum_{1\to n}^{1\to m} SpentHours \quad \text{.......} 3.12$$

$$SPI_{(Phase)} = \sum_{1\to d} \sum_{1\to n}^{1\to m} EarnedHours / \sum_{1\to d} \sum_{1\to n}^{1\to m} IWP \quad \text{.......} 3.13$$

In which

d = Number of discipline in every phase

Although, the objective of the proposed system focuses primarily on tracking and controlling the engineering deliverables in engineering phase of EPC projects, the system could be also used to track other phases such as the procurement and/or construction phase. Thus, **TEDS** has the capability of determining the performance indices in other phases by utilizing the similar concept that is used in the engineering phase. To do so, every activity in other phases should be assigned its man-hour components directly in the project schedule window of the system. Having obtained the performance indices for every phase in the EPC projects, the project management team can identify the phase or phases that experienced unfavourable performance easily.

Now, the overall performance of the EPC project can be determined using the same technique that is used at the work package level, the discipline level, and the phase level. Table 3.8 shows phases of EPC project with their associated disciplines. Therefore, performance indices (CPI and SPI) of the entire project can be obtained based on equations 3.14 and 3.15.

$$\text{CPI}_{(\text{Proj})} = \sum_{1\to d}^{1\to p} \sum_{1\to n}^{1\to m} EarnedHours / \sum_{1\to d}^{1\to p} \sum_{1\to n}^{1\to m} SpentHours \quad \text{.......3.14}$$

$$\text{SPI}_{(\text{Proj})} = \sum_{1\to d}^{1\to p} \sum_{1\to n}^{1\to m} EarnedHours / \sum_{1\to d}^{1\to p} \sum_{1\to n}^{1\to m} IWP \quad \text{.......3.15}$$

In which

p =Number of the phases in project

Thus, TEDS has the capability of reporting EPC projects at three levels: 1) the deliverable level; 2) the activity level; and 3) the project level. Fig.3.10 illustrates the tracking and controlling levels in the proposed system. It should be mentioned that the project level and its sub-levels are considered as one level in this research. Having done that, the project management team can effectively track and control the cost and schedule for all project elements. Indeed, the proposed system has the ability to define the source of unacceptable performance, if any, which is the deliverables.

Table 3. 8 Phases of EPC Projects

Project Phases	Discipline	Total IWP	IWP	Spent Hours	Earned Hours	Percent Comp.	$/wh	CPI	SPI
Engineering Phase	Civil	1303	726.35	722	726.75	56	30	**1.04**	**1.00**
	Mechanical						40		
	Piping						25		
	Electrical						60		
Procurement Phase	Civil						20		
	Mechanical						20		
	Piping						20		
	Electrical						20		
Construction Phase	Civil						50		
	Mechanical						50		
	Piping						50		
	Electrical						50		
Total		Σ	Σ	Σ	Σ				

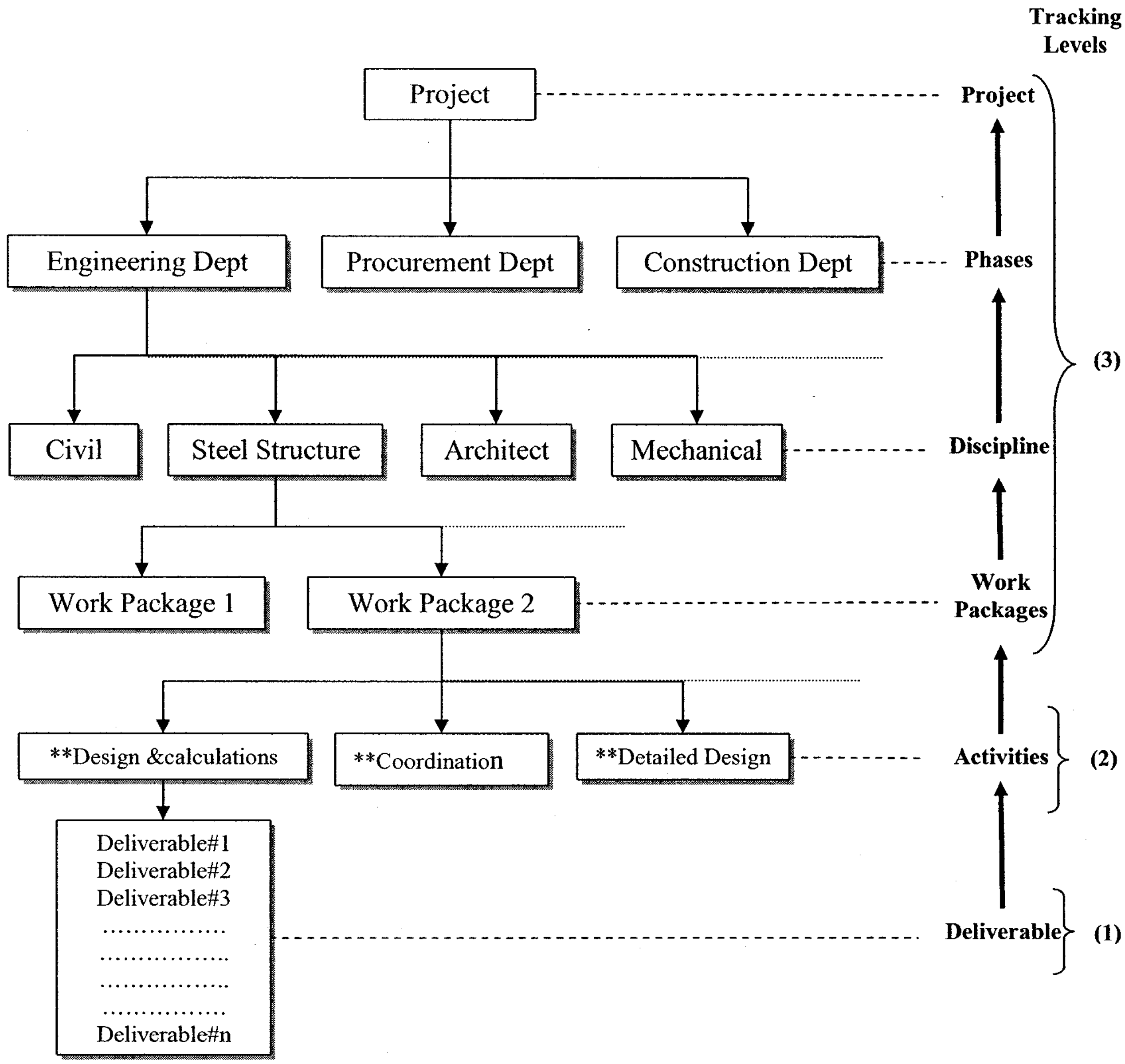


Fig.3. 10 Controlling Levels in TEDS

3.4.3 Forecasting Algorithms

Forecasting the project cost and time at completion is an essential indicator that gives project management teams an idea when the project will be finished and how much the project may cost. The Current project management systems rely on the earned value concept, which employs the cost and schedule performance indices (CPI and SPI), to forecast the project cost and time at completion. These systems presume that the performance established up to the report data shall persist until project completion (Alshaibani 1999). In the proposed system, the forecasting method relies on the performance indices (CPI, SPI) to forecast the cost and time of every element in the project at three levels as stated earlier.

At the deliverables' level, the forecast hours to completion can be achieved while the forecast time can not because the time frame of the deliverables is not defined. As mentioned earlier, deliverables are tracked and controlled through a number of control points in a progress template. Therefore, the proposed system forecasts the hours necessary to complete each control point individually. To do so, two elements should be established: cost performance index (CPI) and remaining budgeted hours to complete a control point. While The CPI is achieved from equation 3.5, the remaining budgeted hours (R.H) to complete a control point in the progress template must be calculated. Since control points and duration of the activities in one work package are interrelated, Beta (**β**) should be taken in account. Equations 3.16 and 3.17 explain this process as follows:

$$R.H_{deliverable} = [(iwp/\beta) - EarnedHours] \quad \text{..............} 3.16$$

$$FTC_{deliverable} = [R.H_{deliverable} / CPI_{deliverable}] \qquad (3.17)$$

In which

iwp = Net internal work package (Equ.3.3)

R.H (deliverable) = Remaining budgeted hours of a control point

FTC (deliverable) = Forecasted hours to complete (reach control point)

The budgeted hours at completion of each control point can be performed as follows:

$$BAC = [FTC + SpentHours] \qquad (3.18)$$

In which

Spent Hours = spent hours at a control point.

BAC = Budgeted hours at completion

Having done that, project managers can detect the status of each deliverable at every control point; thus, a corrective action can be taken at a very early stage. This gives the system its superiority over other control systems for controlling engineering deliverables. Table 3.9 gives an example for determining forecasted hours at completion at a control point in the progress template.

Table 3. 9 Forecasted Hours at Completion

(1)	(2)	(3)	(4)		(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Document description	IWP Total	Template description	%Cumulative		β	iwp	Spent Hour	% Com.	Earned Hour	CPI	Rem. Hours	FTC	BAC
			Rep.	Per.									
Pipe stress#1	60	45D2-Studies completed	80	30	1	30	28	100	30	1.07	0	0	28
Pipe stress#2	100	45D2-Studies completed	80	30	1	50	48	90	45	0.94	5	5.3	53.3
Pipe stress#3	85	45D2-Studies completed	80	40	1	34	9	30	10.2	1.13	23.8	21.1	30.1
Pipe stress#4	88	45D2-Studies completed	80	60	1	17.6	4	20	4.4	1.10	13.2	12	16
Total	333					131.6	89	68	89.6	1.01	42		127.4

As shown in the above table and according to the equations as mentioned earlier

iwp (6) = [column (4_Rep.)- column (4_Per.)] * column (5) * column(2)

Rem. Hours (11) =,[column (6) / column (5)] - column (9)

FTC (12) = column (11) / column (10)

BAC (13) = column (7) + column (12)

At activity level, every activity in every work package in engineering phase has its time frame (early start, early finish and original duration) and its man-hour components (budgeted hours, earned hours, spent hours and remaining hours), which can be expressed in term of cost by multiplying cost per man-hour ($/work hour) by the number of the hours of each component. Thus, the cost forecast at completion of an activity can be calculated as follows:

$$R.C_{activity} = [IWP/\beta - EarnedHours] * (\$/wh) \quad \text{......3.19}$$

$$FTC_{activity} = R.C_{activity} / CPI_{activity} \quad \text{......3.20}$$

In which

$R.C$ (activity) = remaining cost to complete

FTC (activity) = cost forecasted to complete

CPI (activity) = cost performance index derived from equation 3.6

Similarly, forecasting the days to complete an activity can be as follows:

$$R.D_{activity} = OD - WD \quad \text{......3.21}$$

$$FTS_{activity} = R.D_{activity} / SPI_{activity} \quad \text{......3.22}$$

In which

$R.D$ (activity) = remaining duration to complete an activity

OD = original duration of an activity

WD =working days = report date– actual start date of an activity

FTS (activity) = forecast days to complete an activity

SPI (activity) = schedule performance index derived form equation 3.7

Having determined the cost and days forecast to completion for every activity in every work package in the engineering phase, the budgeted cost at completion for every activity can be achieved as follows:

$$BAC_{activity} = FTC_{activity} + SpentHours_{activity} \quad \text{......3.23}$$

In which

$BAC_{(activity)}$ = Budgeted hours/cost At completion

Similarly, the date forecasted at completion of an activity can be determined based on its time frame, which is identified through the start date, the finish date, and the original duration, and working days in the calendar. The date forecasted at completion of an activity is calculated by adding the number of the forecasted days derived from equation 3.22 to its actual start date. Then, the system checks whether the forecasted date is a working day in the calendar or not. If not, a loop is performed through the calendar until the next working day. Forecasting the date at completion of every activity is important since it is used in the impacted activity algorithm, which will be described later. It should be noted that five working days per week are considered as working days, and Saturday and Sunday are not working days. The following equation explains this technique:

$$DOC_{activity} = FTS_{activity} + R \quad \text{......3.24}$$

In which

$DOC_{(activity)}$ = Date Of completion

R = Report date

Forecasting the budgeted hours at completion at the project level and its sub-levels can be, similarly, carried out by forecasting the remaining budgeted hours to complete each component at each sub-level. These sub-levels are as follows: 1) work package level; 2) discipline level; and 3) phase level. To forecast the budgeted hours to complete each element in these levels, the summation of the total man-hour components of each level is computed from the activity level automatically, and then, the remaining budgeted hours to complete is forecasted based on the established performance(CPI) at report date. The forecasting algorithms of the three sub-levels referred to the above are described below.

At work package level, each work package includes a number of activities that have received their man-hour components from the deliverables; thus, the forecast hours to complete every work package can be calculated as follows:

$$R.H_{WP} = Total.IWP - \sum_{1 \to n} EarnedHours \qquad 3.25$$

$$FTC_{WP} = R.H_{WP} / CPI_{WP} \qquad 3.26$$

By doing so, the hours forecasted at completion can be calculated as follows:

$$BAC_{WP} = FTC_{WP} + \sum_{1 \to n} SpentHours \qquad 3.27$$

In which

n = Number of the activity in every work package

Total.IWP = Total internal work hour package for a work package

$R.H_{(WP)}$ = Remaining budgeted hours to complete an activity

$FTC_{(WP)}$ = Hours forecasted at completion of an activity

$BAC_{(WP)}$ = Budgeted hours at completion of an activity

At the discipline level, similarly, forecasting the hours necessary to complete every discipline in the engineering phase can be achieved by summing up the associated work packages' man-hour components.

$$R.H_{Dis} = \sum_{1 \to m} Total.IWP - \sum_{1 \to n}^{1 \to m} EarnedHours \quad \text{.........} 3.28$$

$$FTC_{Dis} = R.H_{Dis} / CPI_{Dis} \quad \text{.........} 3.29$$

After determining the hours forecasted to complete every discipline in the engineering phase, the budgeted hours at completion can be calculated as follows:

$$BAC_{Dis} = FTC_{Dis} + \sum_{1 \to n}^{1 \to m} SpentHours \quad \text{.........} 3.30$$

In which

m = Number of the work packages in every phase

$R.H_{(Dis)}$ = Remaining budgeted hours to complete a work package

$FTC_{(Dis)}$ = Hours forecasted at completion of a work package

$BAC_{(Dis)}$ = Budgeted hours at completion of a work package

At the phase level, projects are broken down into three phases: Engineering, Procurement and Construction. Each phase might comprise many disciplines such as civil, architect, etc. Similarly, the hours forecasted to complete every phase can be achieved as follows:

$$R.H_{Phase} = \sum_{1\to d} \sum_{1\to n}^{1\to m} Total.IWP - \sum_{1\to d} \sum_{1\to n}^{1\to m} EarnedHours \quad \text{......3.31}$$

$$FTC_{Phase} = R.H_{Phase} / CPI_{Phase} \quad \text{......3.32}$$

Similarly, budgeted hours at completion can be obtained as follows:

$$BAC_{Phase} = FTC_{Dis} + \sum_{1\to d} \sum_{1\to n}^{1\to m} SpentHours \quad \text{......3.33}$$

In which

d	= Number of disciplines in every phase
R.H (Phase)	= Remaining budgeted hours to complete a discipline
FTC (Phase)	= Hours forecasted at completion of a discipline
BAC (Phase)	= Budgeted hours at completion of a discipline

At the project level, the overall forecasted hours of the project can be determined using the same technique that is used at the work package level, the discipline level and the phase level. Thus, the overall forecasted hours to complete the project can be obtained using the following questions:

$$R.H_{Proj} = \sum_{1\to d}^{1\to p} \sum_{1\to n}^{1\to m} Total.IWP - \sum_{1\to d}^{1\to p} \sum_{1\to n}^{1\to m} EarnedHours \quad \text{......3.34}$$

$$FTC_{Proj} = R.H_{Proj} / CPI_{Proj} \quad \text{......3.35}$$

Similarly, the budgeted hours at completion can be obtained as follows:

$$BAC_{Proj} = FTC_{Proj} + \sum_{1\to d}^{1\to p} \sum_{1\to n}^{1\to m} SpentHours \quad \text{......} 3.36$$

In which

p	= Number of the phases in project
$R.H_{(Proj)}$	= Remaining budgeted hours to complete the project
$FTC_{(Proj)}$	= Hours forecasted at completion of the project
$BAC_{(Proj)}$	= Budgeted hours at completion of the project

By forecasting the number of hours to completion and budgeted hours at completion for all elements in the project hierarchy, the project management teams can have a full picture of the project and its component up to the lowest level, which is the deliverables.

3.4.4 Variances Algorithms

After determining the budgeted hours/cost at completion for every component in every level in the project hierarchy, the variances, which are another important indicator of the project status, can be computed. In the present research, the earned value concept is adopted to determine variances at the three levels as stated earlier (deliverable, activity and entire project). Therefore, the traditional calculations based on the earned value concept are applied. However, these calculations are performed at the activity level; and they are not performed at other levels (deliverables and the entire project level).

Cost Variance @report date = BCWP-ACWP 3.37

Schedule Variance @report date = BCWP-BCWS 3.38

Total Variance @report date = ACWP-BCWP 3.39

At the deliverable level, the variance in hours at completion of each control point in the progress templates is calculated. Other variances are not computed because they are usually significantly small in value. To determine the variance at completion at each control point, the partial progress of its corresponding activity must be taken into consideration. Thus, the variance in hours at completion of a control point is calculated as follows:

$VAC_{(deliverable)} = iwp/\beta - BAC_{(deliverable}$ 3.40

In which

iwp = Net internal work package hours at end control point (Eq.3.3).

$BAC_{(deliverable)}$ = Budgeted hours at completion of control point (Eq.3.18).

At the activity level, every activity in every work package in the engineering phase has received its man-hour components from its deliverables. And budgeted cost work schedule (BCWS), budgeted cost work preformed (BCWP) and actual cost work performed (ACWP) of every activity in the engineering phase have been computed based on multiplying cost per work hour ($/wh) by man-hour components. Thus, the traditional calculations are applied as follows:

$$C.V_{Activity} = [EarnedHours - SpentHours] * (\$ / wh) \quad \text{3.41}$$

$$S.V_{Activity} = [EarnedHours - IWP] * (\$ / wh) \quad \text{3.42}$$

$$T.V_{Activity} = [SpentHours - IWP] * (\$ / wh) \quad \text{3.43}$$

In which

CV = Cost Variance

SV = Schedule Variance

TV = Total Variance

In the present research, the variance in hours between as-planned hours and budgeted hours at completion is only achieved at the project level and its sub-levels (work package, discipline, and phase level). By computing the variance in hours these levels, the time and memory consumed to detect the project performance at upper-levels are minimized. The following paragraphs describe this concept in detail.

At the work package level, the variance in hours at completion for every work package in the engineering phase can be determined based on calculating the difference between its total internal work package hours (IWP) and its budgeted hours at completion (BAC), which have been achieved from equations 3.25 and 3.27 respectively. Thus, the variance in hours is performed as follows:

$$VAC_{WP} = Total.IWP - BAC_{WP} \qquad 3.44$$

$VAC_{(WP)}$ = Variance in hours at completion for every work package

At the discipline level, every discipline in the engineering phase may encompass a number of work packages. Similarly, the variance in hours for every discipline in the engineering phase is calculated as follows:

$$VAC_{Disc} = \sum_{1 \to m} Total.IWP_{WP} - BAC_{Disc} \qquad 3.45$$

In which

m = Number of work package in one discipline.

$VAC_{(Disc)}$ = Variance in hours at completion for each discipline

At the phase level, projects are broken down into three phases: Engineering, Procurement and Construction. Similarly, the variance in hours for every phase in the project is calculated as follows:

$$VAC_{phase} = \sum_{1 \to m}^{1 \to d} Total.IWP - BAC_{phase} \qquad 3.46$$

In which

d = Number of disciplines in engineering phase.

$VAC_{(phase)}$ = Variance in hours at completion at the phase level

Now, the overall variance in hours at completion of the project is calculated as follows:

$$VAC_{proj} = \sum_{1\to p} \sum_{1\to m}^{1\to d} Total.IWP - BAC_{proj} \quad \text{......3.47}$$

In which

p = Number of phase in project system.

$VAC_{(Proj)}$ = Variance in hours at completion of the project

Having obtained the variance in hours at completion at these levels, project management teams can quickly define the status of each component in the project hierarchy system.

3.4.5 Impacted Activity Algorithm

One of the most important features employed in the proposed system is to identify which activities in the project schedule might be impacted due to an unacceptable performance of the activities in the engineering phase. In the present research a new technique has been developed to identify the impacted activities in the project schedule. This technique relies on three elements as follows: 1) The time frame (the early start date, the early finish date and the original duration) of the activities in the project schedule; 2) The inter-dependence relationships (finish to start, start to start, finish to finish and start to finish) among the activities (see Table 3.3); and 3) The date forecasted at completion of the activity. While the time frames and the interdependence relationships of all activities in the project schedule have been established in the planning phase, the date forecasted at completion is achieved from the forecast algorithm (Equ.3.24). Therefore, if the forecast finish date of the predecessor activity in engineering phase is greater than the early start date of the successor activities, the successor activities may not be started as planned. Consequently, a successive delay may be happened for all activities in the project schedule based on the type of relation and time lag. Fig.3.11 depicts this algorithm. It should be noted the algorithm is limited to finish-start relationships with or without a lag time.

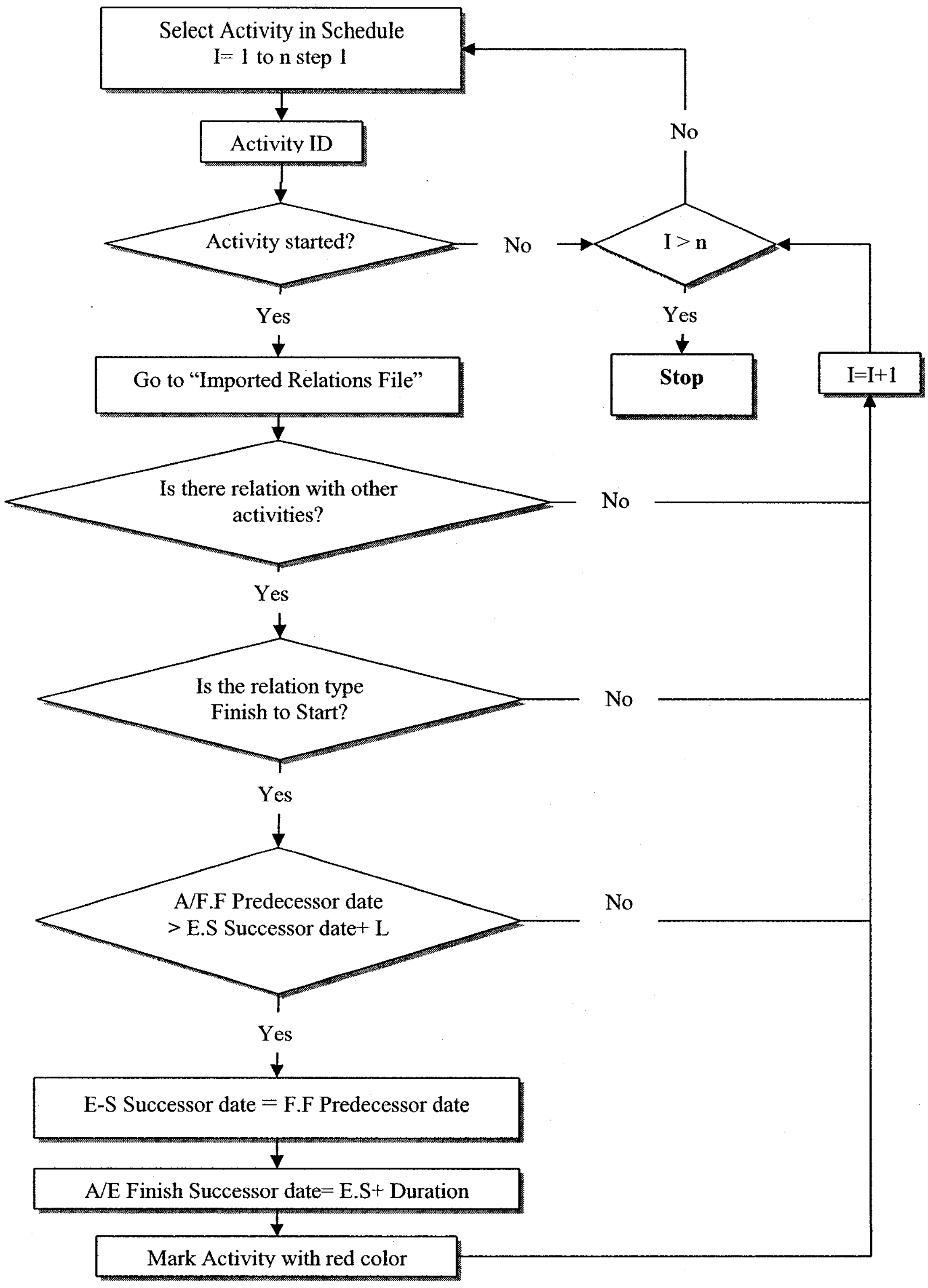


Fig.3. 11 Flow Chart of the Impacted Activity Algorithm

3.5 Summary

This chapter describes the proposed methodology along with its elements. It also introduces the layout and the structure of the developed computerized system that is used to demonstrate the use and essential features of the proposed methodology. Then, it goes through a number of developed algorithms and functions that are employed in the developed system (**TEDS**). This chapter also demonstrates how these algorithms are performed at three levels (deliverables' level, activity level and project level) to track and control every component in the engineering phase. It explains how the engineering deliverables can be integrated in the project schedule to demonstrate their effects on other phases in the project.

Chapter IV – Development of TEDS

4.1 General

The engineering/design phase in EPC projects often includes a large number of deliverables that need to be produced. Tracking and controlling such a large number of deliverables is usually a major problem. Therefore, the developed system, TEDS, is designed in an automated way to minimize the time an effort needed to track and control such complex projects. TEDS has been developed utilizing Microsoft Excel sheet 2004, which has the capability to integrate with scheduling software such as Primavera Project Planner (P3). The following sections describes the developed TEDS in detailed

4.2 Selected Criteria for Development

In the developing process of a management tool, certain features must be included such as the tool availability, the ability to integrate with the planning and scheduling systems, the ability to provide a user-friendly interface (Alshaibani 1999). Since EPC projects include a large number of deliverables that require a complex degree of calculations and rules. The developed tool must have the capability of performing these calculations and rules; it must have its embedded database that can be easily modified; it must have the capability of manipulating and retrieval data timely and effectively. The system must report project status timely and effectively. The system must have the capability of identifying the reasons behind unacceptable performance, if any, at any level. Indeed, the memory capacity of such a tool should be taken into consideration to minimize time during execution and to permit running it on a personal computer. Therefore, Microsoft® Excel 2003 has been chosen as the base of development of the developed system, TEDS, because it is easy to use, it is available, and it is capable of integrating with other planning and scheduling software such as Primavera Project Planner (P3). Moreover, it is has the ability to perform complex calculations and can also provide a number of reports in tabular and graphical formats. Indeed, MS Excel already includes comprehensive groups of rules and functions that can manipulate huge mounts of data effectively. In the present research, the developed Excel sheet, **T**racking **E**ngineering **D**eliverable **S**ystem (**TEDS**), has been coded using Macros and Visual Basic programming language.

4.3 System's Architecture

The developed system, TEDS, has been designed to carry out its embedded algorithms and functions that are introduced in chapter 3. To facilitate uses of the developed system, TEDS, it comprises eighteen modules that are organized under seven menus, namely the following: 1) Import; 2) Updating; 3) Document; 4) Performances; 5) Reports; 6) Templates; and 7) Charts menus. These menus are grouped in one toolbar, namely "Eng Deliverables", which is loaded and unloaded automatically when TEDS is activated and deactivated. Fig. 4.1 depicts the structure of TEDS. The following sections describes in details these modules along with their functions.

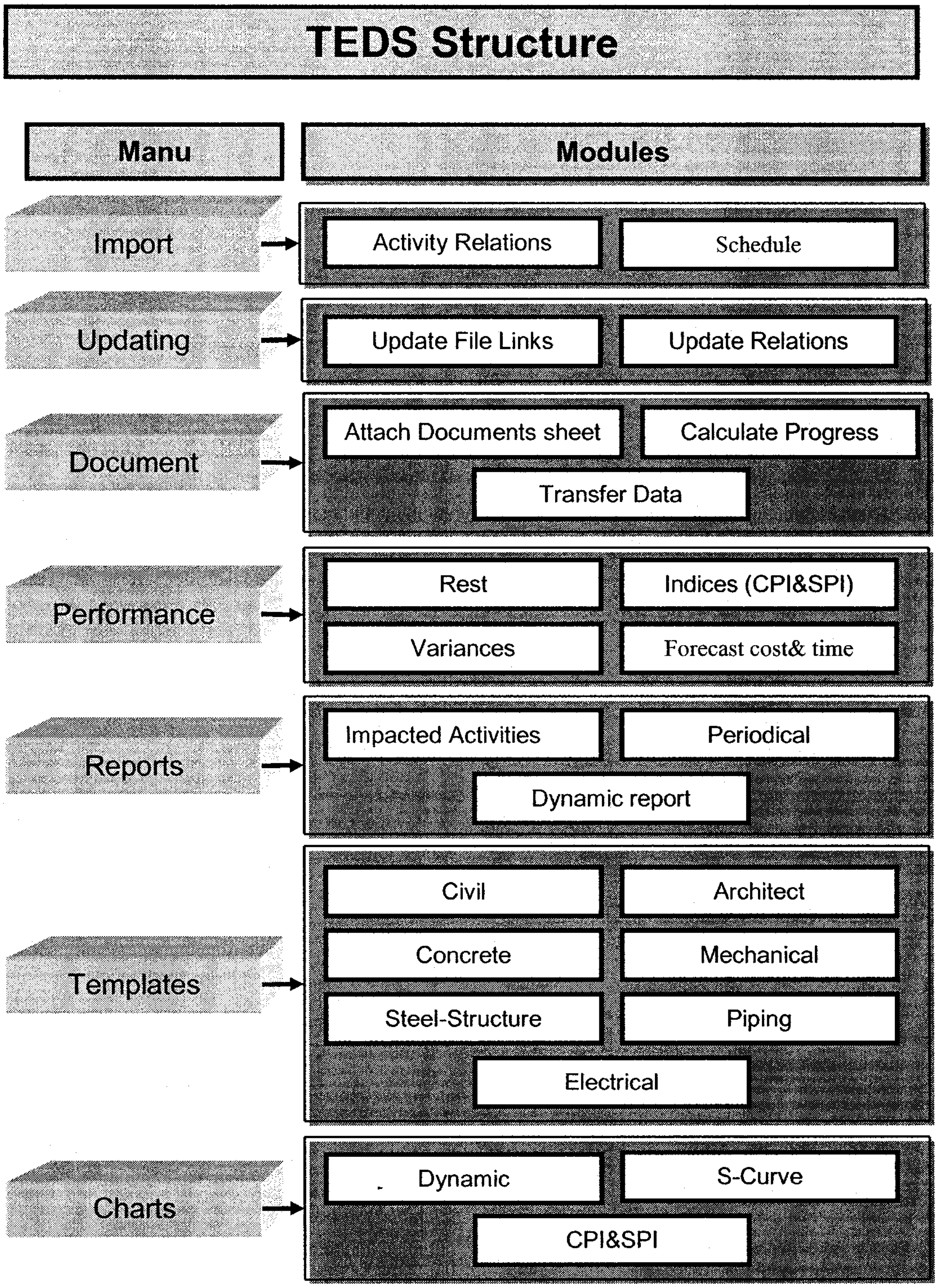


Fig.4. 1 TEDS Structure

4.4 System's Modules

1) Import Modules

These modules are designed to import the project database files (project schedule and interdependence relationships files), which are exported from Primavera Project Planner (P3). They are symbolized in the system's toolbar (Eng Deliverable) as two push-buttons, which are grouped in one dropdown menu, namely "Import" (Fig 4.4). These modules are as follows: 1) Activity Relations; and 2) Schedule modules. Both modules are designed to establish dynamic links between the system and the exported database files from P3. As a result, if the exported database files are modified, the system updates the data automatically. Besides, both modules are designed to terminate the importing process if the project data files exist on the system, so time and memory consumption are minimized.

The function of the Activity Module is to import the interdependence relationships data file, which contains predecessors and successors activities' codes, types of relations (finish to start, start to start, etc.) among activities and lag times. The importing process involves two steps that are done sequentially and automatically: 1) create a new sheet, namely Relation; and 2) store the refined data on the Relation sheet.

The functions of the Schedule module are as follows: 1) create a new sheet, namely, Imported Data; 2) import the project schedule data file into the created sheet; and 3) extract specific data from the imported file such as the activities' codes, descriptions, planned start and finish dates, original durations, and project work break down structure, and organize this data in predefined columns in the main window of the system.

2) Updating Modules

These modules are designed to update data in the Impacted Activities report and to update hyperlinks' passes of document sheets. They are symbolized in the system's toolbar as two push-buttons that are grouped in one dropdown menu, namely "Updating" (Fig.4.5).These push-buttons are used to activate the following modules: 1) Update File Links; and 2) Activity Relations modules.

The function of the Update File Links module is to update the passes of the hyperlinks (addresses) of document sheets, which are generated invisibly by the system (see Document module). By doing so, the embedded document sheets become accessible if the system is transferred from one medium to another (hard drive to portable memory). For instance, a hyperlink's address of a document sheet, namely "Temporary Facility", which is created under C root in a personal computer, is "C\\TEDS.xls-Temporary-Facility". If the system is transferred to another medium such as portable disk "F", the document sheet "Temporary Facility" becomes inaccessible. By using this module, the address of the hyperlink becomes "F\\TEDS.xls-Temporary-Facility" and the document sheet becomes accessible. This function gives the system a high-degree of mobility, so it can be transferred to any medium. See Fig. 4.9.

The function of the Activity Relations Module is to update data in the impacted activities report by integrating data in both interdependence relationships and project schedule files.

3) Document Modules

These modules are designed to work at the deliverables level. They are developed to create document sheets, to determine performance for every deliverable, and to integrate the deliverables with the activity level in the project schedule. They are symbolized in the system's toolbar as three push-buttons that are grouped in one dropdown menu, namely "Document" (Fig 4.6). The three push-buttons are used to activate the following modules: 1) Attach Document Sheets; 2) Calculate Progress; and 3) Transfer Data modules.

The function of the Attach Document Sheets module is to create a unique document sheet for each work package in the engineering/design phase that is linked to the activity level. It should be mentioned that creating document sheets, and then, linking them to the activity level are done automatically. Creating the document sheet involves creating document sheets and representing them in the project schedule as hyperlinks.

First, a user-interface window in which users enter the name of the document sheet is activated. Since many document sheets could be created on the system, it is important to develop a mechanism that prevents the creation of duplicate sheets. Therefore, the module is designed to perform a loop through all existing sheets' names on the system to check whether the new sheet exists on the system. If the sheet name already exists on the system, a message appears advising the user to enter another unique name for the document sheet; if it does not exist, the sheet is created automatically. It should be mentioned that the status of the created document sheets are invisible. . Each document sheet has pre-defined fields that are divided into three fields: 1) direct input fields; 2) database fields; and 3) calculated fields.

The direct input fields are used to record the data for every deliverable such as the description of a deliverable, the total budgeted hour, the cumulative earning percentage of the previous control point in a progress template, the spent hours and the percent complete of accomplishment at every control point during the reporting period. The database fields are designed to facilitate registering information for every deliverable by using two dropdown menus. These dropdown menus include the following: the reference activity in the project schedule and the progress template type. It should be mentioned that the dropdown menu of progress template includes progress template type (civil, architecture, etc.) along with its control points' descriptions and cumulative earning percentages. The calculated fields are designed to provide the user with the performance of every deliverable in each work package during the reporting period. It should be mentioned that this data is performed when the Calculate Progress module is activated. The computed data includes the net budgeted hours, earned hours, performance index, remaining hours to complete, total man-hour components of all the deliverables, and variance in hours.

The second step is to represent each document sheet as a hyperlink in the project schedule. The function of the hyperlink is to change the status of the created document sheet from an invisible to a visible status. It should be noted that when hyperlinks are created, their full passes (addresses) are generated automatically based on the medium in which the system is working. For instance, if the system runs under "C" root on a personal computer, the hyperlink passes are the following: the document sheet name plus the roots pass (C:\\ TEDS.xls-Document sheet name).

The function of the Calculate Progress module is to compute the following: performance index (CPI), earned hours, remaining hours to complete a control point, forecast hours to complete a control point, variances in hours at completion of a control point, and total man-hour components (schedule hours, earned hours and spent hours) of all deliverables in a document sheet. It should be mentioned the computed data is done at every control point in the progress template.

The functions of the Transfer Date module are to transfer the total man-hour components, which are calculated by the Calculate progress module, to a corresponding activity in the project schedule; and then to change the status of the document sheets from visible to invisible. It should be mentioned that when the corresponding button of each module is clicked, its functions are executed automatically and sequentially. Fig.4.13 demonstrates the process of creating a document sheet, of calculating progress, and of transferring data to an activity in the project schedule.

4) Performance Modules

These modules are designed to work at the activity level to determine the performance indices (CPI and SPI), the variances in hours, and the forecast hours and date at completion. They are symbolized in the system toolbar as four push-buttons that are grouped in one dropdown menu, namely “Performances“ (Fig 4.14). These four push-buttons are used to activate the following modules: 1) Reset; 2) Indices; 3) Variances; and 4) Forecast. It should be mentioned that all calculations are performed based on the developed equations in Chapter 3.

Because the developed system utilises a colour pattern technique (Red, Green and Yellow) to depict the activity performance, it is essential to develop a module that clears away all those colours in case of a user’s mistakes. Therefore, the function of the Reset module is to clear all colours that are created by indices, variances and forecast modules.

The functions of the Indices Module are as follows: 1) calculate the cost and schedule performance indices (CPI&SPI) for every activity in the project schedule; and 2) provide every activity in the project schedule with a specific colour (Green, Yellow and Red) based on its performance indices (CPI and SPI). For example, the colour red indicates poor performance (CPI/SPI<1); the colour yellow indicates normal performance (CPI/SPI=1); and the colour green indicates good performance (CPI/SPI>1).

The function of the Variances Module is to calculate the Cost, Schedule and Total variances (CV, SV and TV) for all activities in the project schedule. As stated earlier, the cost, schedule and total variances can be obtained by entering the cost ($) per work hour for every activity in the project schedule.

The functions of the Forecast module are as follows: 1) forecast the cost and time to complete all activities; 2) forecast the date of the completion of activities in progress; and 3) provide every activity in the project schedule with a specific colour (Green, Yellow and Red) based on the its completion date. For example, the colour red indicates that the completion date of an activity is greater than its early finish date; the colour yellow indicates that the completion date is equal to its early finish date; and the colour green indicates that the completion date is less than its early finish date.

5) Database Module

This module is designed to facilitate working with the progress templates' database. It is symbolized in the system toolbar as a push-button, namely "Templates" (Fig.4.10). This button is used to activate a user-friendly interface composed of seven checkboxes. Each checkbox is linked to a sheet that contains a specific database of progress templates for a certain discipline such as Civil, Concrete, Steel Structure, Architect, Piping and Electrical disciplines. By checking any checkbox, the corresponding database sheet becomes visible, so users can add and/or modify its data.

6) Report Modules

These modules are designed to report EPC projects at the project's upper-levels such as the work packages, disciplines (Civil, Concrete, etc) and phases (Engineering, Procurement and Construction) levels. These modules are symbolized in the system toolbar as three push-buttons, which are grouped in one dropdown menu, namely "Report" (Fig.4.10). These push-buttons are used to activate the following modules: 1) Impacted Activity; 2) Dynamic; and 3) Periodical.

The function of the Impacted Activity module is to report any delayed activities in the project schedule due to the unfavourable performance of any activity in any phase of EPC projects. When this module is activated, the system integrates activity data (codes and descriptions, actual start and forecast finish dates) in the project schedule and imported interdependence relationships file (predecessors' and successors' codes, types of relations and lag times). Then, the integrated data is organized in the impacted activities window. This data includes predecessors' and successors' information such as codes, descriptions, actual start and forecast finish dates, relations type, and lag times. After that, a loop composed of If-Then rules is activated automatically in the integrated data to examine the forecast finish dates of the predecessors' activities against the early start dates of the successors' activities (see Fig. 3.11). It should be mentioned that the developed system is limited to one type of interdependence relationship (Finish to start with or without a lag time).

The function of the Dynamic module is to generate a dynamic report, which reports the status of the project at project's upper-levels (phase, discipline and work package). When this module is activated, a dynamic report (Pivot table) is generated and a series of calculations are performed automatically based on the data in the project activities window. This dynamic report is developed to organize data, to aggregate man-hour components, and to calculate performance for each component at different levels based on WBS of the project. For instance, data can be aggregated by phase, discipline and work package. The dynamic report's data is composed of two main fields: derivative data from the activities such as total budgeted hours, earned hours and spent hours; and the calculated data such as the percentage complete of the budgeted hours, cost performance index (CPI), forecast hours at completion, budgeted hours at completion and variances in hours at completion. Extracting particular information at any level can be achieved by selecting different filters that are employed in this report. This module has a function that terminates the generating process if the dynamic report exists on the system, so time and memory consumption are minimized.

The function of the Periodical module is to report the project performance during its lifecycle. It is designed to integrate with the project schedule and dynamic report. Integrating with the project schedule, the module is designed to determine the number of reporting periods based on monthly calculations. While integrating with the dynamic reports, the periodical report extracts the project data during reporting period such as the cost and schedule performance indices, the forecasted and budgeted hours at completion and variance in hour at completion.

7) Chart Modules

These modules are designed to report the project data graphically. They are symbolized in the system toolbar as three push-buttons, which are grouped in one dropdown menu, namely "Charts" (Fig 4.14). These three push-buttons are used to activate the chart modules, namely: 1) Dynamic; 2) S-Curve; and 3) CPI/SPI. To minimize time and memory consumption, each module has a function that terminates the generating process of the chart if it already exists on the system.

The function of the Dynamic module is to generate a dynamic chart that is linked automatically with the dynamic report to illustrate its data graphically. For example, determining the data of a particular component in a project such as the work package is accomplished by using different filters in the dynamic report screen; consequently, the dynamic chart reflects this data in graphically.

The S-Curve module is designed to report the Earned Value component of a project during its lifecycle graphically. It is developed to integrate with the periodical report's data to generate a chart that is developed to depict three curves as follows: the schedule hours, the earned hours and the spent hours.

The CPI/SPI module is designed to report the project performance indices (CPI and SPI) graphically. It is developed to integrate with the periodical report's data to generate a chart that is designed to illustrate the cost and schedule performance indices (CPI&SPI) during the project lifecycle.

4.5 Data Processing

Processing data on TEDS is accomplished in two phases: Planning and Execution phases. In the planning phase, the project data files (project schedule and interdependence relationships) are imported by the system, while document sheets, which carry engineering deliverables, are entered into the system as described in Section 3.3. Fig. 4.2 illustrates the exporting process of the project data files from the Primavera Project Planner (P3). In the second phase, the Execution phase, the user is requested to key a set of data on the project schedule and the document sheets windows. In the project schedule window, the actual start and the report dates are entered for each activity in progress. Consequentially, the ratio between the working days and the original duration (**β**) is calculated automatically by the system. Then, the corresponding document sheet for each activity in progress is activated by the user. In these document sheets, the user is requested to key and select a set of data for each deliverable such as the reference activity in the project schedule, the cumulative earning percentages from the progress template at the previous and the report stages, the actual spent hours and the percent complete of each control point. It should be mentioned that the reference activities and cumulative earning percentage at the report date are selected from dropdown menus while the other data is keyed by the user. When that is done, the system is ready to carry out all functions and algorithms and to generate reports. It should be noted that values of (**β**) are transferred automatically from the project schedule window to the deliverables in the document sheets when they are activated by the user.

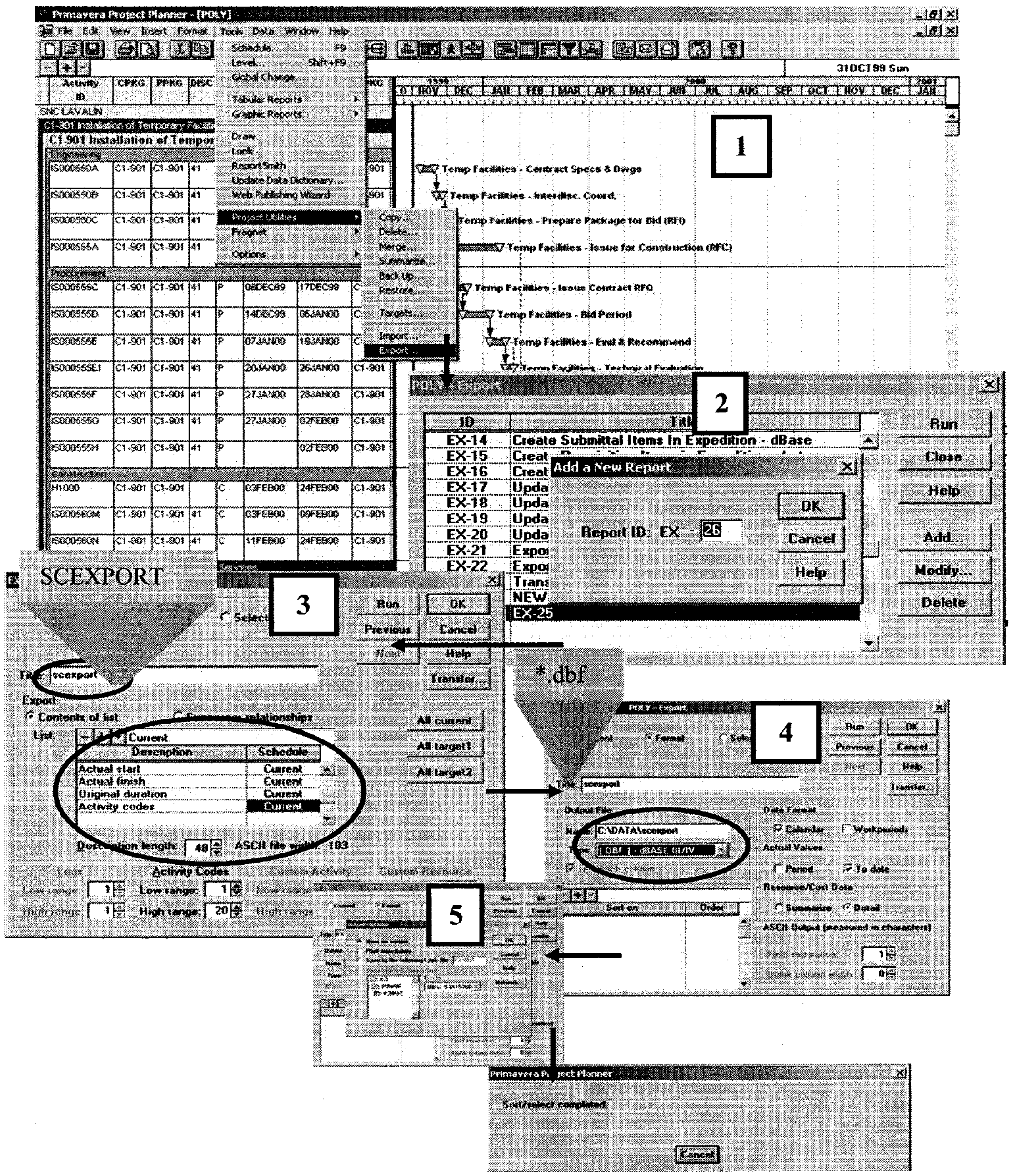


Fig.4. 2 Process of Exporting Schedule File from P3

4.6 Reporting Process

The reporting process in TEDS diversifies at different levels of EPC projects such as deliverables, activities, work packages, disciplines, phases and entire project levels. Each report provides the user with particular information according to its type. These reports are as follows: 1) Deliverables; 2) Activities; 3) Dynamic; 4) Periodical; 5) Impacted Activities; and 6) Graphical reports.

The deliverables report window is the first report that users encounter in which the calculating of the progress and the determining status of every deliverable in every work package can be achieved. This report provides the following data at one control point in each progress template during the reporting period:

1- Man-hour components (budgeted hours, earned and spent hours).
2- Cost Performance Index (CPI).
3- Remaining hours to complete a control point.
4- Forecast hours to complete a control point.
5- Variance in hours at completion of a control point.

The activities report window is designed to provide the user with the status of each activity in the project schedule. Since EPC projects consist of large numbers of activities, reporting the performance indices of all activities consumes time and effort. Therefore, two main techniques are employed in TEDS to minimize time and effort: filtering and colour pattern techniques. The filtering technique is used to extract a specific type of data. For instance, extracting activities that have an unacceptable cost performance (CPI<1.0) in civil discipline in the engineering phase in the project schedule can be achieved by selecting filters of the following types: phase (engineering); discipline (civil); and CPI less than one. The colour pattern technique is used to facilitate demonstrating the status of every activity in the project schedule by utilizing three different colors: Red; Yellow; and Green. For example, the cell for the forecast date at completion of an activity receives the colour red if the completion date of an activity is greater than its early finish date; in contrast, it receives the colour green if the completion date of an activity is less than its early finish date. The colour yellow indicates that the forecast date at completion for an activity is equal to its early finish date. Therefore, providing the status of every activity in the project schedule is achieved in a timely and effective manner. The output of this report is as follows:

1- Cost and Schedule Performance Indices (CPI&SPI)
2- Cost and Schedule Variances (CV&SV)
3- Total Variances(TV)
4- Forecast Cost, Time and Date at completion.

The Dynamic report is designed to provide the user with the status of each level in the project hierarchy system such as the work package, discipline and phase levels. Determining the status of each level is accomplished by using three filters: Phase, Discipline; and Work package. The output of this report is as follows:

1- Percentage complete of budgeted hours.

2- Cost Performance Index (CPI).

3- Forecast hours to complete.

4- Budgeted hours at completion.

5- Variance in hours at completion.

The Periodical report is designed to report the status of the entire project during its lifecycle. The output of this report is as follows:

1- Percentage complete of budgeted hours.

2- Cost and Schedule performance Indices (CPI&SPI).

3- Forecast hours to complete.

4- Budgeted hours at completion.

5- Variance in hours at completion.

The Impacted activity report is designed to report any activities that might be delayed due to the unacceptable performance of other activities based on the described concept in Section 3.5. The output of this report is as follows:

1- Actual started and Finished dates of the activities.

2- Late started activities.

The Graphical reports are designed to provide the user with charts that facilitate tracking and controlling the project elements. There are three types of charts: 1) Dynamic; 2) S-curve; and 3) CPI&SPI charts. The Dynamic chart is linked with the dynamic report automatically; thus, it depicts the selected data on the dynamic report. The S-Curve chart illustrates the man-hour component (budgeted hours, earned hours and spent hours) during the project lifecycle. The CPI&SPI chart depicts the cost and schedule performance indices of a project during its lifecycle.

4.7 Description of TEDS Toolbar and Screens

TEDS has been designed to be shown in MS Excel as a toolbar, namely "Eng Deliverables", which is loaded automatically when TEDS is activated. This toolbar is composed of six dropdown menus and one push-button. While each menu includes a number of push-buttons that are used to activate its embedded modules, the push-button is used to activate a popup window that includes a number of checkboxes (Fig.4.3).

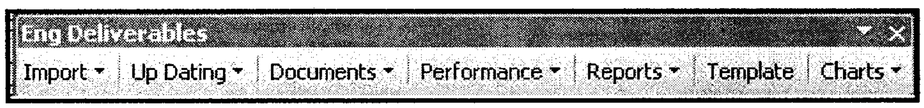


Fig.4. 3 TEDS Toolbar "Eng Deliverables"

The **Import menu** comprises two push-buttons, namely: 1) Schedule; and 2) Activity relations. These buttons are designed to activate the Schedule and Activity Relations modules respectively (see Fig.4.4). By clicking the Schedule button, a new sheet is automatically created, namely "Imported Data", which is used as a container for imported data. Then, this data is refined and organized in the main window of TEDS. Fig 4.5 and Fig 4.6 show screens of the importing and organizing process of the project schedule data file on the system. Similarly, by clicking the Activities Relations button, a new sheet, namely "Relations", is created and the imported data is stored on it automatically. Fig.4.7 depicts the screen of the created sheet with its associated imported relation file.

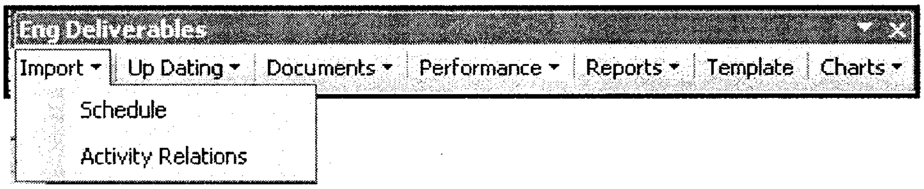
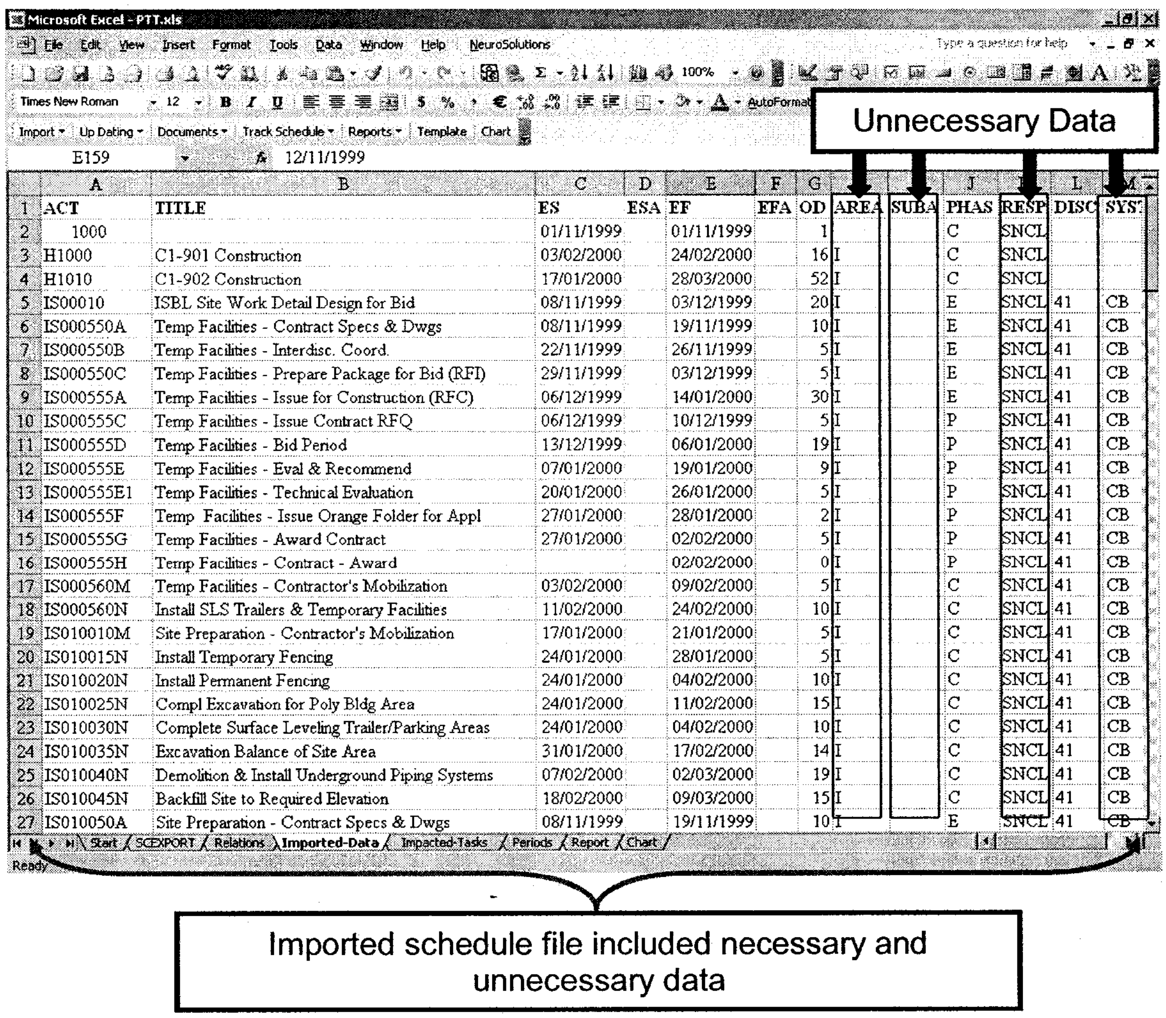


Fig.4. 4 Import Dropdown Menu



1	ACT	TITLE	ES	ESA	EF	EFA	OD	AREA	SUBA	PHAS	RESP	DISC	SYS
2	1000		01/11/1999		01/11/1999		1			C	SNCL		
3	H1000	C1-901 Construction	03/02/2000		24/02/2000		16	I		C	SNCL		
4	H1010	C1-902 Construction	17/01/2000		28/03/2000		52	I		C	SNCL		
5	IS00010	ISBL Site Work Detail Design for Bid	08/11/1999		03/12/1999		20	I		E	SNCL	41	CB
6	IS000550A	Temp Facilities - Contract Specs & Dwgs	08/11/1999		19/11/1999		10	I		E	SNCL	41	CB
7	IS000550B	Temp Facilities - Interdisc. Coord.	22/11/1999		26/11/1999		5	I		E	SNCL	41	CB
8	IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	29/11/1999		03/12/1999		5	I		E	SNCL	41	CB
9	IS000555A	Temp Facilities - Issue for Construction (RFC)	06/12/1999		14/01/2000		30	I		E	SNCL	41	CB
10	IS000555C	Temp Facilities - Issue Contract RFQ	06/12/1999		10/12/1999		5	I		P	SNCL	41	CB
11	IS000555D	Temp Facilities - Bid Period	13/12/1999		06/01/2000		19	I		P	SNCL	41	CB
12	IS000555E	Temp Facilities - Eval & Recommend	07/01/2000		19/01/2000		9	I		P	SNCL	41	CB
13	IS000555E1	Temp Facilities - Technical Evaluation	20/01/2000		26/01/2000		5	I		P	SNCL	41	CB
14	IS000555F	Temp Facilities - Issue Orange Folder for Appl	27/01/2000		28/01/2000		2	I		P	SNCL	41	CB
15	IS000555G	Temp Facilities - Award Contract	27/01/2000		02/02/2000		5	I		P	SNCL	41	CB
16	IS000555H	Temp Facilities - Contract - Award			02/02/2000		0	I		P	SNCL	41	CB
17	IS000560M	Temp Facilities - Contractor's Mobilization	03/02/2000		09/02/2000		5	I		C	SNCL	41	CB
18	IS000560N	Install SLS Trailers & Temporary Facilities	11/02/2000		24/02/2000		10	I		C	SNCL	41	CB
19	IS010010M	Site Preparation - Contractor's Mobilization	17/01/2000		21/01/2000		5	I		C	SNCL	41	CB
20	IS010015N	Install Temporary Fencing	24/01/2000		28/01/2000		5	I		C	SNCL	41	CB
21	IS010020N	Install Permanent Fencing	24/01/2000		04/02/2000		10	I		C	SNCL	41	CB
22	IS010025N	Compl Excavation for Poly Bldg Area	24/01/2000		11/02/2000		15	I		C	SNCL	41	CB
23	IS010030N	Complete Surface Leveling Trailer/Parking Areas	24/01/2000		04/02/2000		10	I		C	SNCL	41	CB
24	IS010035N	Excavation Balance of Site Area	31/01/2000		17/02/2000		14	I		C	SNCL	41	CB
25	IS010040N	Demolition & Install Underground Piping Systems	07/02/2000		02/03/2000		19	I		C	SNCL	41	CB
26	IS010045N	Backfill Site to Required Elevation	18/02/2000		09/03/2000		15	I		C	SNCL	41	CB
27	IS010050A	Site Preparation - Contract Specs & Dwgs	08/11/1999		19/11/1999		10	I		E	SNCL	41	CB

Fig.4. 5 Project's Schedule Data File (before refinement)

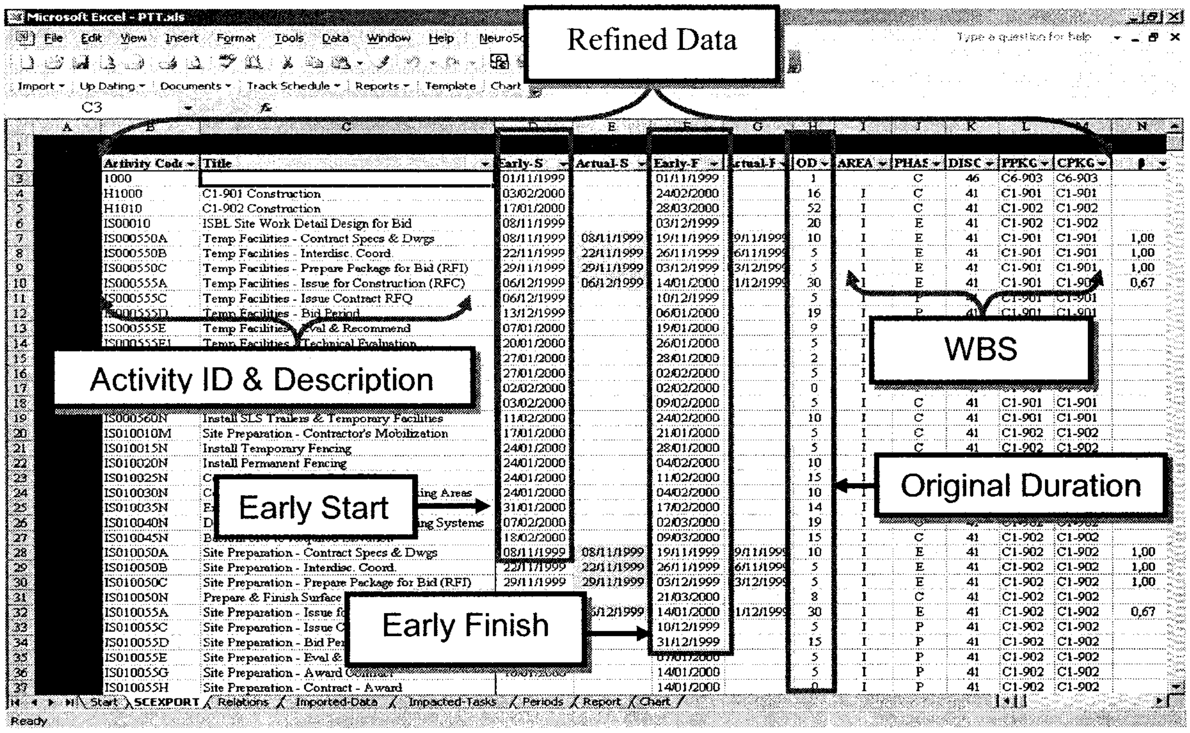


Fig.4. 6 Project's Schedule Data File (after refinement)

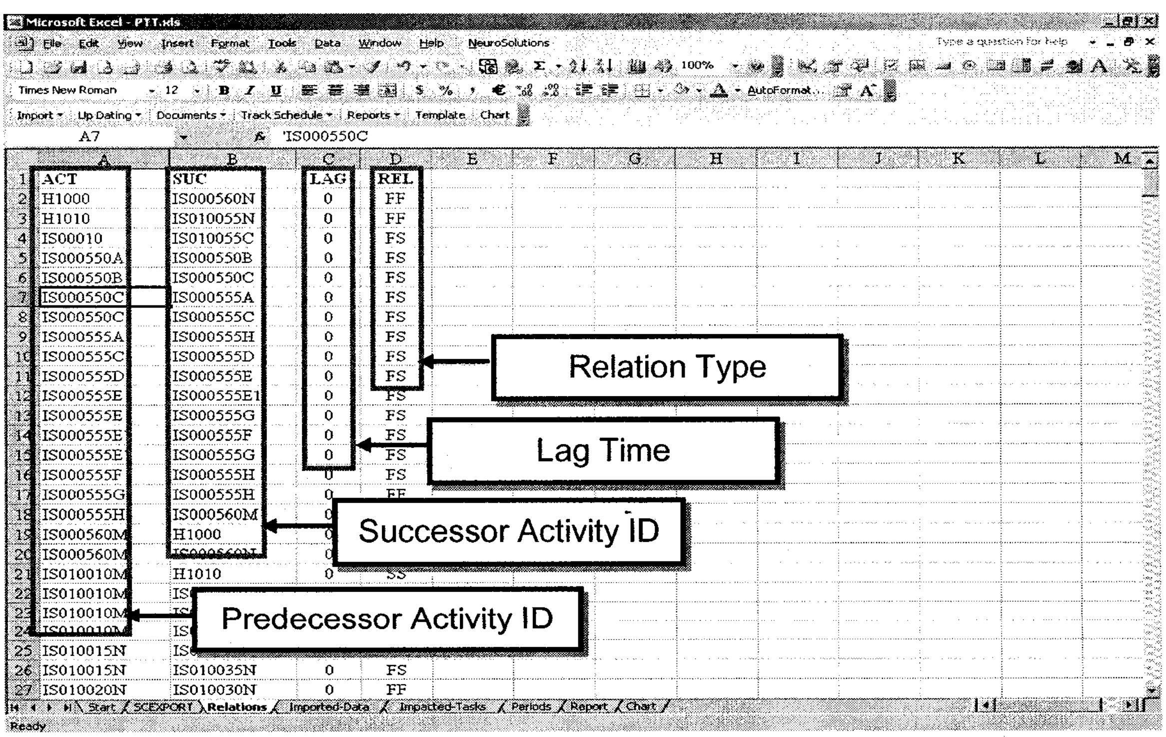


Fig.4. 7 Interdependence Relationships Data File

The **Updating menu** comprises two push-buttons, namely: 1) Update File Links; and 2) Update Relations. See Fig.4.8. These buttons are used to activate the Update File Links and the Update Relations modules respectively. By clicking Update File links, the associated module is activated. Fig.4.9 depicts the process of updating the hyperlinks of document sheets. Similarly, when the Update Relations button is clicked, the associated module is activated thereby forcing data files (project schedule and activity relations files) to be integrated in the impacted activity sheet for the purpose of reporting. See Fig.4.10.

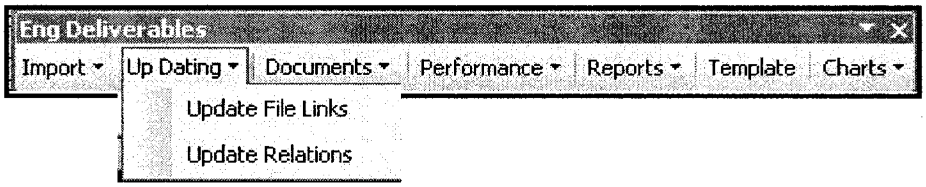


Fig.4. 8 Updating Dropdown Menu

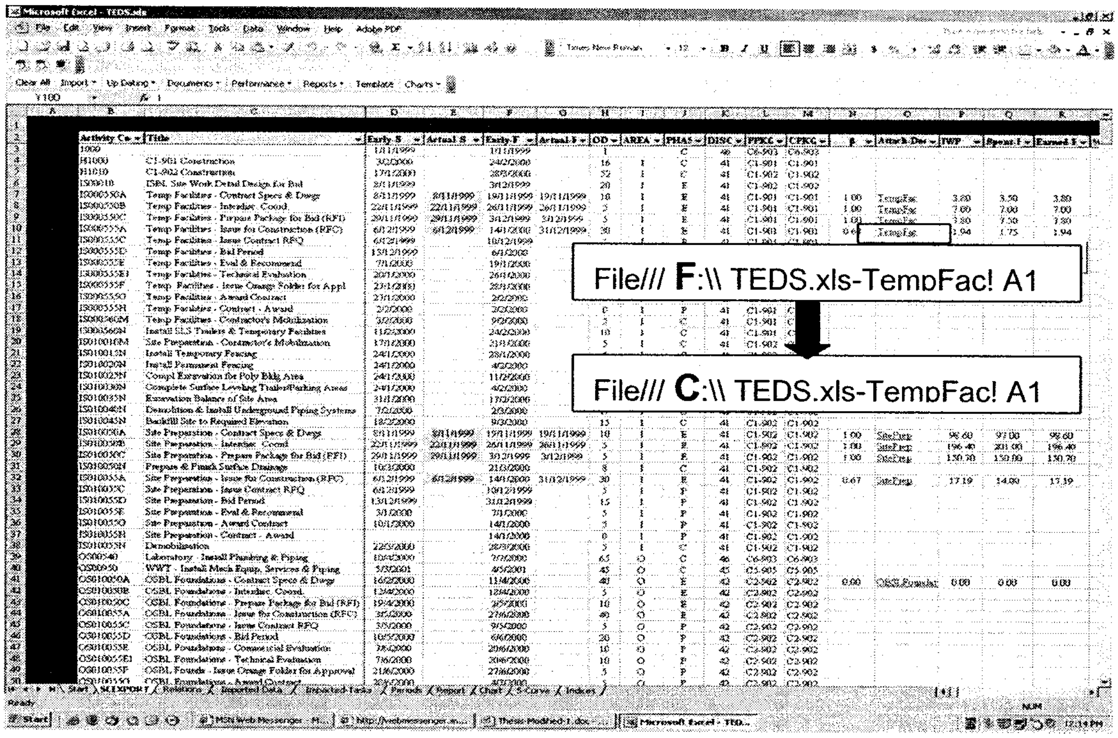


Fig.4. 9 Updating Hyperlinks' Passes of Document Sheets

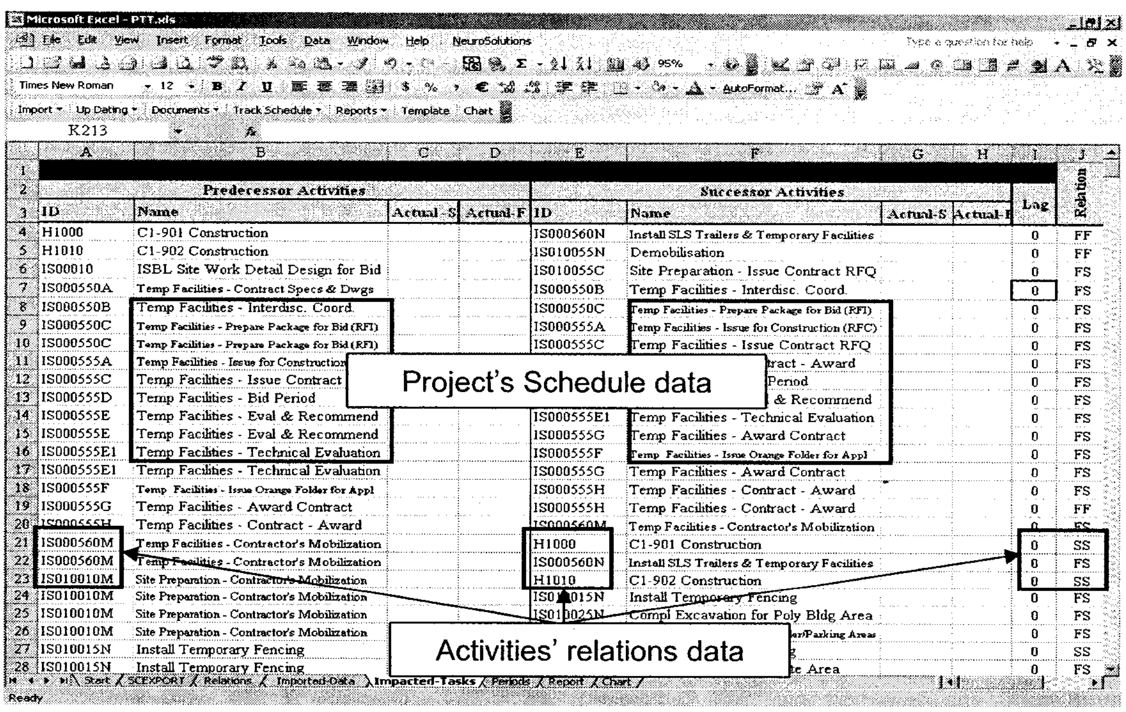


Fig.4. 10 Integrating Project's Data Files

The **Document menu** comprises three push-buttons, namely: 1) Attached Document Sheet; 2) Calculate Progress; and 3) Transfer to Schedule (see Fig.4.11). These buttons are designed to activate the Attach Document Sheet, the Calculate Progress and Transfer data modules respectively. Fig.4.12 depicts the screens of creating a document sheet. Fig.4.13 illustrates different screens when the Calculate progress and Transfer data push-buttons are used. It should be noted that the Calculate progress and Transfer-To-Schedule buttons are designed to work in document sheets only.

The **Performance menu** includes four push-buttons, namely: 1) Reset; 2) Performance; 3) Variances; and 4) Forecast buttons. See Fig.4.14. These buttons are designed to activate Reset, Indices, Variances and Forecast modules. By clicking the Reset button, the Rest module is activated. When the Indices button is clicked, the Performance module is activated. Fig 4.15 depicts the calculated fields in the project schedule window due to the activation of the Performance push-button. Similarly, clicking Variance button leads to calculate of the cost, schedule and total variances for every activity in the project schedule (Variance Module). Eventually, when the Forecast button is clicked, the Forecast module is activated.

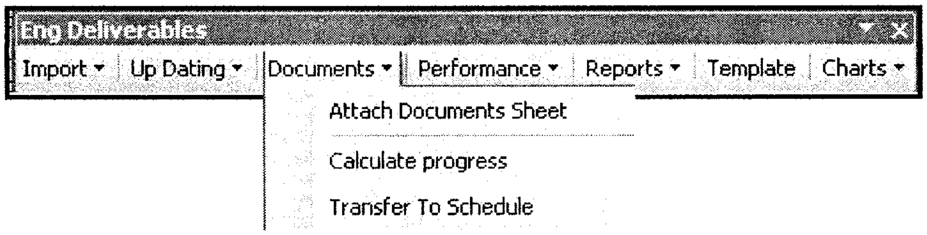


Fig.4. 11 Documents Dropdown Menu

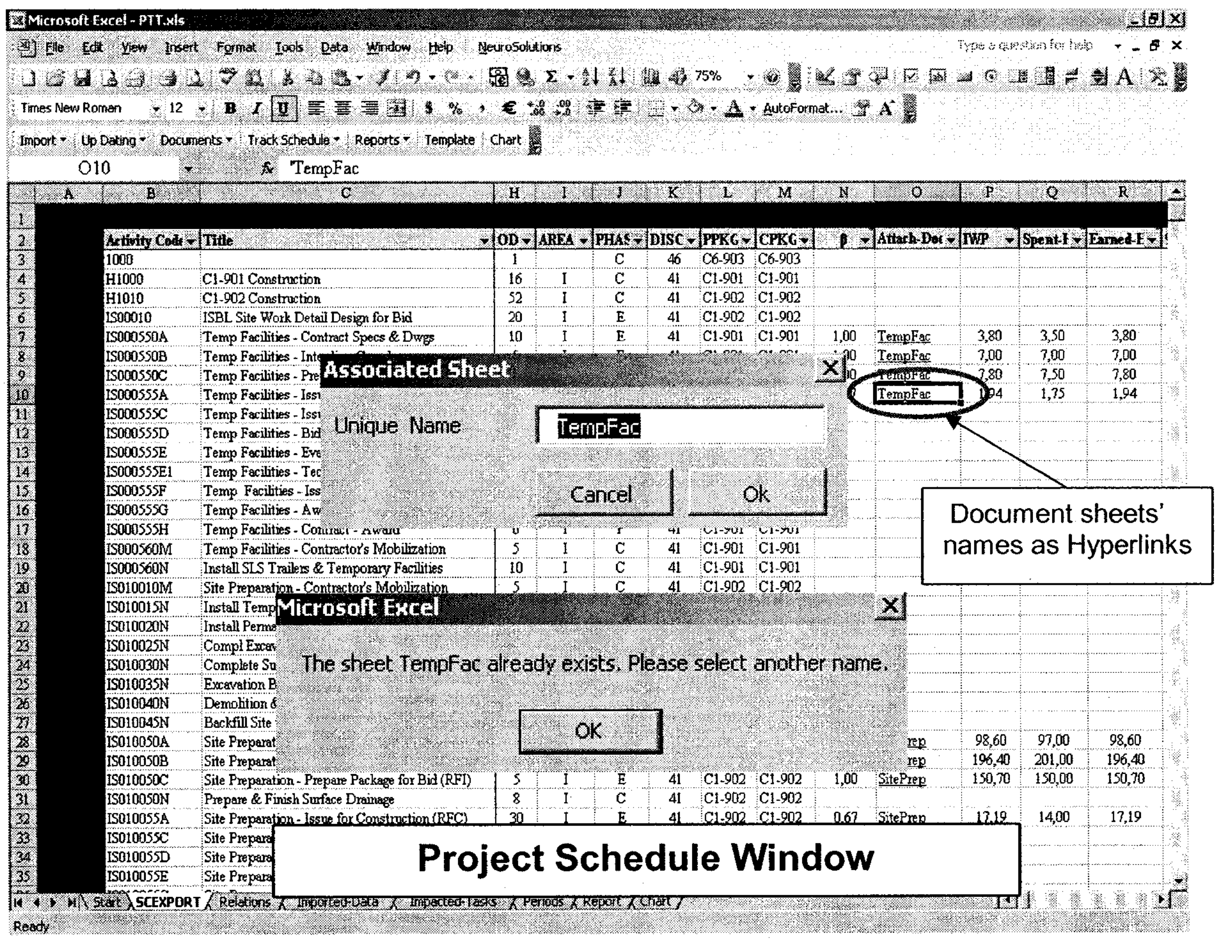


Fig.4. 12 Process of Generating Document Sheets

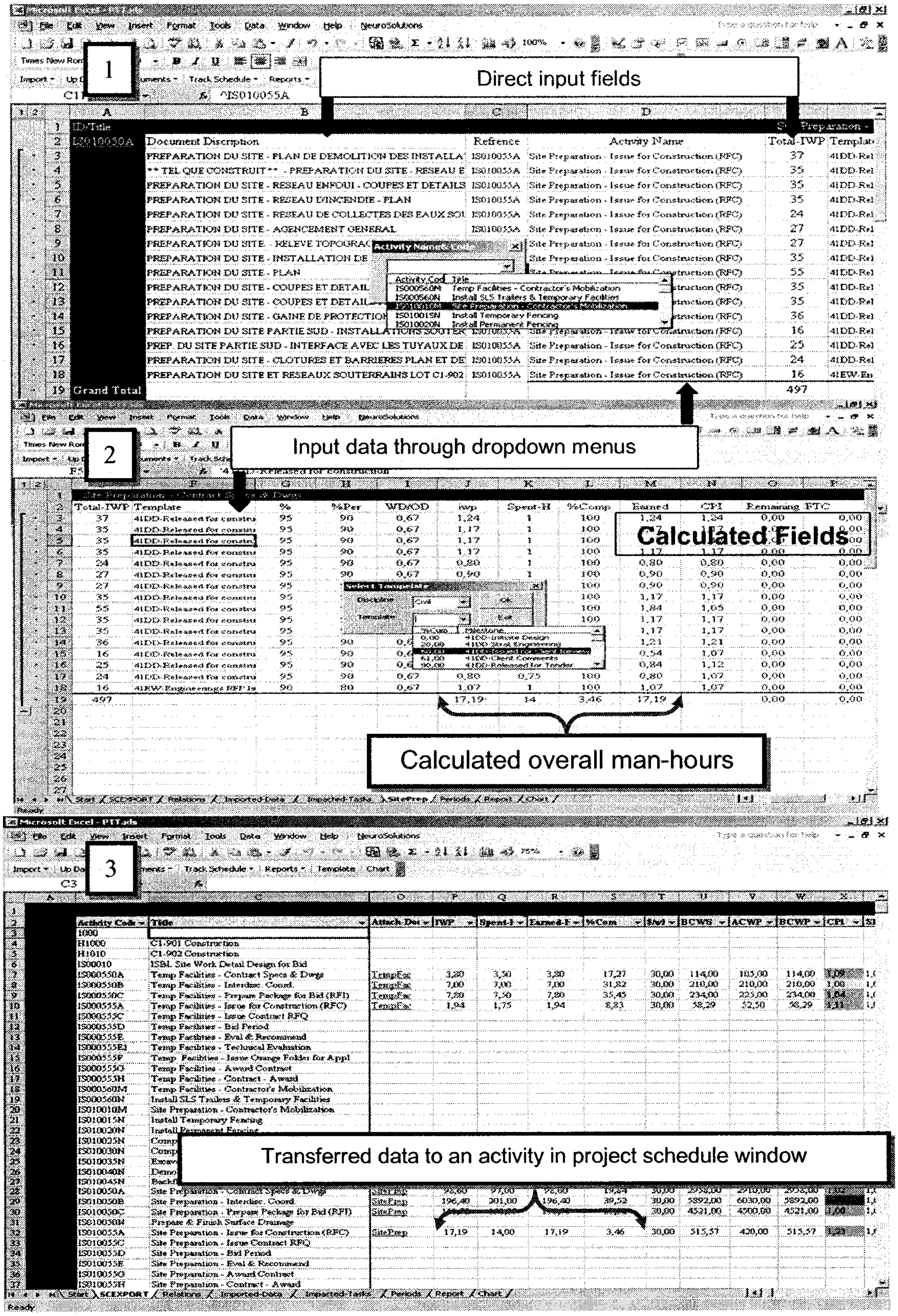


Fig.4. 13 Process of Calculating the Progress & Transferring the Data

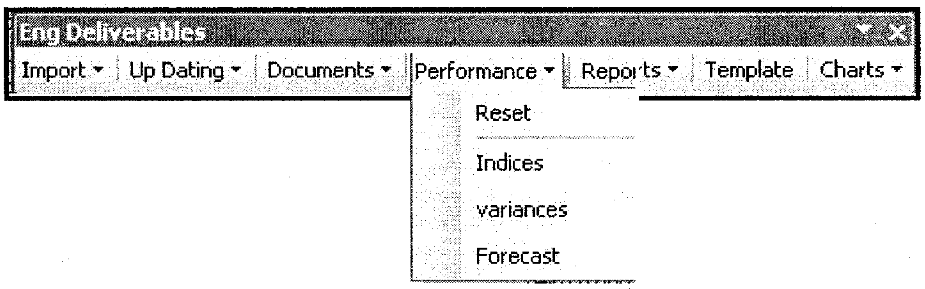


Fig.4. 14 Performance Dropdown Menu

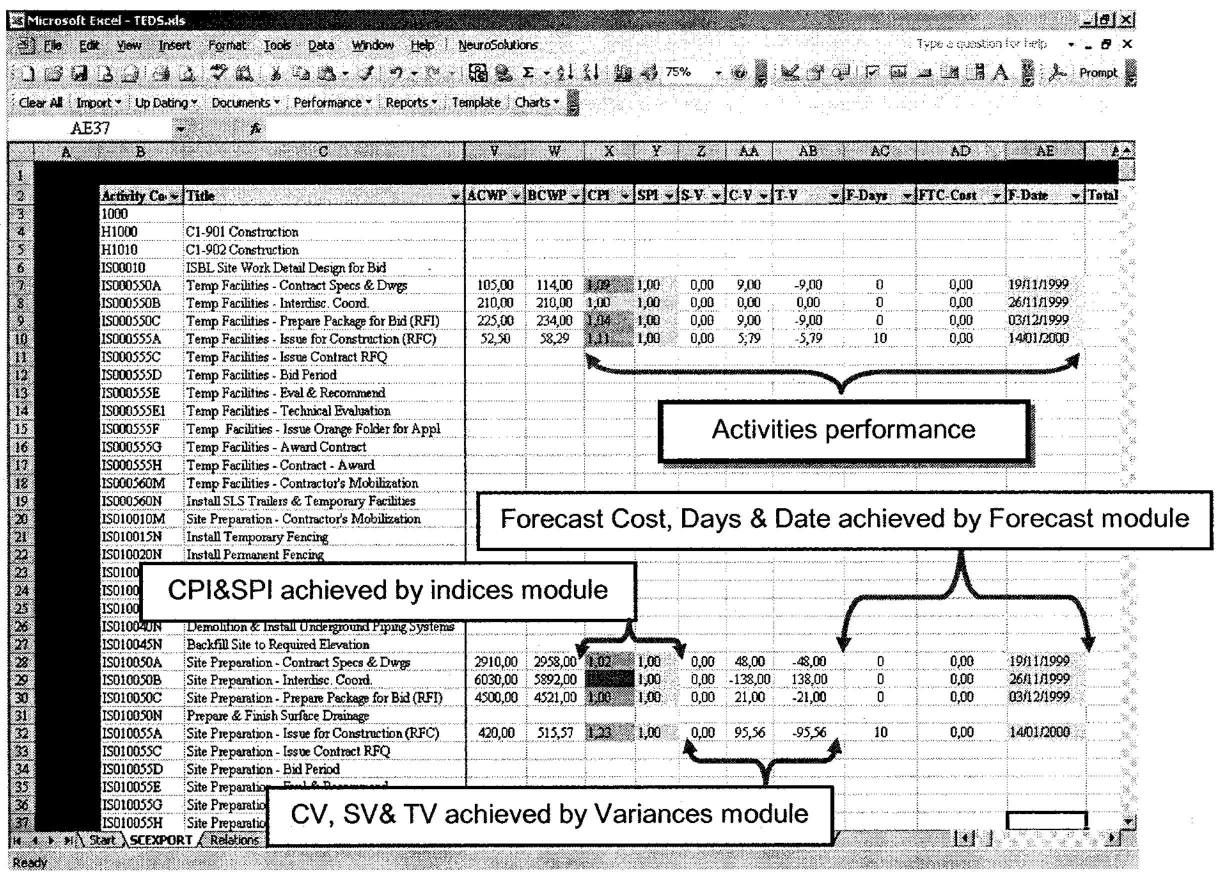


Fig.4. 15 Determining Activities' Performance

The **Report menu** is designed to carry three push-buttons, namely: 1) Impacted Activities; 2) Dynamic; and 3) Periodical. See Fig.4.16. These push-buttons are used to activate the Impacted activities, the Dynamic and the Periodical modules respectively. When Impacted activities button is clicked, the Impacted activities report is generated. When the Dynamic button is clicked, a dynamic report is activated or created if it does not already exist on TEDS. Similarly, when the Periodical button is clicked, a periodical report is activated depicting the status of the project during its lifecycle. Fig 4.17, Fig 4.18 and Fig 4.19 show screens of Impacted Activity, Dynamic and Periodical reports respectively.

The **Template menu** is designed as a push-button that is used to activate database of the progress templates (see Fig.4.3). When the Template button is clicked, a new popup window, namely Templates, which comprises six checkboxes that are linked to the database sheets, appears. When any box is checked, the corresponding database of progress template appears, so the user can add and/or modify its components. Fig.4.20 illustrates the Templates window with its associated checkboxes.

The **Charts menu** is composed of three push-buttons, namely: 1) Dynamic; 2) S-Curve; and 3) CPI/SPI. See Fig. 4.21. These buttons are used to generate activate the Dynamic chart, S-Curve chart and CPI/SPI chart automatically. Fig 4.22(a, b and c) gives snapshots of these charts.

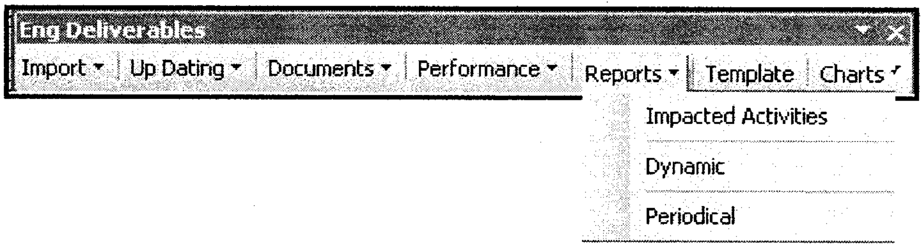
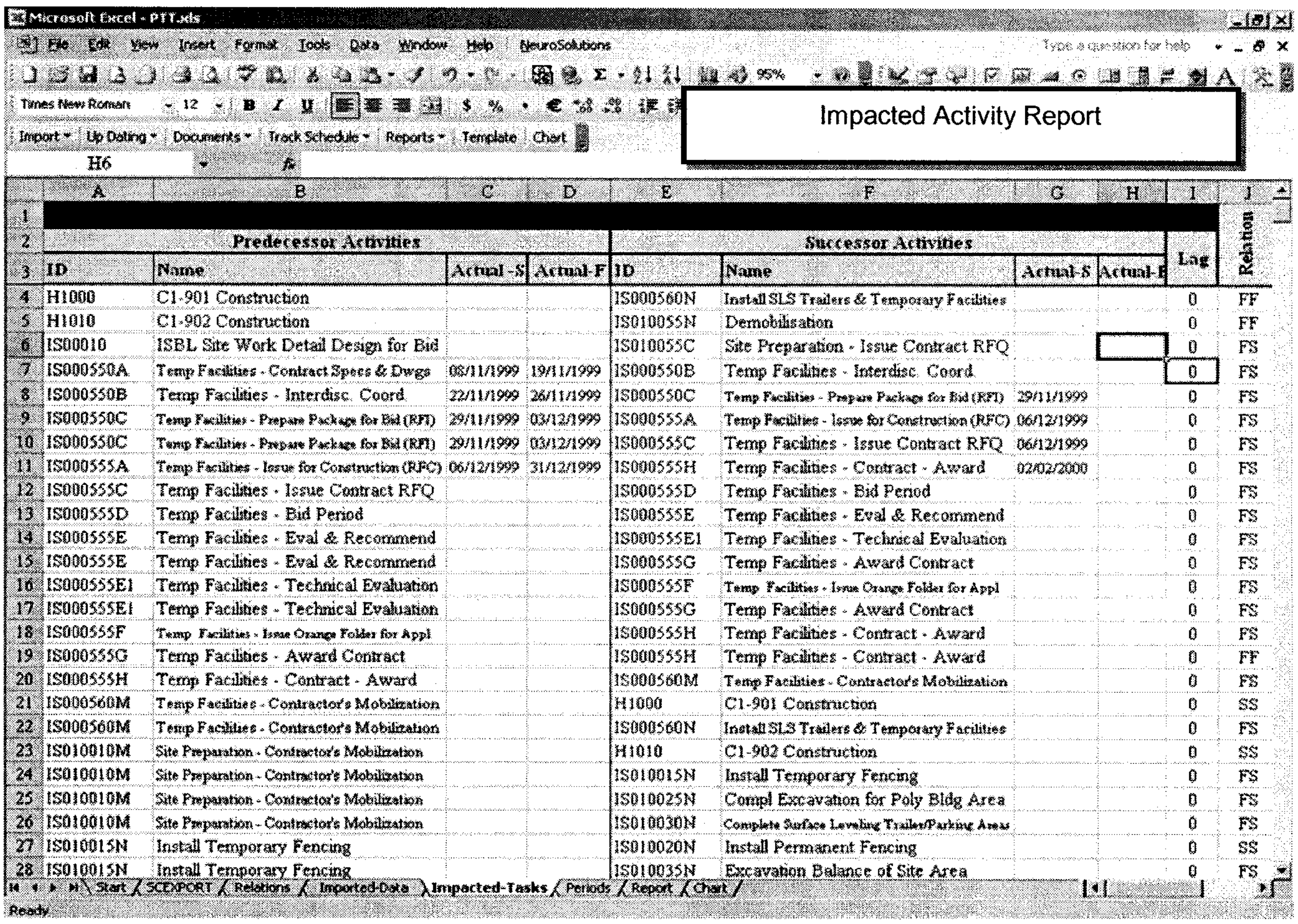


Fig.4. 16 Reports Dropdown Menu



	Predecessor Activities				Successor Activities				Lag	Relation
	ID	Name	Actual -S	Actual-F	ID	Name	Actual-S	Actual-F		
4	H1000	C1-901 Construction			IS000560N	Install SLS Trailers & Temporary Facilities			0	FF
5	H1010	C1-902 Construction			IS010055N	Demobilisation			0	FF
6	IS00010	ISBL Site Work Detail Design for Bid			IS010055C	Site Preparation - Issue Contract RFQ			0	FS
7	IS000550A	Temp Facilities - Contract Specs & Dwgs	08/11/1999	19/11/1999	IS000550B	Temp Facilities - Interdisc. Coord.			0	FS
8	IS000550B	Temp Facilities - Interdisc. Coord.	22/11/1999	26/11/1999	IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	29/11/1999		0	FS
9	IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	29/11/1999	03/12/1999	IS000555A	Temp Facilities - Issue for Construction (RFC)	06/12/1999		0	FS
10	IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	29/11/1999	03/12/1999	IS000555C	Temp Facilities - Issue Contract RFQ	06/12/1999		0	FS
11	IS000555A	Temp Facilities - Issue for Construction (RFC)	06/12/1999	31/12/1999	IS000555H	Temp Facilities - Contract - Award	02/02/2000		0	FS
12	IS000555C	Temp Facilities - Issue Contract RFQ			IS000555D	Temp Facilities - Bid Period			0	FS
13	IS000555D	Temp Facilities - Bid Period			IS000555E	Temp Facilities - Eval & Recommend			0	FS
14	IS000555E	Temp Facilities - Eval & Recommend			IS000555E1	Temp Facilities - Technical Evaluation			0	FS
15	IS000555E	Temp Facilities - Eval & Recommend			IS000555G	Temp Facilities - Award Contract			0	FS
16	IS000555E1	Temp Facilities - Technical Evaluation			IS000555F	Temp Facilities - Issue Orange Folder for Appl			0	FS
17	IS000555E1	Temp Facilities - Technical Evaluation			IS000555G	Temp Facilities - Award Contract			0	FS
18	IS000555F	Temp Facilities - Issue Orange Folder for Appl			IS000555H	Temp Facilities - Contract - Award			0	FS
19	IS000555G	Temp Facilities - Award Contract			IS000555H	Temp Facilities - Contract - Award			0	FF
20	IS000555H	Temp Facilities - Contract - Award			IS000560M	Temp Facilities - Contractor's Mobilization			0	FS
21	IS000560M	Temp Facilities - Contractor's Mobilization			H1000	C1-901 Construction			0	SS
22	IS000560M	Temp Facilities - Contractor's Mobilization			IS000560N	Install SLS Trailers & Temporary Facilities			0	FS
23	IS010010M	Site Preparation - Contractor's Mobilization			H1010	C1-902 Construction			0	SS
24	IS010010M	Site Preparation - Contractor's Mobilization			IS010015N	Install Temporary Fencing			0	FS
25	IS010010M	Site Preparation - Contractor's Mobilization			IS010025N	Compl Excavation for Poly Bldg Area			0	FS
26	IS010010M	Site Preparation - Contractor's Mobilization			IS010030N	Complete Surface Leveling Trailer/Parking Areas			0	FS
27	IS010015N	Install Temporary Fencing			IS010020N	Install Permanent Fencing			0	SS
28	IS010015N	Install Temporary Fencing			IS010035N	Excavation Balance of Site Area			0	FS

Fig.4. 17 Impacted Activity Report Screen

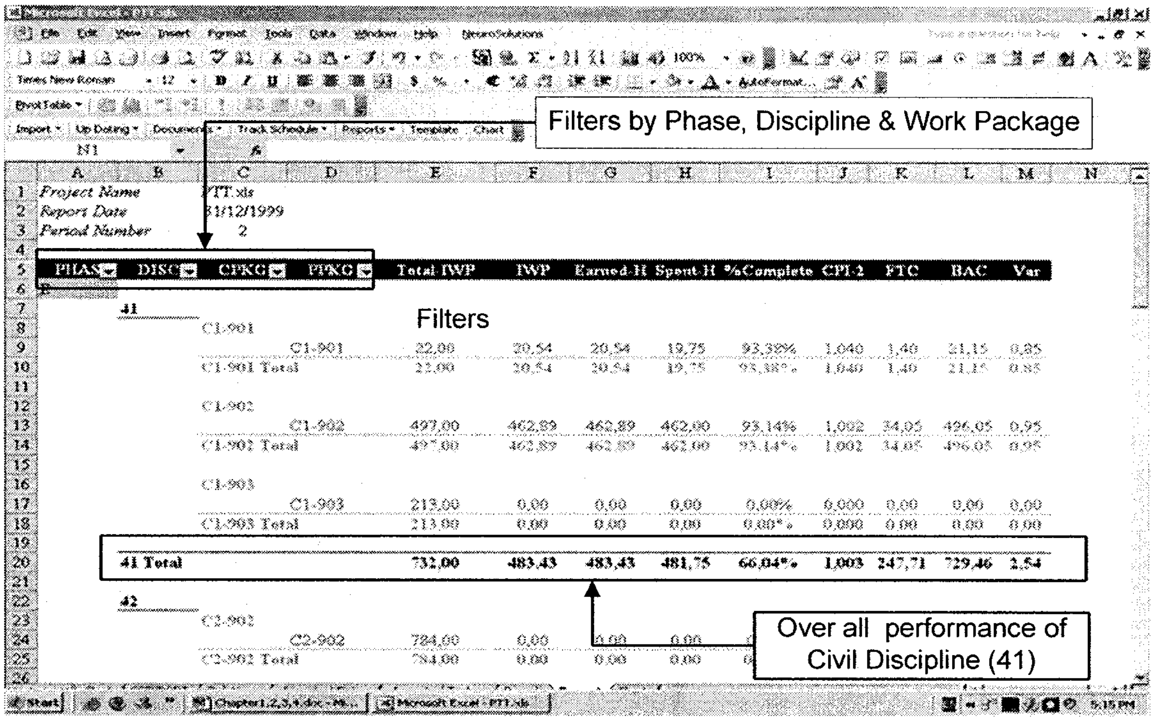


Fig.4. 18 Dynamic Report Screen

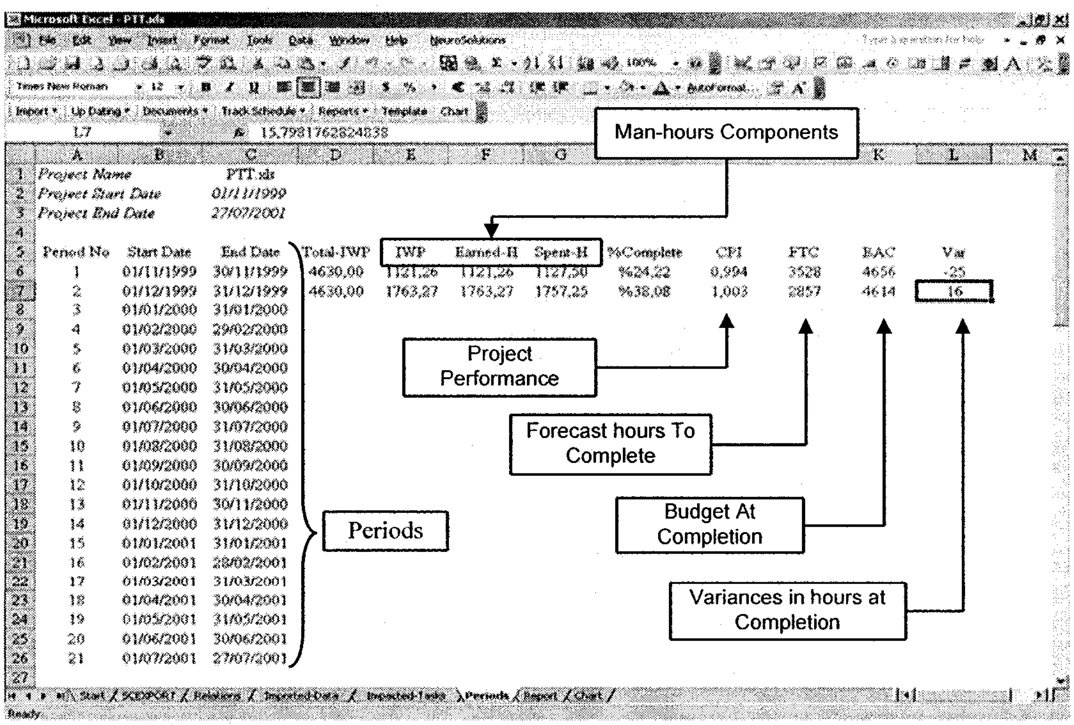


Fig.4. 19 Periodical Report Screen

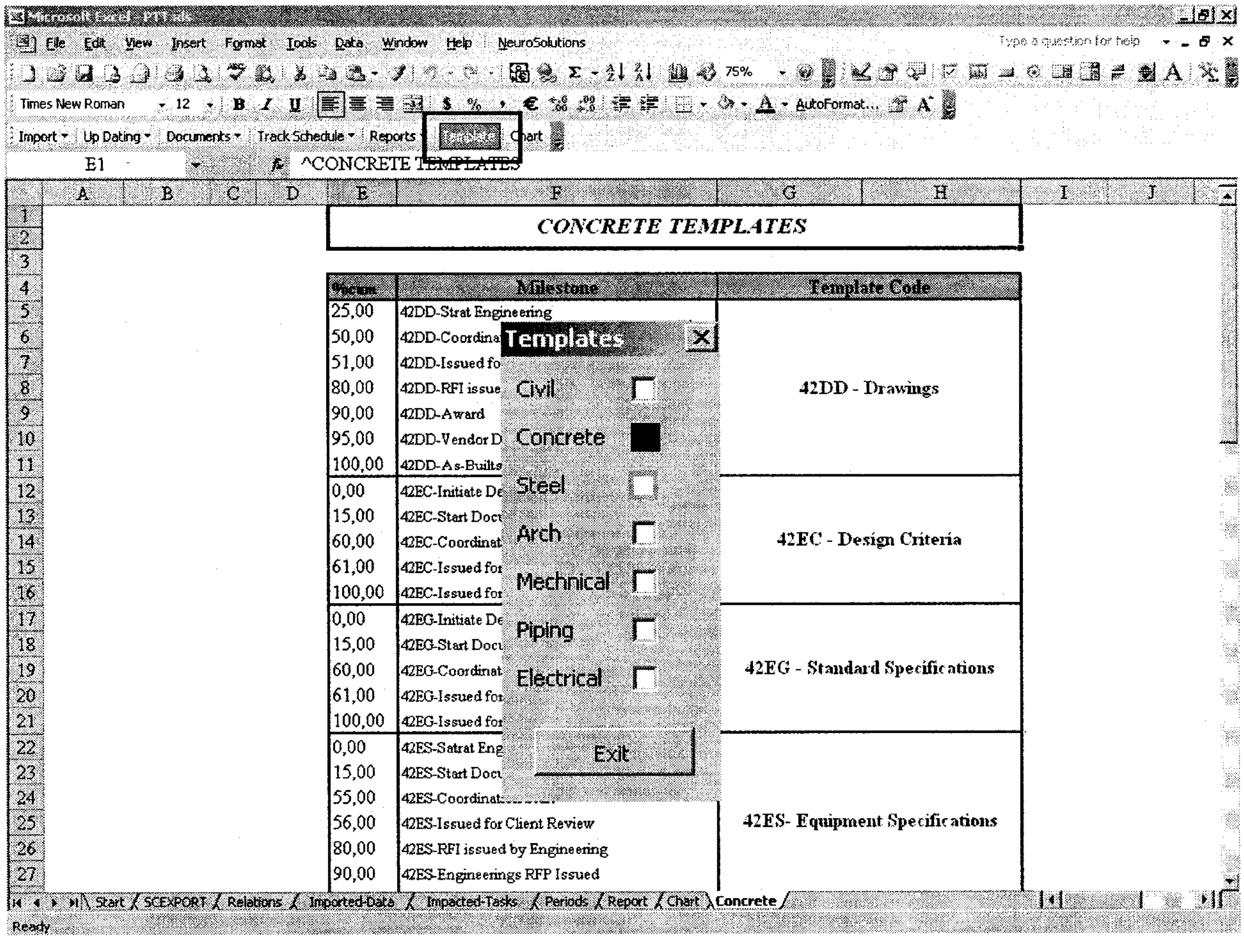


Fig.4. 20 Progress Templates Database Screen

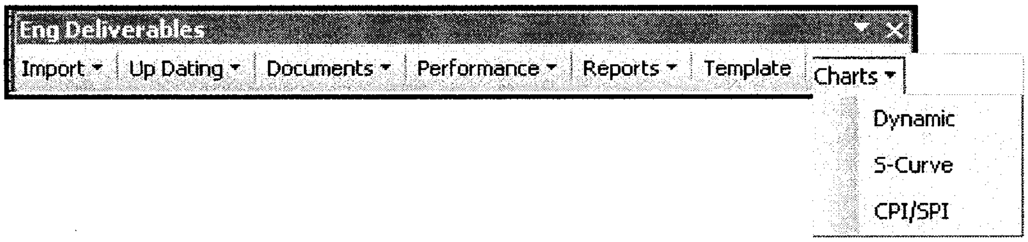
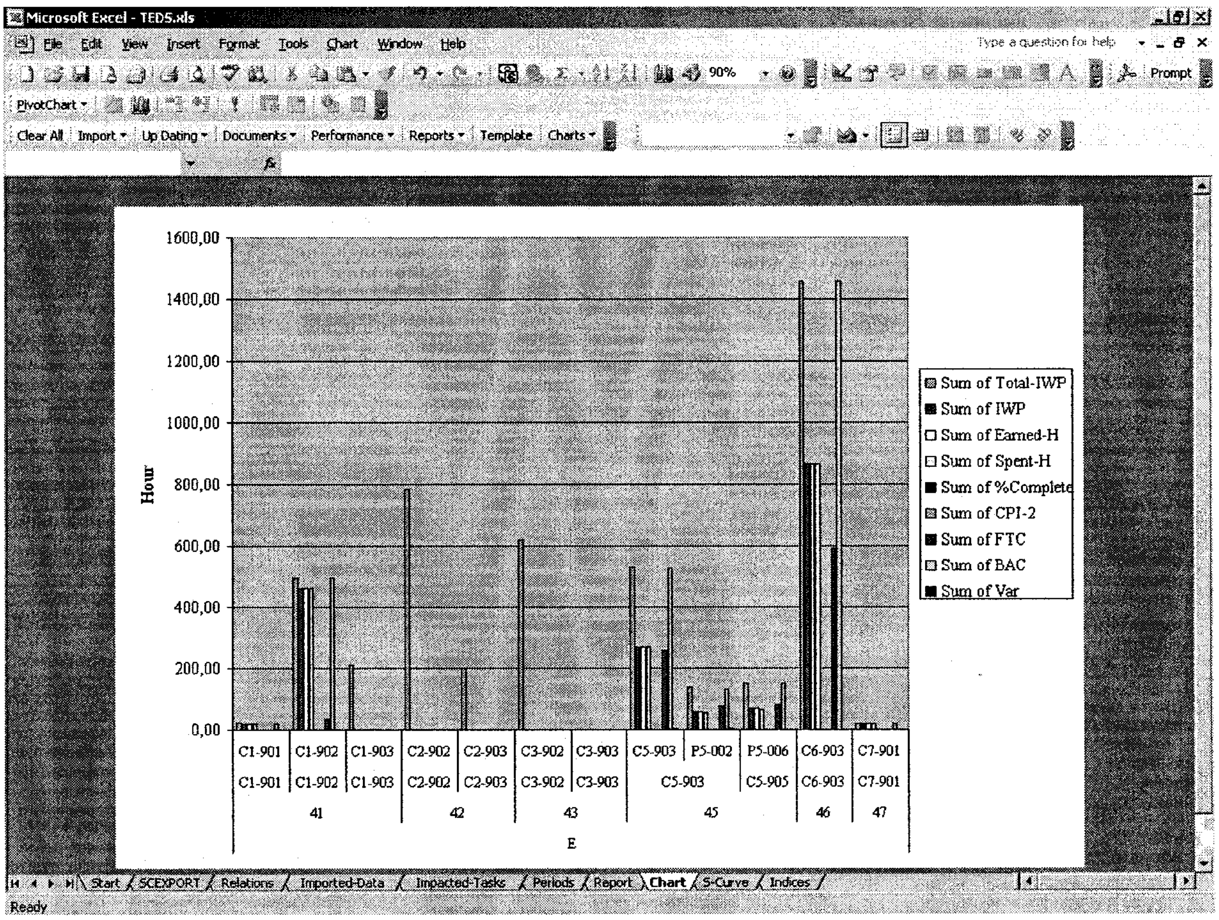
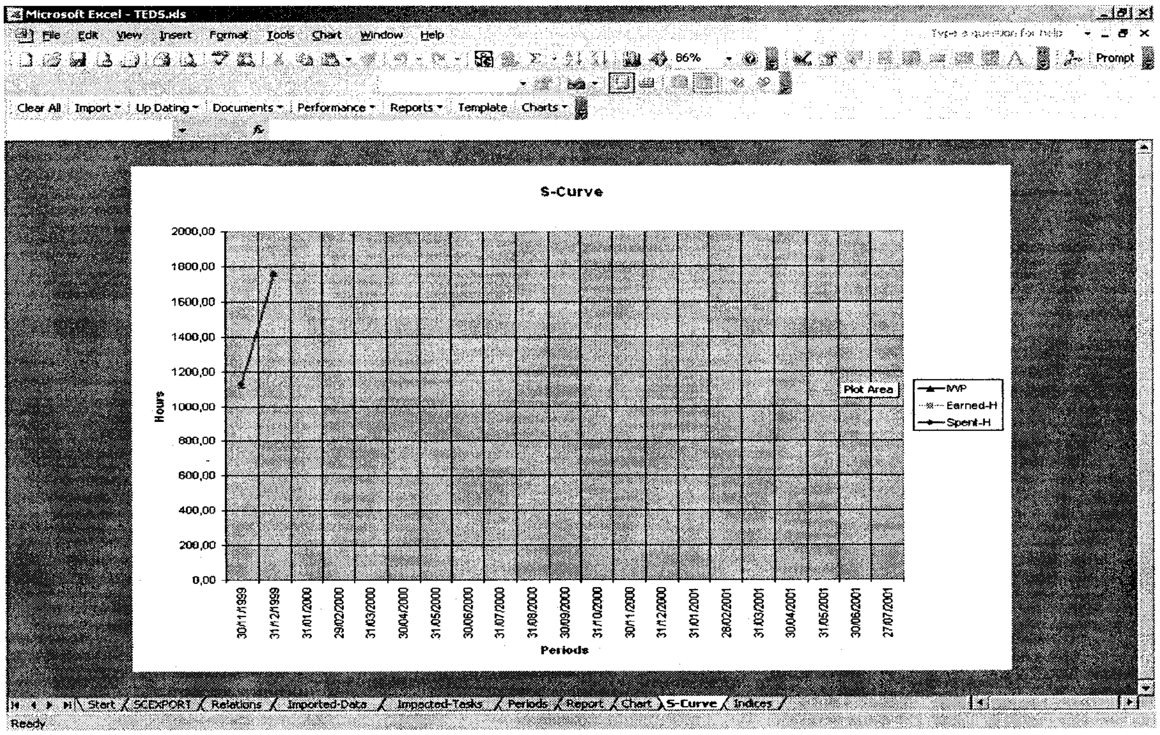


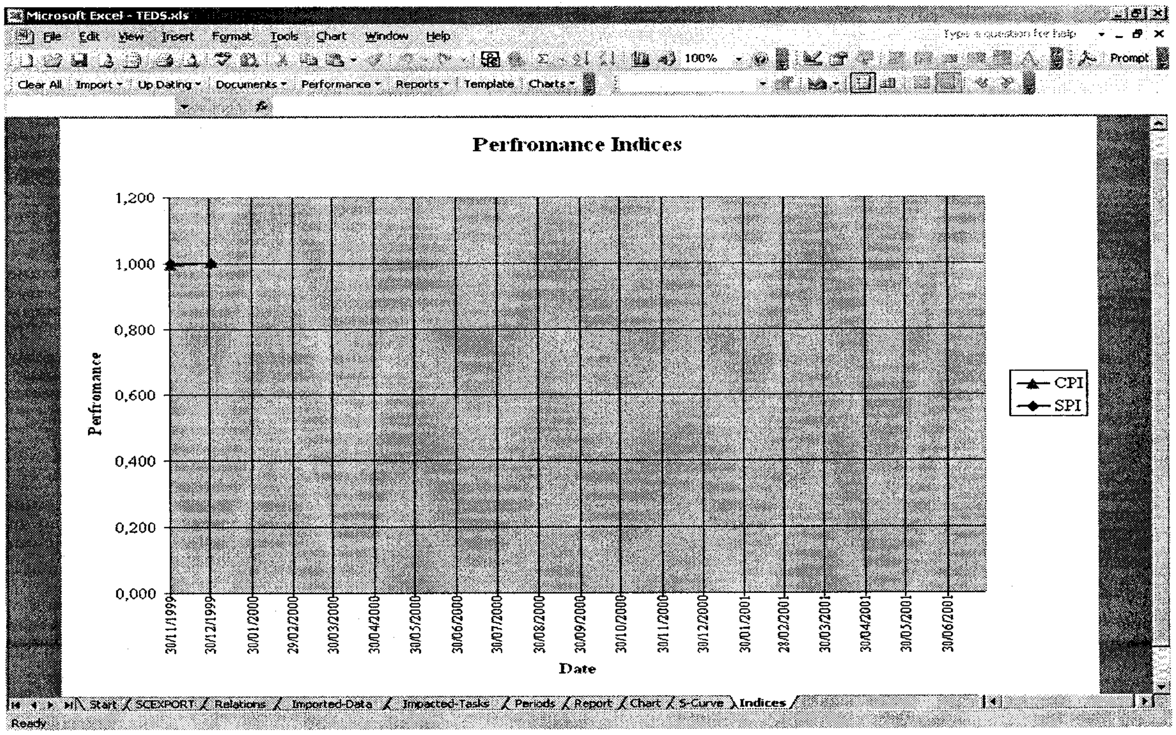
Fig.4. 21 Charts Dropdown Menu



(a) Dynamic Report Chart



(b) S-Curve Chart



(c) Performance Indices Chart

Fig.4. 22 (a, b, c) Charts Reports Screens

4.8 Validation and System's Limitations

A set of training data, which was extracted from an actual project proposed by an industrial partner, is used as a case study to validate the functionality and accuracy of the developed system. The case study is focused primarily on the management of the engineering deliverables in the engineering phase of an EPCM project. This case study is presented in chapter 5. The developed Excel sheet, TEDS, has a number of limitations as follows:

1- The system can operate up to 700 activities in the project schedule.

2- It is limited to the direct cost associated with the engineering deliverables; other costs such as those of the supervision and supporting services are not taken into account.

3- The system is limited to one type of inter-dependence relation which is Start-to-Finish.

4- The scope change, errors and omissions, and re-design are not taken into consideration by the system.

5- The crews' responsibilities and the cost for the crews are not taken into account by the system.

4.9 Summary

This chapter has described the selected criteria for the development of **TEDS**. It has also demonstrated the implementation of the proposed system utilizing Microsoft® Excel sheet 2003 in a Microsoft® Windows XP environment. The system's structure has been illustrated, along with a full explanation of its embedded modules. Then, it shows how data is processed on the system. A number of reports and their output have then been pointed out. Following this, a description of the **TEDS's** toolbar with its menus and samples of screens have been illustrated. The limitations of the developed system have been pointed out.

Chapter V – Case Study

5.1 General

The case study utilized in this thesis was developed collaboratively with the industrial partner, SNC-LAVALIN. It was used in this research to validate and demonstrate the uses of the developed system (**TEDS**). It involves the planning and scheduling of an EPCM training project that has a budget of CA$ 20 millions and a duration of 545 days. It should be mentioned that the utilized training data was extracted from a real project and modified for confidentiality purpose. The training project was named "Poly", which comprises 75 commitment packages that cover the direct and indirect costs of the entire training project. To simplify data processing in the case study, only 12 commitment packages have been chosen to be processed using two scenarios (See Fig.5.5). The selection of these commitment packages was for two reasons: 1) to maintain the logical order of the project execution and 2) to demonstrate different disciplines. The total number of internal work hours of all deliverables in the selected commitment packages is 4630 hours. These two scenarios were created using the selected 12 commitment packages, and were then analyzed using **TEDS** and the in house software system of the industrial partner, SNC-LAVALIN, which will be referred to later as **PM+**. It should be mentioned that description of **PM+** is presented in chapter 2, section 2.6.

5.2 Project Description and Characteristics

The source project involved the construction of an industrial plant that produces 300 metric tonne per day of PTT in Montreal, Quebec. PTT is an innovative polyester polymer used for the production of fibres and yarns that are used to enhance the properties of carpets, textiles, clothing, etc. The plant includes two main areas: In Side Battery Limit (ISBL) the process area, which was excluded from the case study, and Out Side Battery Limit (OSBL), which includes: PTA Unloading, PDO Unloading and Storage, PTT loading, Waste Water Treatment, Infrastructure and Utilities. Fig.5.1 and Fig.5.2 depict general layout of the PTT project and its components.

SNC-Lavalin mandate was to provide services up to mechanical completion as follows:

- Overall Project Management.
- Detailed Engineering of OSBL.
- Supply of OSBL Equipments and Materials.
- Construction Management.

<u>Project Characteristics</u>

- **Engineering**
    - Deliverables: drawings, specifications, calculation sheets
    - Contractor/vendor documents review
    - Administrative tasks: management, secretarial, visits
- **Procurement**

- Purchasing, contract administration, expediting, logistic

- **Construction**
  - Management, site engineering, contract administration, progress reporting
  - Tie-ins, commissioning

- **Management**
  - Reporting, meetings, project controls

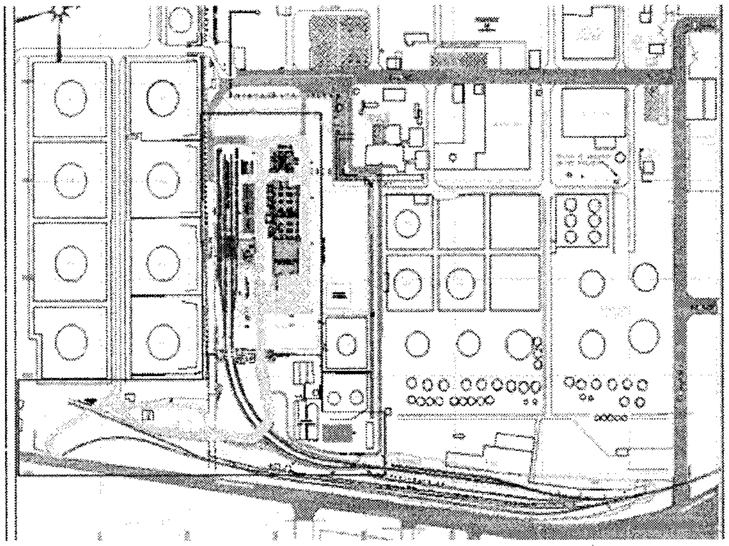


Fig.5. 1 Key Plan of Poly project (SNC-LAVALIN 2006)

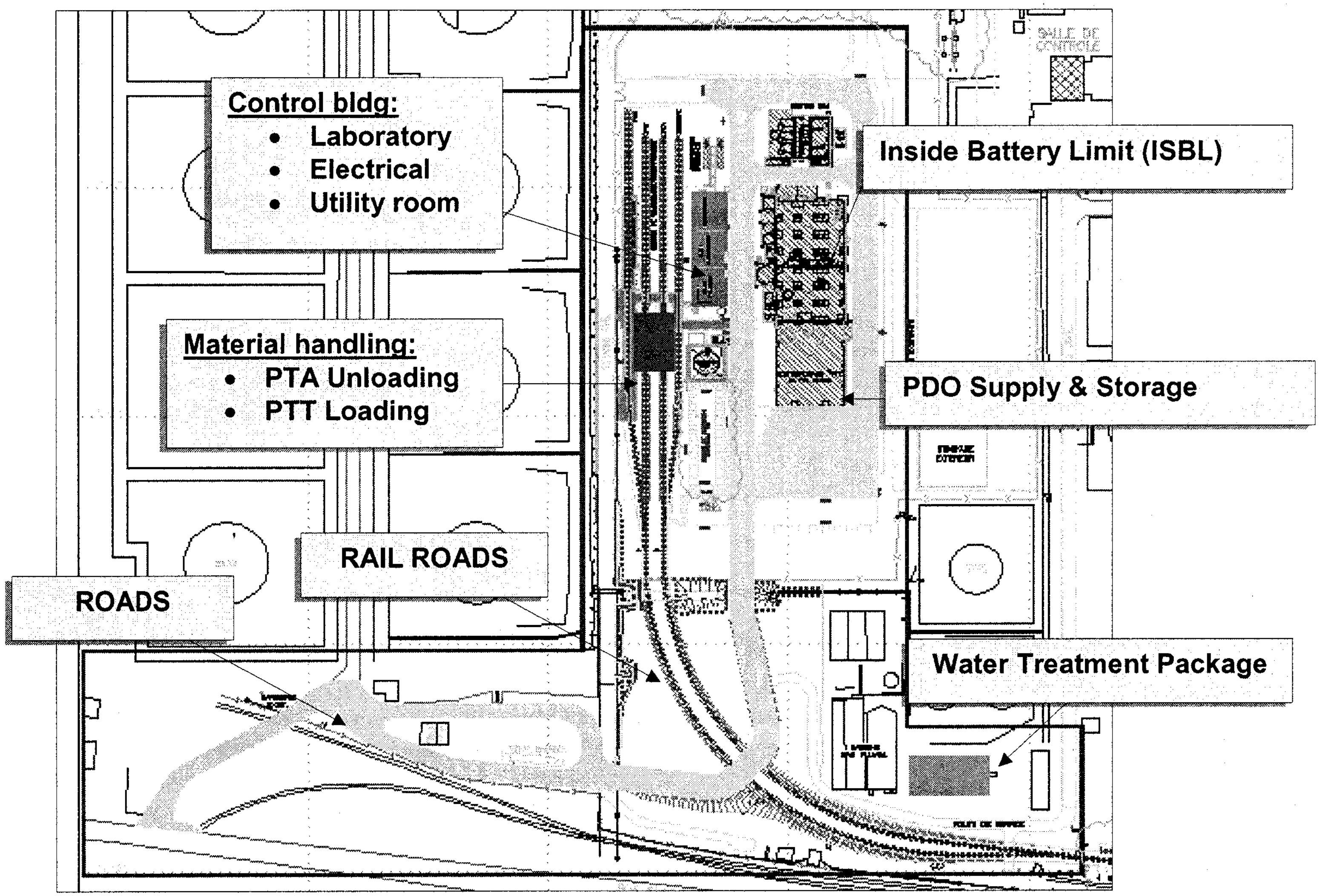


Fig.5. 2 General Layout of Poly Project (Training) (SNC-LAVALIN 2006)

5.3 Project Work Breakdown Structure

The work breakdown structure (WBS) is used to assist in planning and budgeting functions. The project was broken down into four main levels to identify the project components and to describe the work effort required to accomplish the project objectives. Fig. 5.3 depicts the four levels used in the project. Fig.5.4. illustrates the "coding structure" of the project in PM+. Another form of WBS, which is shown in Fig. 5.5, was developed to demonstarte the selected commitment packages utilized in this thesis.

WBS Levels

- Level 1 :Overall Project
- Level 2 : Project Costs (Direct, Indirect and Owner Costs).
- Level 3 : Inside Battery Limit, OutsideBattery Limit, and Indirect Costs.
- Level 4 : Detailed works related to each level.

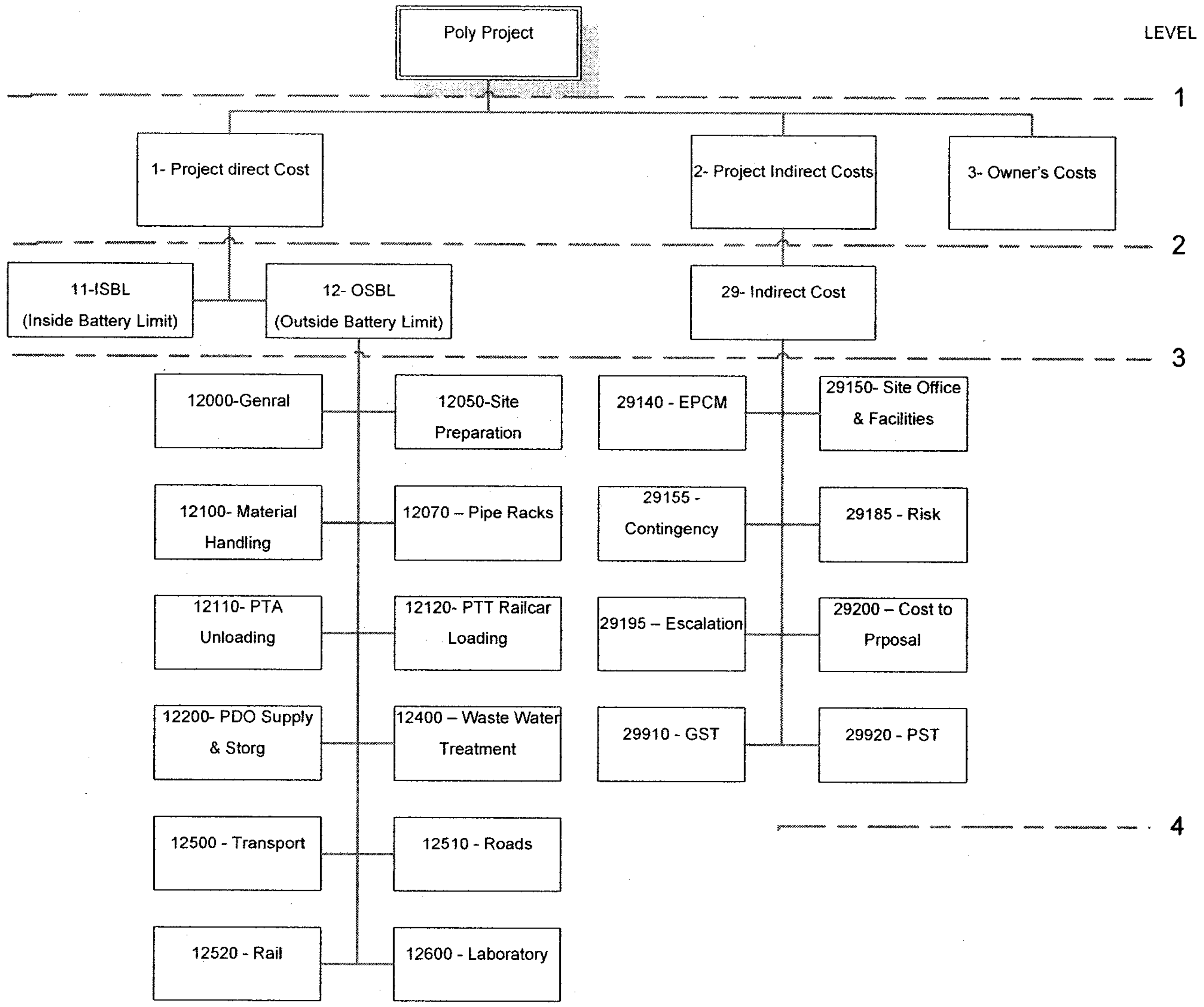
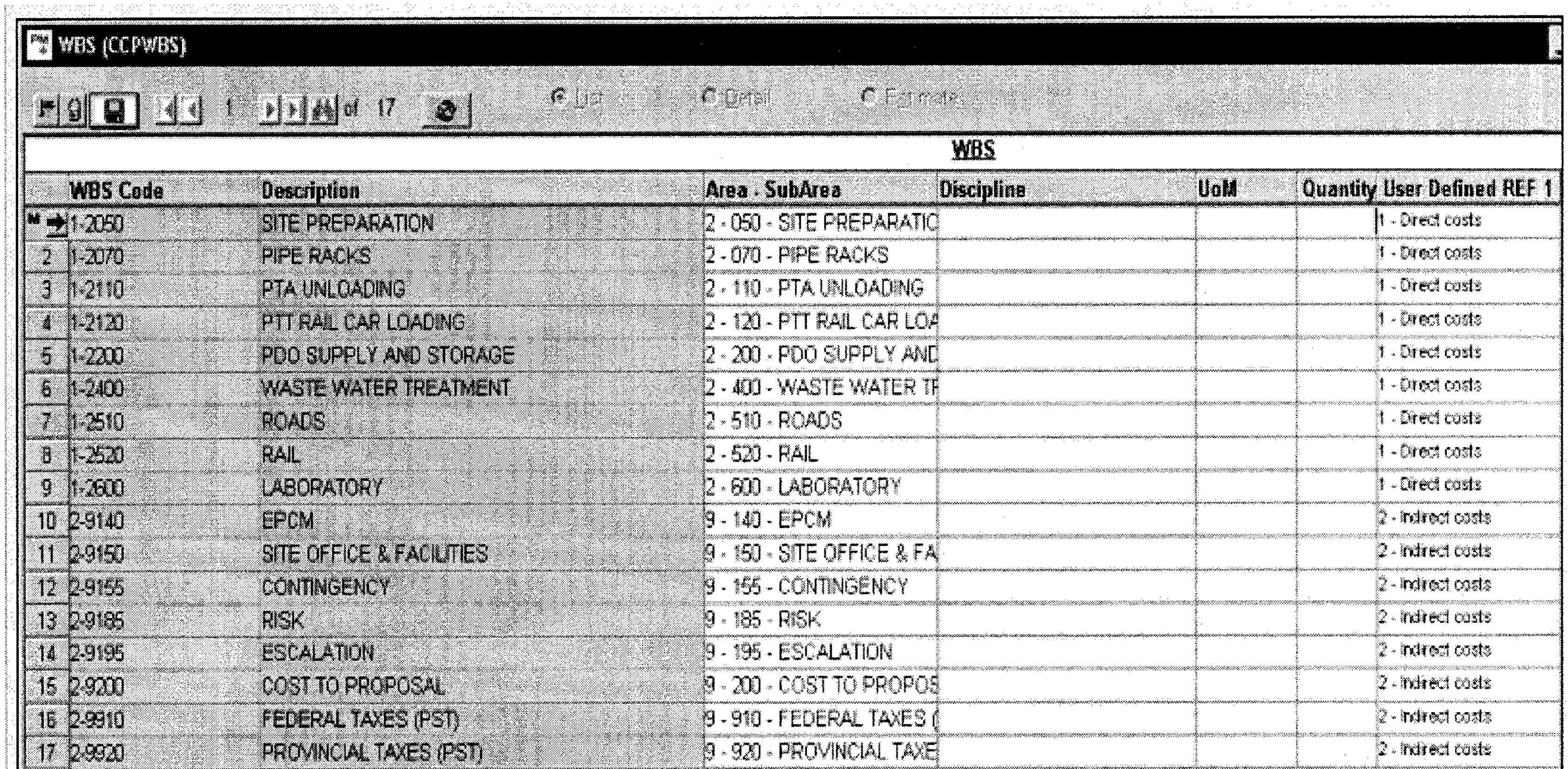


Fig.5. 3 WBS of the Poly Project (Training) (SNC-LAVALIN 2006)



WBS (CCPWBS)

1 of 17 — List / Detail / Estimate

WBS

	WBS Code	Description	Area . SubArea	Discipline	UoM	Quantity	User Defined REF 1
	1-2050	SITE PREPARATION	2 - 050 - SITE PREPARATIC				1 - Direct costs
2	1-2070	PIPE RACKS	2 - 070 - PIPE RACKS				1 - Direct costs
3	1-2110	PTA UNLOADING	2 - 110 - PTA UNLOADING				1 - Direct costs
4	1-2120	PTT RAIL CAR LOADING	2 - 120 - PTT RAIL CAR LOA				1 - Direct costs
5	1-2200	PDO SUPPLY AND STORAGE	2 - 200 - PDO SUPPLY AND				1 - Direct costs
6	1-2400	WASTE WATER TREATMENT	2 - 400 - WASTE WATER TF				1 - Direct costs
7	1-2510	ROADS	2 - 510 - ROADS				1 - Direct costs
8	1-2520	RAIL	2 - 520 - RAIL				1 - Direct costs
9	1-2600	LABORATORY	2 - 600 - LABORATORY				1 - Direct costs
10	2-9140	EPCM	9 - 140 - EPCM				2 - Indirect costs
11	2-9150	SITE OFFICE & FACILITIES	9 - 150 - SITE OFFICE & FA				2 - Indirect costs
12	2-9155	CONTINGENCY	9 - 155 - CONTINGENCY				2 - Indirect costs
13	2-9185	RISK	9 - 185 - RISK				2 - Indirect costs
14	2-9195	ESCALATION	9 - 195 - ESCALATION				2 - Indirect costs
15	2-9200	COST TO PROPOSAL	9 - 200 - COST TO PROPOS				2 - Indirect costs
16	2-9910	FEDERAL TAXES (PST)	9 - 910 - FEDERAL TAXES (				2 - Indirect costs
17	2-9920	PROVINCIAL TAXES (PST)	9 - 920 - PROVINCIAL TAXE				2 - Indirect costs

Fig.5. 4 WBS Code in PM+ (SNC-LAVALIN 2006)

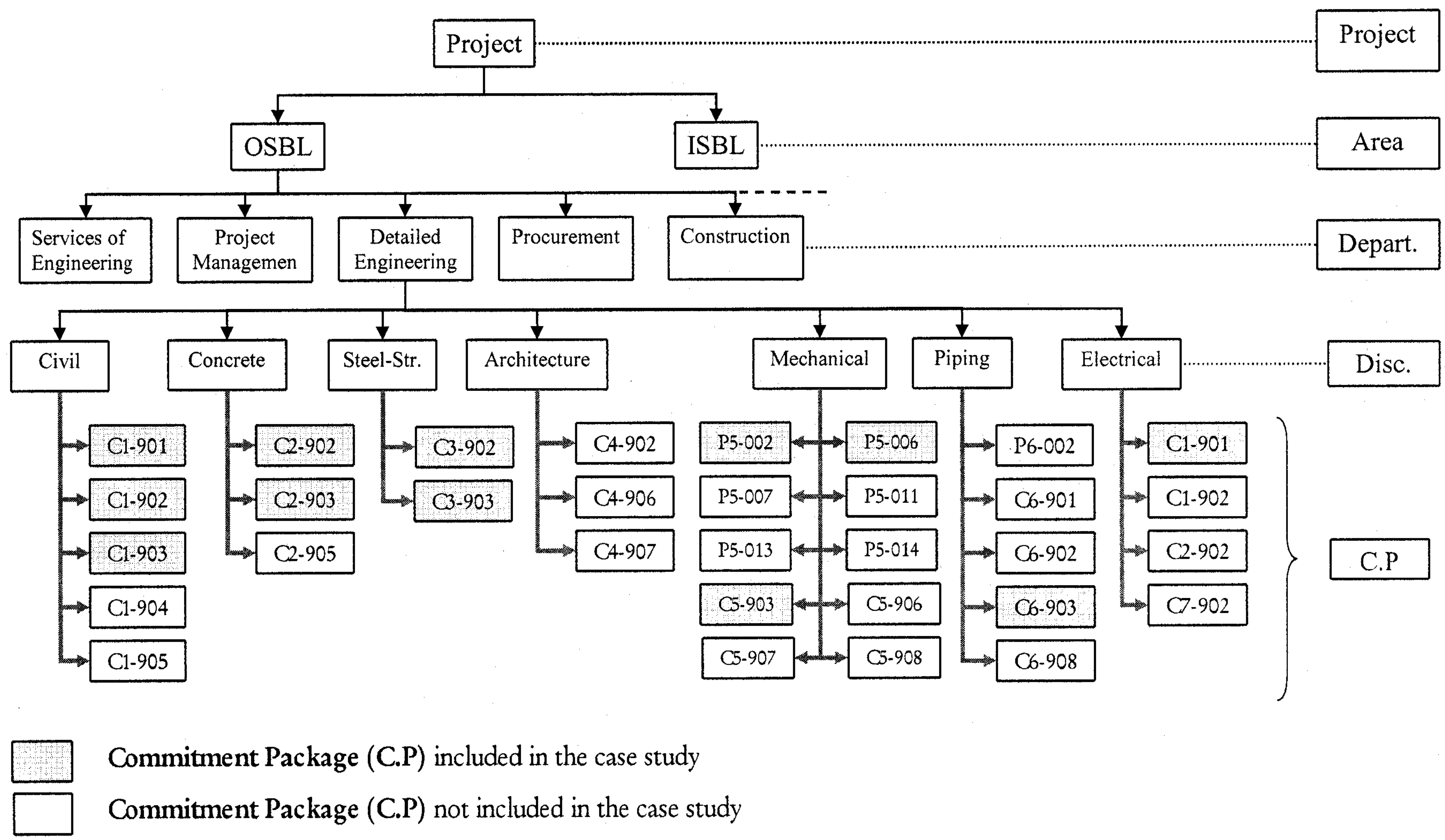


Fig.5. 5 Detailed WBS of the Poly Project (Training)

5.4 Commitment Packages

A commitment package is used to describe the work in detail. "It is a planned or pre-award grouping of tasks or acquisitions in order to define the method of execution of the work, especially as related to the supplier and subcontractor marketplaces for a given project. Eventually, these packages become post-award commitments, purchase orders or contracts" (Bebawi 2006). Fig. 5.6 depicts the structure of a commitment package. A dictionary is used to describe each commitment package in detailed (see Fig. 5.7). The dictionary consists of the following items: 1) commitment package number; 2) commitment package description; 3) scope of work (including and excluding); 4) associated contracts; and 5) milestones.

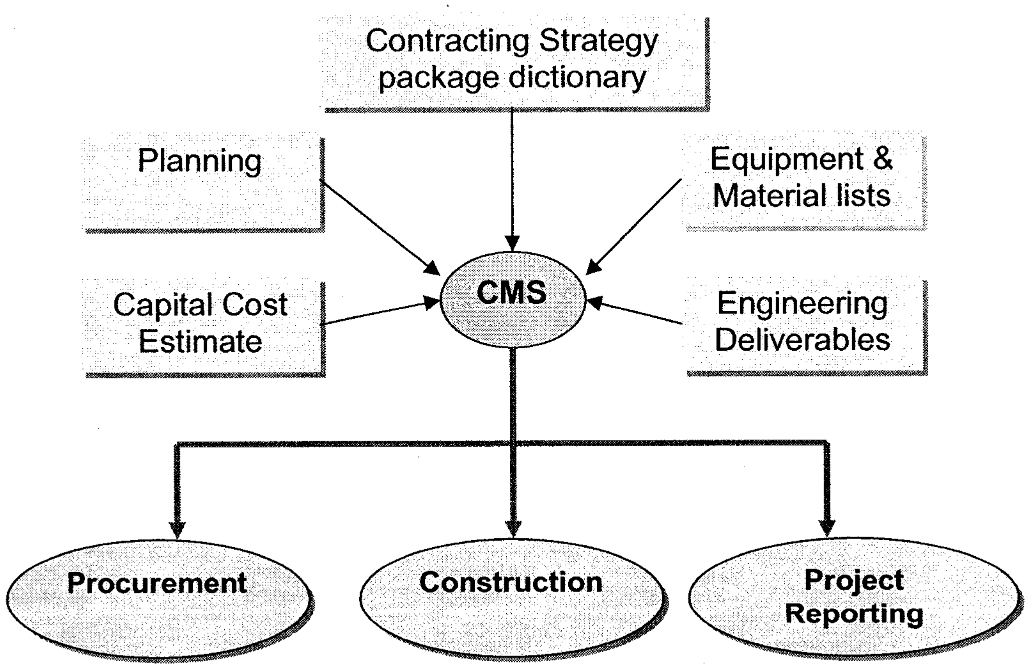


Fig.5. 6 Commitment Packages Structure (Bebawi 2006)

SNC • LAVALIN	Project # and Name	CP #:		
	Package Dictionary	Rev.	Date	Page
		00	99/12/01	1/1

CP Description :

Discipline :	Civil	Currency:	CAD
Administrator:		Engineer:	
Quality Assurance :		Purchaser:	

Scope:

Included	
Excluded	
Transfers	

Associated Internal Work Package (IWP):

Disc.		**No**		**Name**	
Disc.		**No**		**Name**	
Disc.		**No**		**Name**	

Associated PO / Contract:

No		Name	
VDR / Contractor			
No		Name	
VDR / Contractor			

Milestones:

	Planned	Forecast	Actual		Planned	Forecast	Actual
Start Eng.	08 Nov 99			Del. Start			
RFI	03 Dec 99			Del. Complete			
Award	05 Jan 00			Const. Start	17 Jan 00		
				Const. Complete	04 Apr 00		

Fig.5. 7 Commitment Package Dictionary (Bebawi 2006)

5.5 Organizational Structure

Fig.5.8 shows the Project organizational Breakdown Structure (OBS) while Fig.5.9 depicts logging OBS in PM+.

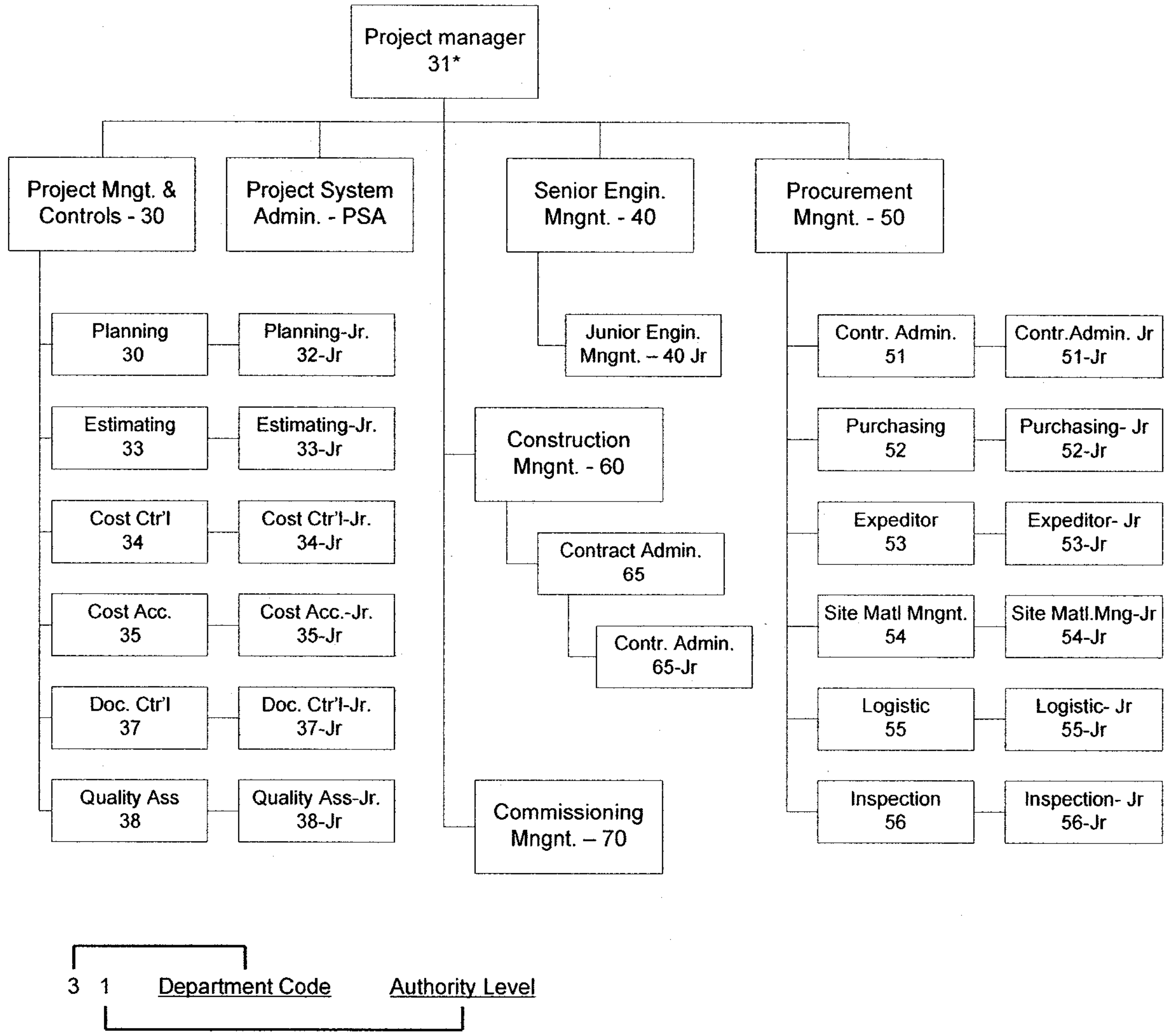
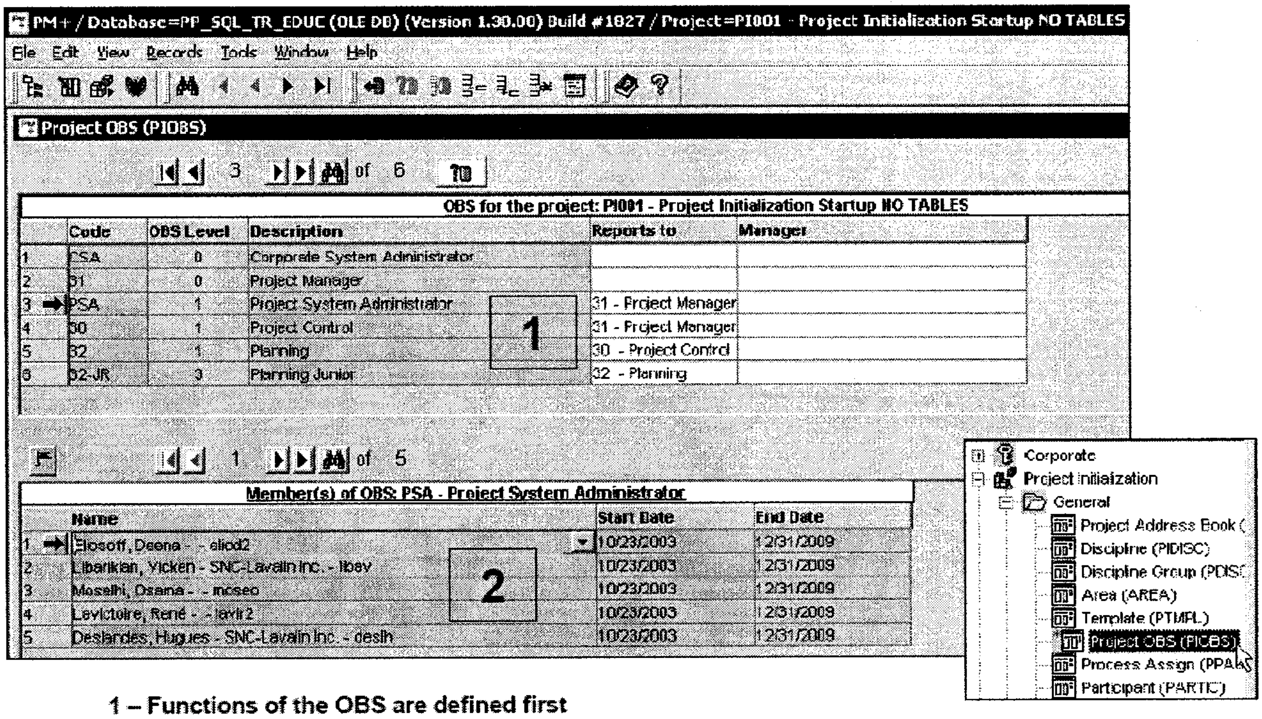


Fig.5. 8 OBS of the Poly Project (SNC-LAVALIN 2006)



1 – Functions of the OBS are defined first

2 – Members of the project team are associate to the OBS secondly

Fig.5. 9 Coding OBS in PM+ (SNC-LAVALIN 2006)

5.6 Coding Structure

Coding structure is the process of coding the project in PM+ in terms of alphanumeric data. It is divided by types into seven categories as shown in Fig. 5.10; each type has its length. For instance, the coding structure for documents (technical) is divided into 3 categories. Each category has a label and a length.

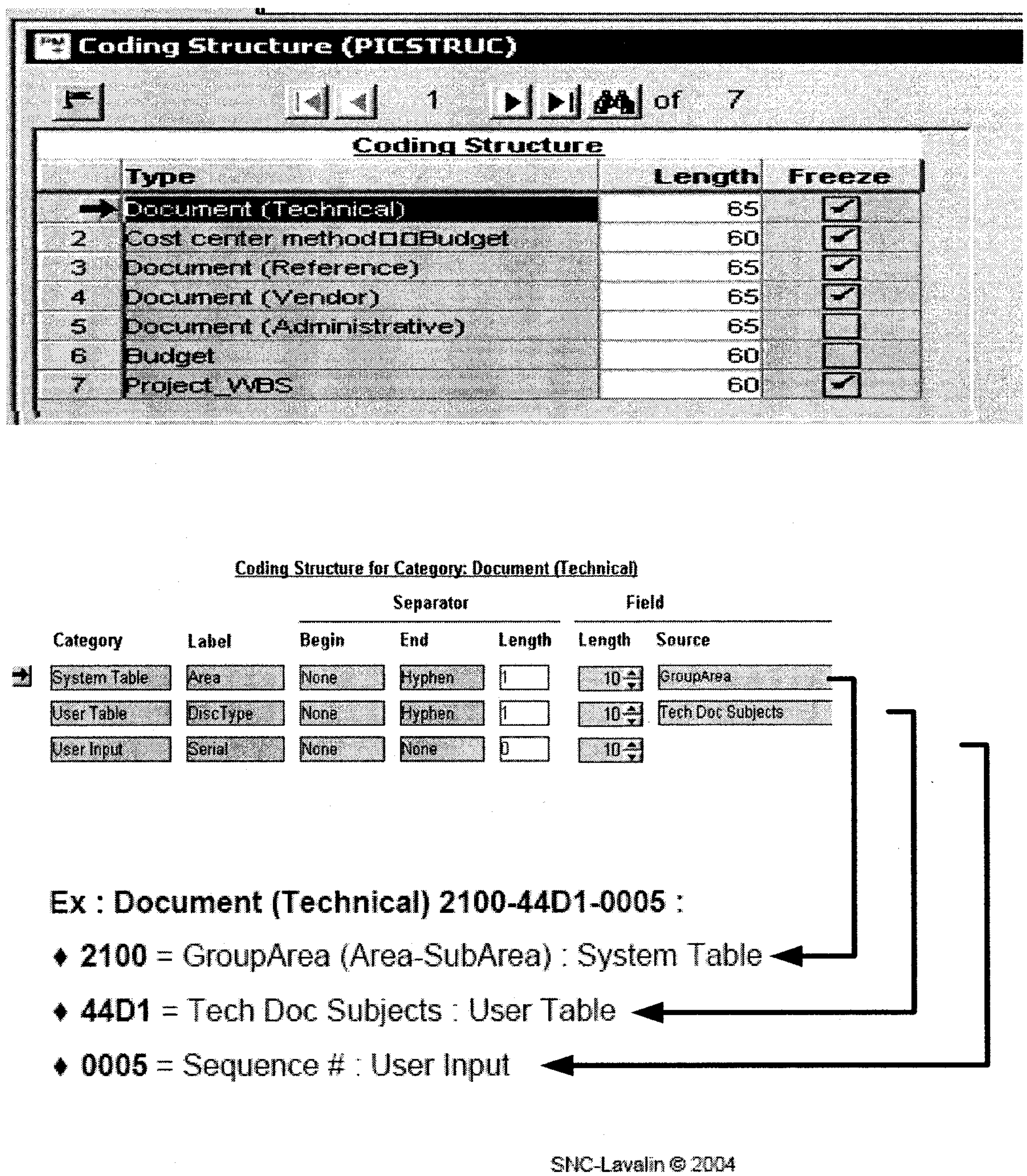


Fig.5. 10 Coding Structure in PM+ (SNC-LAVALIN 2006)

5.7 Project Schedule

The project network schedule and its bar chart representation were extracted from the as-planned schedule for the selected commitment packages. The total number of activities in the project schedule is 175. Fig. 5.11 depicts snapshot of the project schedule extracted from Primavera Project Planner (P3).

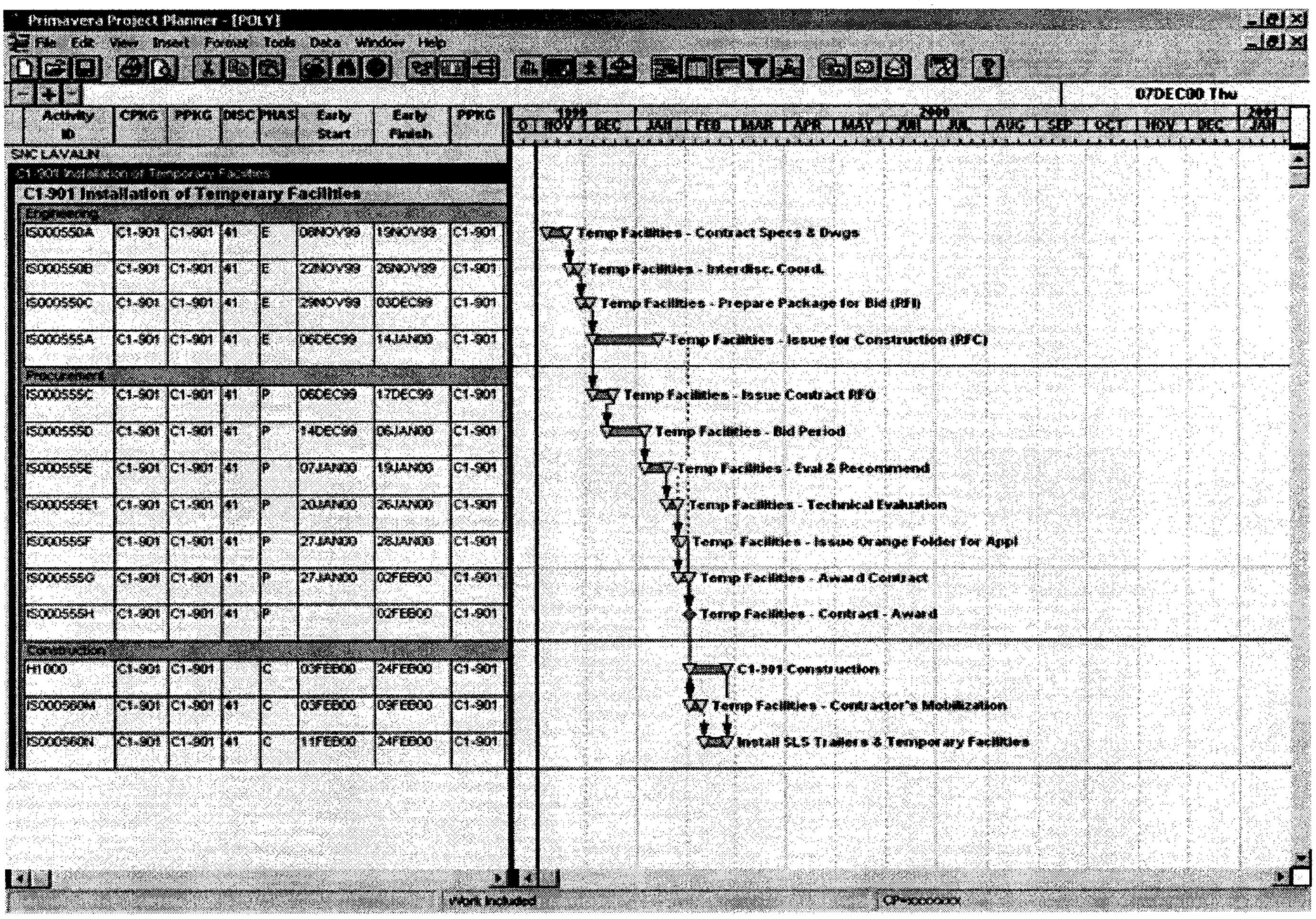


Fig.5. 11 Schedule of Training Project (Poly) (SNC-LAVALIN 2006)

5.8 Input Data Preparation

The required data is keyed into **TEDS** in two stages as stated earlier in Section 3.3. In the first stage, i.e. the planning phase, project schedule and its activity relationships files are exported from Primavera Project Planner (P3) to a transition directory; and then they are imported automatically into TEDS. Table 5.1 and Table 5.2 demonstrate a sample of the project schedule and activity relationships files respectively. Next, a unique document sheet that includes a number of deliverables is created for each commitment package. Identification of each deliverable requires that certain data be entered into it. This data includes the following: description, total internal work hours, and associated progress template. This information was extracted from **PM+** and keyed into **TEDS** (See Table 5.3). The second stage, the execution phase, is to record the progress of work in every deliverable in each commitment package on both models **PM+** and **TEDS**. Whereas recording the progress for every deliverable in PM+ can be accomplished by selecting "percentage complete" from the progress templates or by issuing transmittal document from the document control module, recording the progress for every deliverable in TEDS is accomplished by selecting "percentage complete" from the progress templates.

Table 5. 1 Project Schedule File

Activity ID	TITLE	Early Start	Actual Start	Early Finish	Actual Finish	Original Duration	AREA	PHASE	DISC	CPKG
IS00010	ISBL Site Work Detail Design for Bid	08/11/99		03/12/99		20	I	E	41	C1-902
IS000550A	Temp Facilities- Contract Specs & Drawing	08/11/99		19/11/99		10	I	E	41	C1-901
IS000550B	Temp Facilities- Internal Coordination.	22/11/99		26/11/99		5	I	E	41	C1-901
IS000550C	Temp Facilities - Prepare Package for Bid	29/11/99		03/12/99		5	I	E	41	C1-901
IS000555A	Temp Facilities - Issue for Construction	06/12/99		14/01/00		30	I	E	41	C1-901
IS000555C	Temp Facilities - Issue Contract RFQ	06/12/99		10/12/99		5	I	P	41	C1-901
IS000555D	Temp Facilities - Bid Period	13/12/99		06/01/00		19	I	P	41	C1-901
IS000555E	Temp Facilities - Eval & Recommend	07/01/00		19/01/00		9	I	P	41	C1-901
IS000555E1	Temp Facilities - Technical Evaluation	20/01/00		26/01/00		5	I	P	41	C1-901
IS000555F	Temp Facilities - Issue Orange Folder	27/01/00		28/01/00		2	I	P	41	C1-901
IS000555G	Temp Facilities - Award Contract	27/01/00		02/02/00		5	I	P	41	C1-901
IS000555H	Temp Facilities -Contract - Award			02/02/00		0	I	P	41	C1-901
IS000560M	Temp Facilities -Contractor's Mobilization	03/02/00		09/02/00		5	I	C	41	C1-901
IS000560N	Install SLS Trailers & Temporary Facilities	11/02/00		24/02/00		10	I	C	41	C1-901
IS010010M	Site Preparation - Contractor's Mobilization	17/01/00		21/01/00		5	I	C	41	C1-902
IS010015N	Install Temporary Fencing	24/01/00		28/01/00		5	I	C	41	C1-902

Table 5. 2 Activity Relationships File

No	Activity ID	Successor	Lag	Relation
1	H1000	IS000560N	0	FF
2	H1010	IS010055N	0	FF
3	IS00010	IS010055C	0	FS
3	IS000550A	IS000550B	0	FS
4	IS000550B	IS000550C	0	FS
5	IS000550C	IS000555A	0	FS
6	IS000550C	IS000555C	0	FS
7	IS000555A	IS000555H	0	FS
8	IS000555C	IS000555D	0	FS
9	IS000555D	IS000555E	0	FS
10	IS000555E	IS000555E1	0	FS
11	IS000555E	IS000555G	0	FS
12	IS000555E1	IS000555F	0	FS
13	IS000555E1	IS000555G	0	FS
14	IS000555F	IS000555H	0	FS
15	IS000555G	IS000555H	0	FF
16	IS000555H	IS000560M	0	FS
17	IS000560M	H1000	0	SS
18	IS000560M	IS000560N	0	FS
19	IS010010M	H1010	0	SS
20	IS010010M	IS010015N	0	FS
21	IS010010M	IS010025N	0	FS
22	IS010010M	IS010030N	0	FS
23	IS010015N	IS010020N	0	SS
24	IS010015N	IS010035N	0	FS
25	IS010020N	IS010030N	0	FF
26	IS010030N	IS000560N	4	FS
27	IS010030N	IS010040N	0	FS

Table 5. 3 List of Documents in CP: C6-903 (Piping)

No	Description	Budgeted Hours	Progress Template
1	FOURNITURE FABVRICATION ET INSTALLATION	50	46EW
2	PIPING STUDY - OSBL PIPERACK	50	46D3
3	PIPE SUPPORTS	75	46D5
4	PIPING G.A. - TUYAUTERIE RATELIER - GAS NATUREL	100	46D3
5	AGENCEMENT TUYAUTERIE - RACCORDEMENTS	100	46D3
6	AGENCEMENT DE TUYAUTERIE RATELIER AZOTE	100	46D3
7	GENERAL ARRANGEMENT	100	46D3
8	PIPING ISOMETRICS	150	46D9
9	PIPE RACKSTRESS SKETCHES	25	46D9
10	PIPE STRESS ANALYSIS	26	46DD1
11	PIPE STRESS ANALYSIS	26	46DD1
12	PIPE STRESS ANALYSIS	25	46DD1
13	PIPE STRESS ANALYSIS	25	46DD1
14	FIELD DESIGN	136	46D3
15	PIPING GENERAL ARRANGEMENT DRAWINGS	83	46D3
16	PIPING GENERAL ARRANGEMENT DRAWINGS	83	46D3
17	PIPE SUPPORTS	32	46D5
18	PIPE SUPPORTS	45	46D5
19	PIPING ISOMETRICS	100	46D9
20	STRESS SKETCHES	21	46D9
21	FGH	30	46D9
22	PIPE SUPPORTS	25	46DD1
23	PIPE SUPPORTS	25	46DD1
24	PIPE SUPPORTS	25	46DD1
	Total	**1457**	

5.9 Analysis of Results

As stated earlier, two scenarios were created to process the data in both of **PM+** and **TEDS** models. The first period, which starts on 1st November 1999 and ends on 30 November 1999, represents the first scenario. The second period, which starts on 1st December and ends on 31st December 1999, represents the second scenario. The main objective of the two scenarios is to validate the functionality and accuracy of TEDS. The progress reports were generated in PM+ and TEDS models monthly; and subsequently, the outputs resulting from both models were analyzed and compared. The results indicate close agreement (see Table 5.6 and Table 5.10). Indeed, TEDS has the capability to integrate engineering deliverables in the project schedule, in order to assess their cost and schedule impact on procurement and construction phases. TEDS also has the capability to identify the source of the problem, if any, since it operates at three levels (deliverables, activity and project). It should be mentioned that a sample of the complete progress reports is presented in Appendix A.

Period No 1: Progress Reports (at month 1)

The first snapshot of the project performance was taken from the dynamic report at the project upper levels (phase, discipline and commitment package). The report indicates that 1121.26 hours have been earned while 1127.5 hours have been spent during this period. The Cost Performance Index (CPI) of the project was 0.994, indicating poor performance (CPI<1), and the forecasted hours at completion exceeded 24 hours, indicating the project experienced a cost overrun.

EPC project includes three phases (engineering, procurement, and construction); to identify which phase has experienced low performance, many filters that are employed in the dynamic report must be activated.

At the phase level, the report shows that there was a work in progress in the engineering phase only; as a result, the depicted unacceptable performance has come from the engineering phase. Therefore, the discipline filter must be activated to exhibit the performance of every discipline in the engineering phase. By activating the filters at the phase and at the discipline levels respectively, determining the source of the low performance became easier.

At the discipline level, the report shows that there was a work in progress in 7 commitment packages out of the 12 considered in this study. These commitment packages are as follows: C1-901; C1-902; C5-903; P5-002; P5-006; C6-903; and C7-901.The results derived from the dynamic report indicate that: 369.20 hours have been earned while 370.50 hours have been spent in the civil discipline, which has a cost performance index of 0.995, indicating a poor performance(CPI<1.0); 261.24 hours have been earned while 260 hours have been spent in the mechanical discipline, which has a cost performance index of 1.01 indicating a good performance(CPI>1.0); 477.88 hours have been earned whereas 485 hours have been spent in the piping discipline, which has a cost performance index of 0.98, indicating a poor performance(CPI<1.0); and 12.44 hours have been earned while 12 hours have been spent in the electrical discipline, which has a cost performance index of 1.04, indicating a good performance(CPI>1.0). It is apparent from the above results that the reasons behind low performance have come from the civil and piping disciplines. Therefore, the work package filter must be activated to define which commitment package(s) has an impact on the project performance.

At the work package level, the civil discipline filter was activated to demonstrate the performance of the civil discipline and its commitment packages. The report shows that the civil discipline encompasses three commitment packages (C1-901, C1-902, and C1-903). There was a work in progress in two commitment packages (C1-901 and C1-902) out of three. The report indicates that the commitment package C1-902 (Site Preparation) experienced a poor performance (CPI=0.995) while the performance of the commitment package C1-901(Temporary Facility) was good (CPI=1.03). Table.5.4 demonstrates the performance of the civil discipline and its commitment packages. By changing the discipline filter from civil to piping, the report shows that the piping discipline encompasses one commitment package, C6-903(OBSL-Piping), which has a poor performance (CPI=0.985). Table 5.5 demonstrates the performance of the piping discipline along with its commitment packages. Thus, the poor performance of the project has come form the commitment packages C1-902 in the civil discipline and C6-903 in the piping discipline in the engineering phase. Therefore, the dynamic report has the capability of easily and effectively defining the reasons behind unacceptable performance at the project upper levels (phase, discipline and commitment package). Subsequently, the activity and deliverables reports, which are generated automatically, should be checked to further identifying the source of unacceptable performance, if any.

In the activity report screen, many filters have been employed to facilitate the manipulation and retrieval of data. Since the problem was reported in the commitment packages C1-902 in the civil discipline and C6-903 in the piping discipline, the filters in the phase column, discipline column, and commitment package column are activated respectively to assist in identifying which activity in C1-902 and C6-903 experienced poor performance. In the commitment package C1-901, the activity report shows that two activities "Contract drawings and Specifications" and "Interdisciplinary Coordination" have been completed while the activity "Prepare Package for Bid" was in progress. The CPI(s) of these activities were 1.02, 0.98 and 1.02 respectively, while the SPI(s) of these activities was 1.0. In the commitment package C6-903, the report shows that only one activity "Preparing drawings and specification", which has CPI of 0.98 and SPI of 1.0, was in progress. This indicates that the activity "Interdisciplinary Coordination" in C1-902 and the activity "Prepare Package for Bid" in C6-90 experienced a cost overrun. Up to this level, defining the source of the problem has been achieved, but determining the deliverable(s) that has an effect on such a performance is not clear yet. Therefore, the deliverable report must be checked to identify the source of the problem.

In the Deliverables report, commitment package C1-902 is described to have 16 deliverables. The CPI(s) of 3 deliverables out of 16 were 0.80, 0.90 and 0.90 respectively, indicating poor performances. The commitment package C6-903 is described to have 24 deliverables. 12 deliverables out of 24 had low cost performance indices. The CPI(s) of 6 deliverables out of these 12 deliverables ranged between 0.93~0.94; others ranged between 0.97~ 0.98. By performing the previous steps, the source of the problem behind unacceptable performance of the project is identified.

Finally, the Impacted activity report must be activated to check whether there is any impact on other phases of the project due to the low performance of some deliverables in the commitment packages C1-902 and C6-903. The report shows there was no impact on other activities. See Fig. 5.12. This is true since the activities of the C1-902 and C6-903 have a schedule performance index (SPI) of 1.0. Therefore, the poor performances of the commitment packages C1-902 and C6-903 impact on the overall performance of the project; as a result, the forecasted hours at completion exceeded 25 hours. Therefore, the project experienced a cost over run only.

In addition to the previous reports, three charts were activated to check the status of the project and its components. They are as follows: 1) Dynamic chart; 2) S-Curve; and 3) Periodical report. Fig. 5.13 and Fig. 5.14 illustrate the dynamic chart and Indices chart reports respectively.

Table 5. 4 Dynamic Report of Civil Discipline

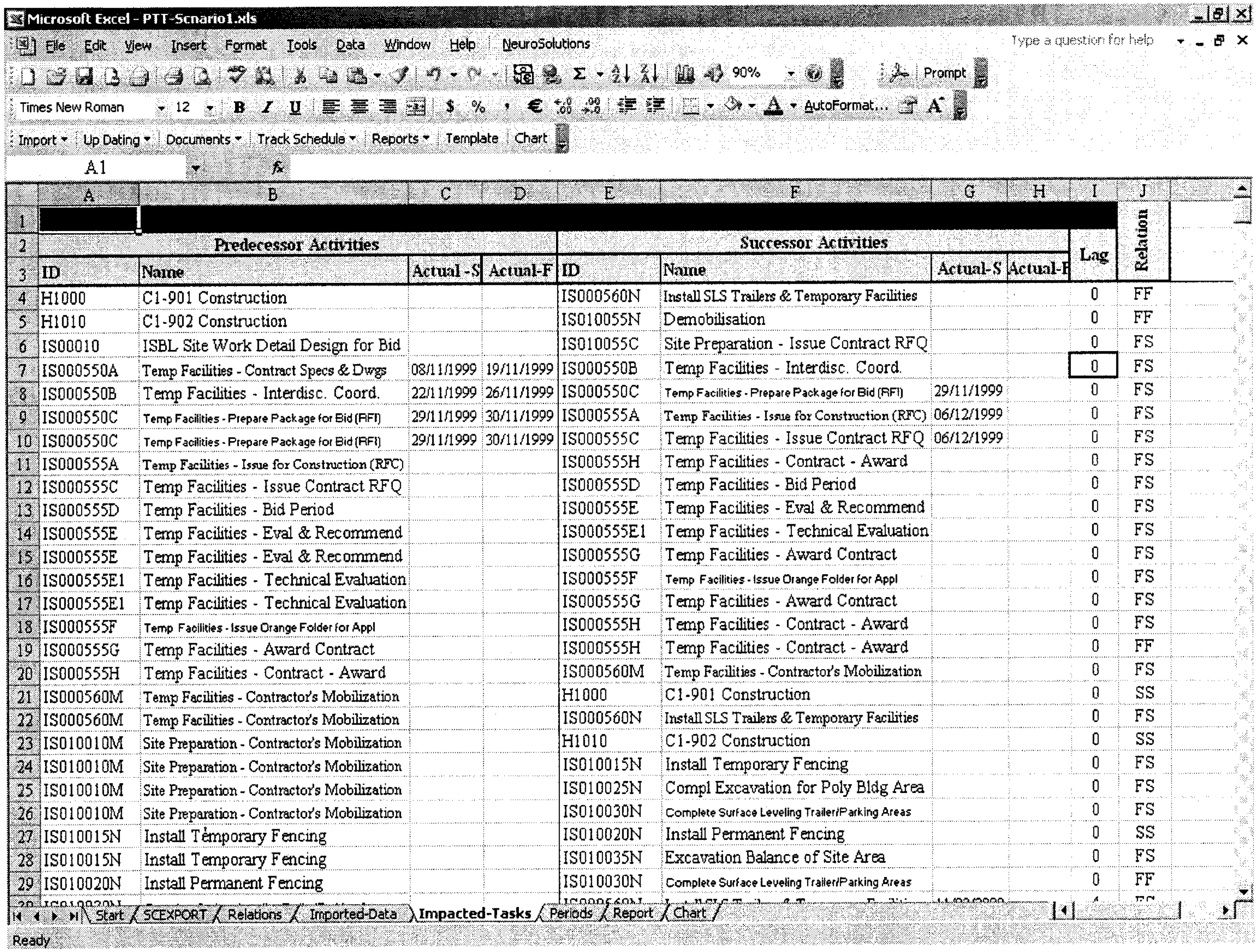
Project Name	Poly.xls
Report Date	30/11/1999
Period Number	1

PHAS	DISC	CPKG	PPKG	Total IWP	IWP	Earned Hrs	Spent Hrs	Percent Complete	CPI	FTC	BAC	Variance Hrs
E												
	41											
		C1-901										
			C1-901	22.00	13.92	13.92	13.50	63.27%	1.031	7.84	21.34	0.66
		C1-901 Total		**22.00**	**13.92**	**13.92**	**13.50**	**63.27%**	**1.031**	**7.84**	**21.34**	**0.66**
		C1-902										
			C1-902	497.00	355.28	355.28	357.00	71.48%	0.995	142.41	499.41	-2.41
		C1-902 Total		**497.00**	**355.28**	**355.28**	**357.00**	**71.48%**	**0.995**	**142.41**	**499.41**	**-2.41**
		C1-903										
			C1-903	213.00	0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
		C1-903 Total		**213.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0,000**	**0.00**	**0.00**	**0.00**
	41 Total			**732.00**	**369.20**	**369.20**	**370.50**	**50.44%**	**0.996**	**364.08**	**734.58**	**-2.58**
E Total				**732.00**	**369.20**	**369.20**	**370.50**	**50.44%**	**0.996**	**364.08**	**734.58**	**-2.58**
Grand Total				**732.00**	**369.20**	**369.20**	**370.50**	**50.44%**	**0.996**	**364.08**	**734.58**	**-2.58**

Table 5. 5 Dynamic Report of Piping Discipline

Project Name	Polyxls
Report Date	30/11/1999
Period Number	1

PHAS	DISC	CPKG	PPKG	Total IWP	IWP	Earned Hours	Spent Hours	Percent Complete	CPI	FTC	BAC	Variance (hours)
E												
	46											
		C6-903										
			C6-903	1457.00	477.88	477.88	485.00	32.80%	0.985	993.71	1478.71	-21.71
		C6-903 Total		**1457.00**	**477.88**	**477.88**	**485.00**	**32.80%**	**0.985**	**993.71**	**1478.71**	**-21.71**
	46 Total			**1457.00**	**477.88**	**477.88**	**485.00**	**32.80%**	**0.985**	**993.71**	**1478.71**	**-21.71**
E Total				**1457.00**	**477.88**	**477.88**	**485.00**	**32.80%**	**0.985**	**993.71**	**1478.71**	**-21.71**
Grand Total				**1457.00**	**477.88**	**477.88**	**485.00**	**32.80%**	**0.985**	**993.71**	**1478.71**	**-21.71**



ID	Name	Actual-S	Actual-F	ID	Name	Actual-S	Actual-F	Lag	Relation
H1000	C1-901 Construction			IS000560N	Install SLS Trailers & Temporary Facilities			0	FF
H1010	C1-902 Construction			IS010055N	Demobilisation			0	FF
IS00010	ISBL Site Work Detail Design for Bid			IS010055C	Site Preparation - Issue Contract RFQ			0	FS
IS000550A	Temp Facilities - Contract Specs & Dwgs	08/11/1999	19/11/1999	IS000550B	Temp Facilities - Interdisc. Coord.			0	FS
IS000550B	Temp Facilities - Interdisc. Coord.	22/11/1999	26/11/1999	IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	29/11/1999		0	FS
IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	29/11/1999	30/11/1999	IS000555A	Temp Facilities - Issue for Construction (RFC)	06/12/1999		0	FS
IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	29/11/1999	30/11/1999	IS000555C	Temp Facilities - Issue Contract RFQ	06/12/1999		0	FS
IS000555A	Temp Facilities - Issue for Construction (RFC)			IS000555H	Temp Facilities - Contract - Award			0	FS
IS000555C	Temp Facilities - Issue Contract RFQ			IS000555D	Temp Facilities - Bid Period			0	FS
IS000555D	Temp Facilities - Bid Period			IS000555E	Temp Facilities - Eval & Recommend			0	FS
IS000555E	Temp Facilities - Eval & Recommend			IS000555E1	Temp Facilities - Technical Evaluation			0	FS
IS000555E	Temp Facilities - Eval & Recommend			IS000555G	Temp Facilities - Award Contract			0	FS
IS000555E1	Temp Facilities - Technical Evaluation			IS000555F	Temp Facilities - Issue Orange Folder for Appl			0	FS
IS000555E1	Temp Facilities - Technical Evaluation			IS000555G	Temp Facilities - Award Contract			0	FS
IS000555F	Temp Facilities - Issue Orange Folder for Appl			IS000555H	Temp Facilities - Contract - Award			0	FS
IS000555G	Temp Facilities - Award Contract			IS000555H	Temp Facilities - Contract - Award			0	FF
IS000555H	Temp Facilities - Contract - Award			IS000560M	Temp Facilities - Contractor's Mobilization			0	FS
IS000560M	Temp Facilities - Contractor's Mobilization			H1000	C1-901 Construction			0	SS
IS000560M	Temp Facilities - Contractor's Mobilization			IS000560N	Install SLS Trailers & Temporary Facilities			0	FS
IS010010M	Site Preparation - Contractor's Mobilization			H1010	C1-902 Construction			0	SS
IS010010M	Site Preparation - Contractor's Mobilization			IS010015N	Install Temporary Fencing			0	FS
IS010010M	Site Preparation - Contractor's Mobilization			IS010025N	Compl Excavation for Poly Bldg Area			0	FS
IS010010M	Site Preparation - Contractor's Mobilization			IS010030N	Complete Surface Leveling Trailer/Parking Areas			0	FS
IS010015N	Install Temporary Fencing			IS010020N	Install Permanent Fencing			0	SS
IS010015N	Install Temporary Fencing			IS010035N	Excavation Balance of Site Area			0	FS
IS010020N	Install Permanent Fencing			IS010030N	Complete Surface Leveling Trailer/Parking Areas			0	FF

Fig.5. 12 Impacted Activities Report Screen

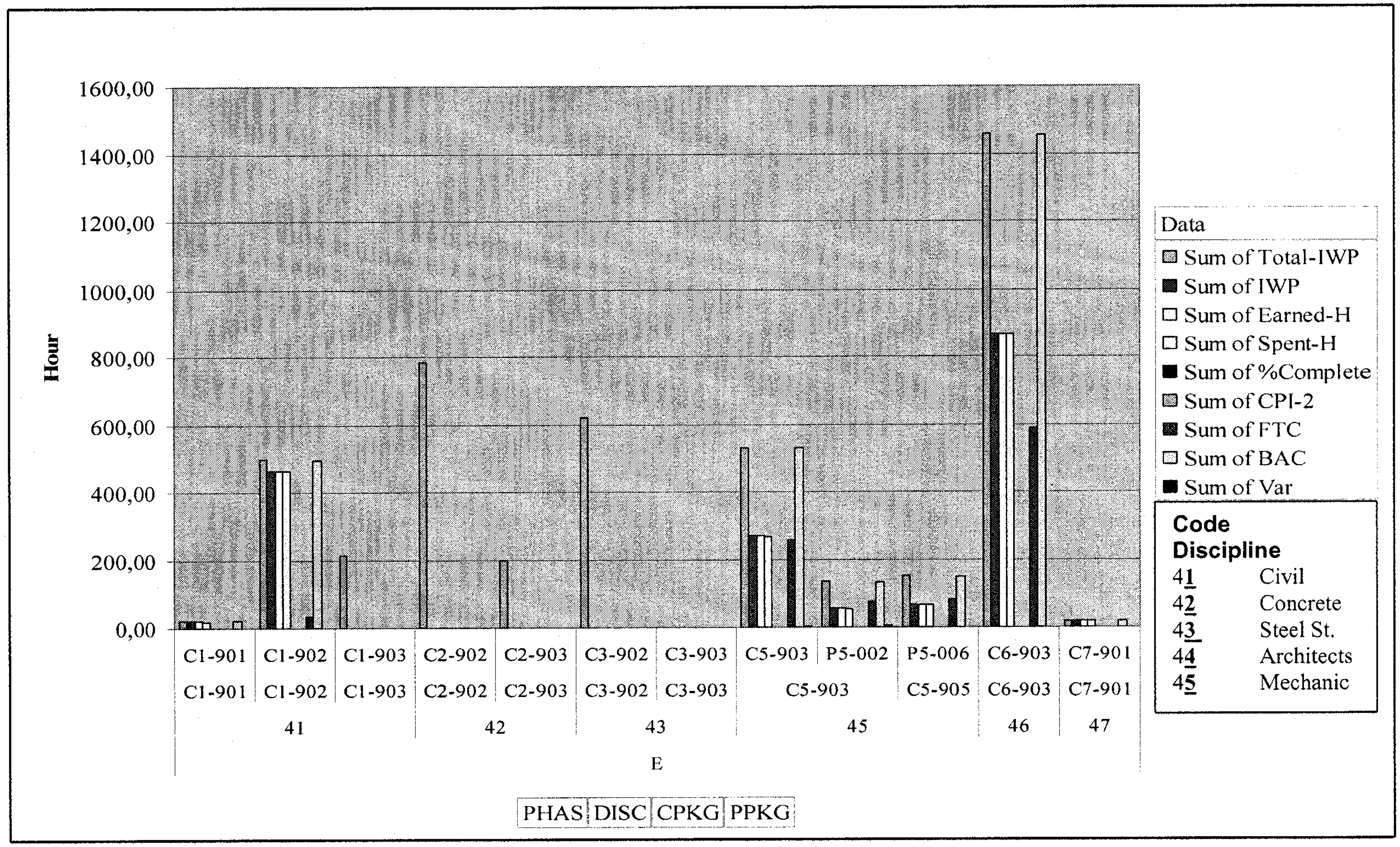


Fig.5. 13 Dynamic Chart (Eng. phase/All Disc. /All CPs)

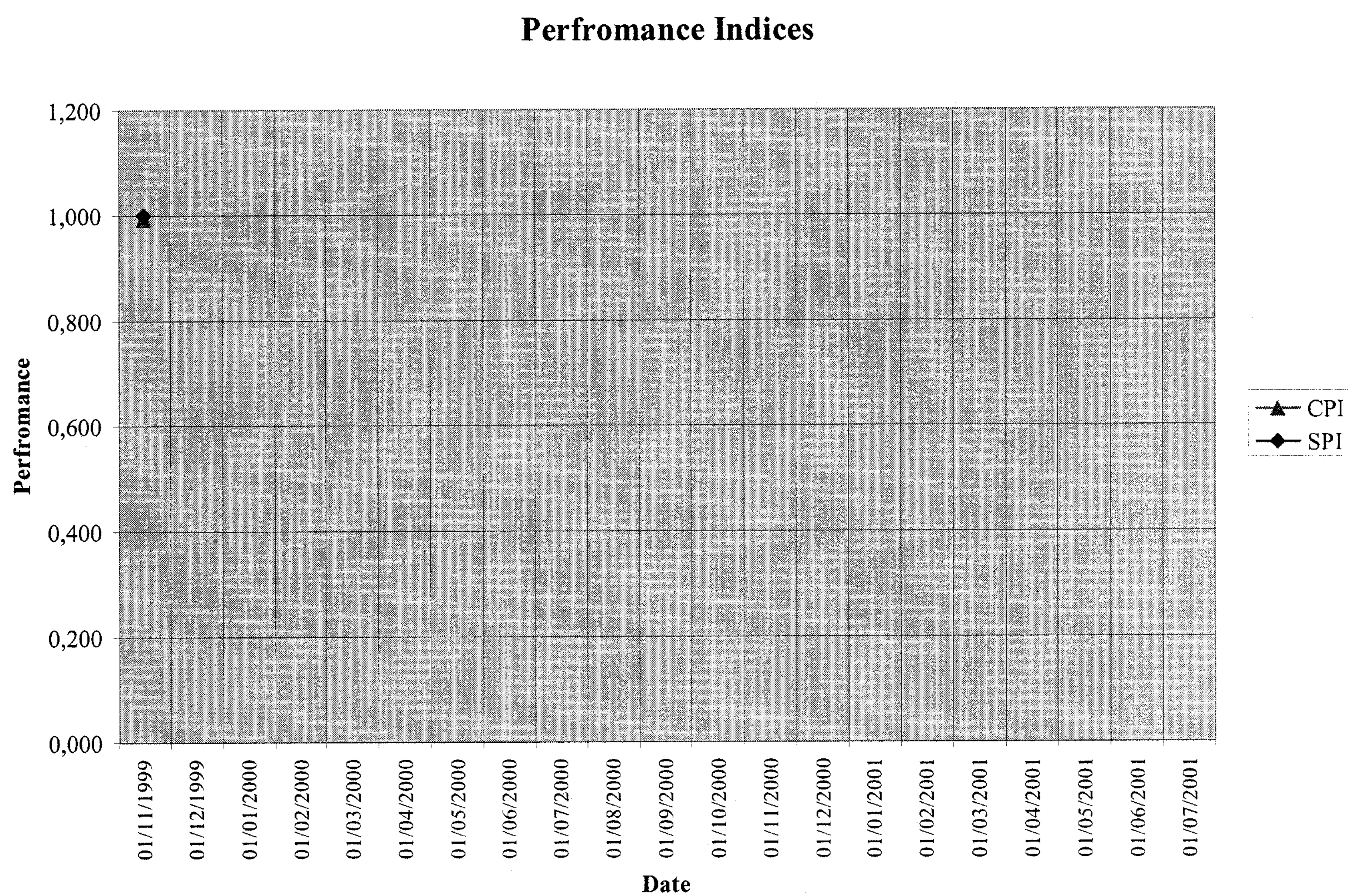


Fig.5. 14 Performance Indices Chart

Table 5. 6 Comparison of the Results for Period #1

Discipline Name	Commitment Package	%Complete		CPI		Variances (hrs)	
		PM+	TEDS	PM+	TEDS	PM+	TEDS
Civil	C1-901	63.00	63.27	1.03	1.031	1.00	0.66
	C1-902	71.00	71.48	0.99	0.995	0.00	-2.41
	C1-903	0.00	0.00	-----	-----	0.00	0.00
Concrete	C2-902	0.00	0.00	-----	-----	0.00	0.00
	C2-903	0.00	0.00	-----	-----	0.00	0.00
Steel Structure	C3-902	0.00	0.00	-----	-----	0.00	0.00
	C3-903	0.00	0.00	-----	-----	0.00	0.00
Mechanical	P5-002	15.00	14.89	1.02	1.02	1.00	-2.69
	P5-006	45.00	45.00	1.01	1.007	1.00	1.11
	C5-903	10.00	29.12	1.00	1.005	0.00	2.56
Piping	C6-903	31.00	32.80	0.98	0.985	-11	-21.71
Electrical	C7-901	62.00	62.20	1.04	1.037	0.00	0.71
Total Engineering Department			**24.22**	**0.99**	**0.994**	**-8**	**-25.77**

As anticipated, the results derived from both models (**PM+** and **TEDS**) indicated close agreement except for the commitment packages C1-902, P5-002, C5-903 and C6-903 (see Table 5.6). These variations were emerged because of using different forecasting methods (direct estimate and mathematical calculations). And also, the percent complete of C5-903 derived from PM+ is different from that derived from TDES. The reason behind this variation is 8 documents (530 budgeted hours) out of 23 (1693 budgeted hours) have been chosen to be processed into TEDS.

Period No 2: Progress Reports (at month 2)

In this period, there was a work in progress in the same commitment packages (C1-901, C1-902, C5-903, P5-002, P5-006, C6-903, and C6-903). After recognizing the low performance of some deliverables in the commitment package C1-902 and C6-903, a corrective action has been taken to enhance the performance of the both commitment packages.

When the dynamic report is activated, the results show that 1763.27 hours have been earned while 1757.25 hours have been spent in the engineering phase, which has a cost performance index of 1.003, indicating a good performance(CPI>1.0). The report also shows that the forecasted hours at completion were less than the original budgeted hours by 16 hours, meaning the project has a cost under run. Many filters are activated to track every component in the engineering phase. At the discipline level, the report shows the following: 483.43 hours have been earned and 481.75 hours have been spent in the civil discipline, which has a cost performance index of 1.003(CPI>1.0), indicting a good performance; 394.79 hours have been earned while 391.0 hours have been spent in the mechanical discipline, which has a cost performance index of 1.10, indicating a good performance; 866.30 hours have been earned whereas 866 hours have been spent in the piping discipline, which has a cost performance index of 1.0, indicating a good performance; and 18.75 hours have been earned while 18.5 hours have been spent in the electrical discipline, which has a cost performance index of 1.04, indicating a good performance. Next, the commitment package filter was activated to track the performance of every commitment package in every discipline. For instance, to determine the performance of the commitment package C1-902 (Temporary Facility), the phase filter (Engineering), discipline filter (Civil), and commitment package filter (C1-901) were activated sequentially. Table 5.7 shows the dynamic report of the commitment package C1-901 whereas Table 5.8 demonstrates the overall performance of the civil discipline with its associated commitment packages. The graphical reports were also activated to depict the performance of the civil discipline (Fig. 5.15 and Fig. 5.16).

In order to ensure that every element in the project is on track, the activity and deliverable reports were also activated. Both reports show that the majority of the commitment package components have a good performance. The periodical report was also activated to track the project performance through the two periods. This report shows that an improvement has been achieved in the second period (see Table5.9). To depict the project performance a graphical reports were activated. Fig.5.17 and Fig.5.18 depict performance indices (CPI and SPI) and S-curve charts during two periods. The impacted activity report was also checked; its results indicate that no further impact on other phases of the project (Fig. 5.19)

Table 5. 7 Dynamic Report of CP-C1-901

Project Name	Poly.xls
Report Date	31/12/99
Period Number	2

PHAS	DISC	CPKG	PPKG	Total IWP	IWP	Earned Hrs	Spent Hrs	Percent Complete	CPI	FTC	BAC	Variance Hrs
E												
	41											
		C1-901										
			C1-901	22.00	20.54	20.54	19.75	93.38%	1.040	1.40	21.15	0.85
		C1-901 Total		**22.00**	**20.54**	**20.54**	**19.75**	**93.38%**	**1.040**	**1.40**	**21.15**	**0.85**
	41 Total			**22.00**	**20.54**	**20.54**	**19.75**	**93.38%**	**1.040**	**1.40**	**21.15**	**0.85**
E Total				**22.00**	**20.54**	**20.54**	**19.75**	**93.38%**	**1.040**	**1.40**	**21.15**	**0.85**
Grand Total				**22.00**	**20.54**	**20.54**	**19.75**	**93.38%**	**1.040**	**1.40**	**21.15**	**0.85**

Table 5. 8 Dynamic Report of Civil Discipline

Project Name	Poly.xls
Report Date	31/12/19
Period Number	2

PHAS	DISC	CPKG	PPKG	Total IWP	IWP	Earned Hrs	Spent Hrs	Percent Complete	CPI	FTC	BAC	Variance Hrs
E												
	41											
		C1-901										
			C1-901	22.00	20.54	20.54	19.75	93.38%	1.040	1.40	21.15	0.85
		C1-901 Total		**22.00**	**20.54**	**20.54**	**19.75**	**93.38%**	**1.040**	**1.40**	**21.15**	**0.85**
		C1-902										
			C1-902	497.00	462.89	462.89	462.00	93.14%	1.002	34.05	496.05	0.95
		C1-902 Total		**497.00**	**462.89**	**462.89**	**462.00**	**93.14%**	**1.002**	**34.05**	**496.05**	**0.95**
		C1-903										
			C1-903	213.00	0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
		C1-903 Total		**213.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	41 Total			**732.00**	**483.43**	**483.43**	**481.75**	**66.04%**	**1.003**	**247.71**	**729.46**	**2.54**
E Total				**732.00**	**483.43**	**483.43**	**481.75**	**66.04%**	**1.003**	**247.71**	**729.46**	**2.54**
Grand Total				**732.00**	**483.43**	**483.43**	**481.75**	**66.04%**	**1.003**	**247.71**	**729.46**	**2.54**

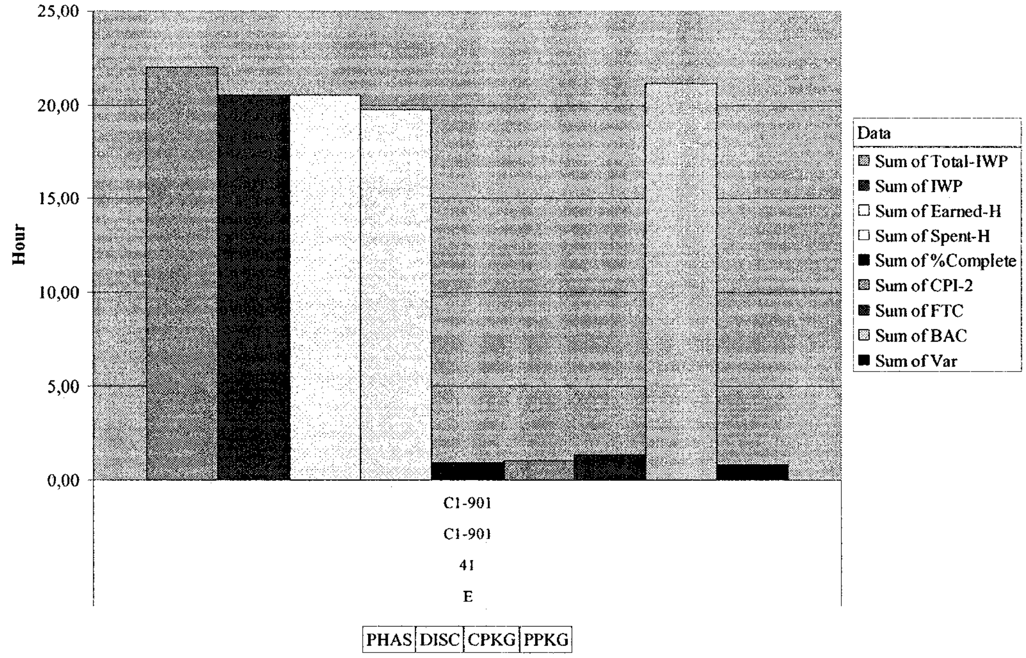


Fig.5. 15 Dynamic Chart Report of CP-C1-901

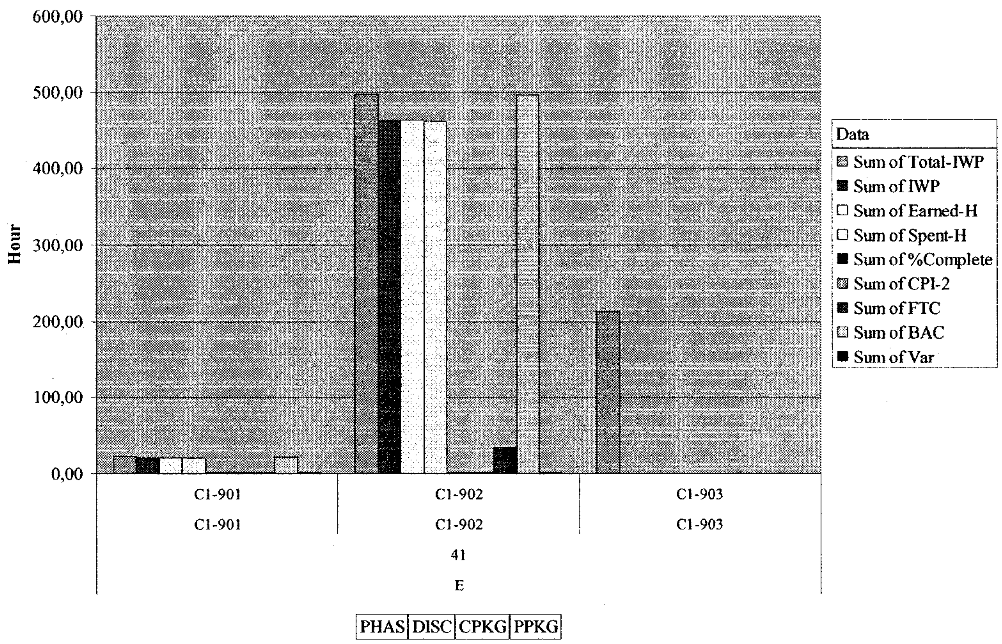


Fig.5. 16 Dynamic Chart Report of the Civil Discipline

Table 5. 9 Periodical Report of the Project

Project Name	Poly.xls
Project Start Date	*01/11/1999*
Project End Date	*27/07/2001*

Period No	Start Date	End Date	Total-IWP	IWP	Earned-Hours	Spent Hours	Percent Complete	CPI	FTC	BAC	Variance Hours
1	01/11/1999	30/11/1999	4630.00	1121.26	1121.26	1127.50	%24.22	0.994	3528	4656	-25
2	01/12/1999	31/12/1999	4630.00	1763.27	1763.27	1757.25	%38.08	1.003	2857	4614	16
3	01/01/2000	31/01/2000									
4	01/02/2000	29/02/2000									
5	01/03/2000	31/03/2000									
6	01/04/2000	30/04/2000									
7	01/05/2000	31/05/2000									
8	01/06/2000	30/06/2000									
9	01/07/2000	31/07/2000									
10	01/08/2000	31/08/2000									
11	01/09/2000	30/09/2000									
12	01/10/2000	31/10/2000									
13	01/11/2000	30/11/2000									
14	01/12/2000	31/12/2000									

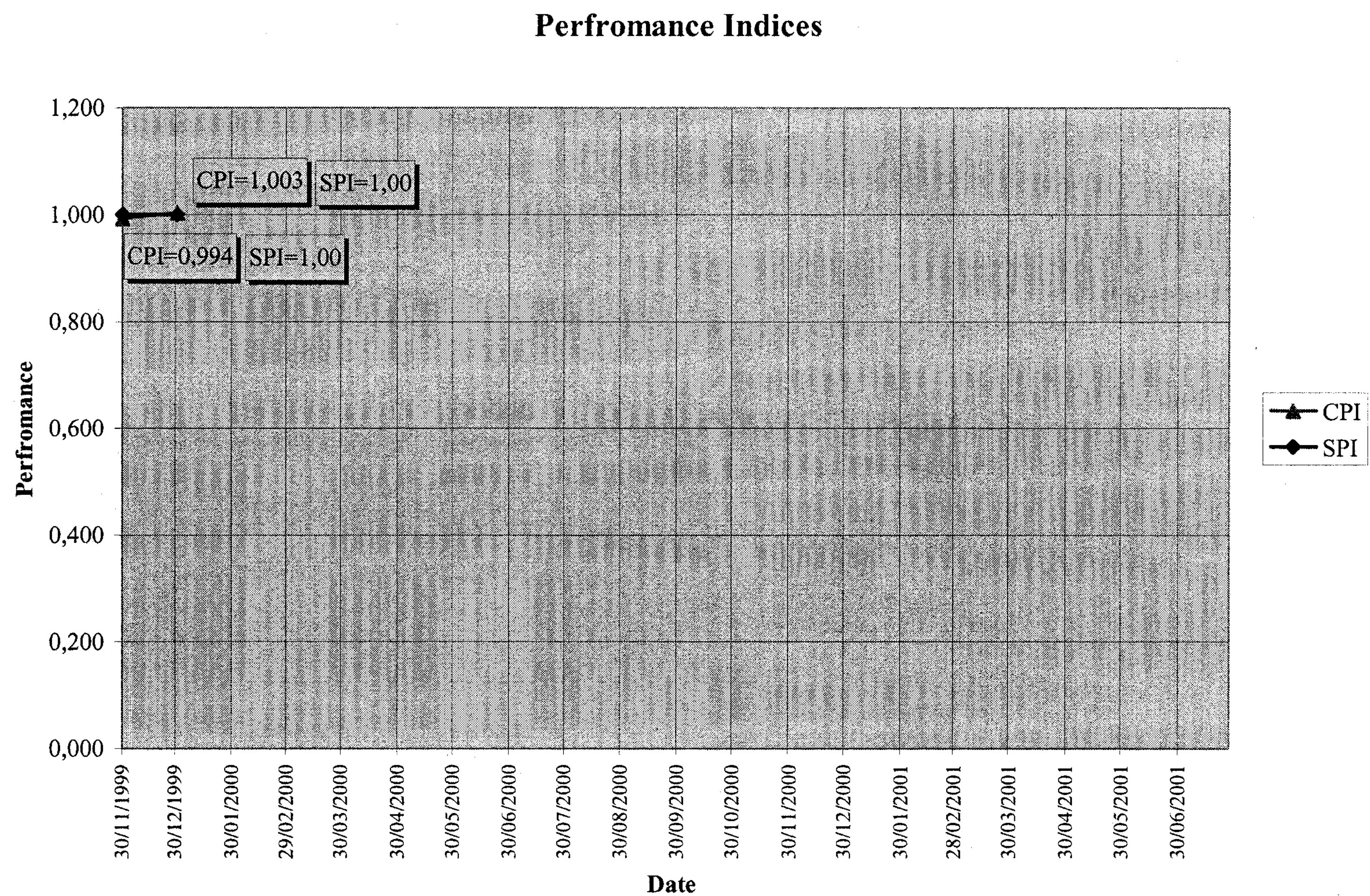


Fig.5. 17 Performance Indices Report during two periods

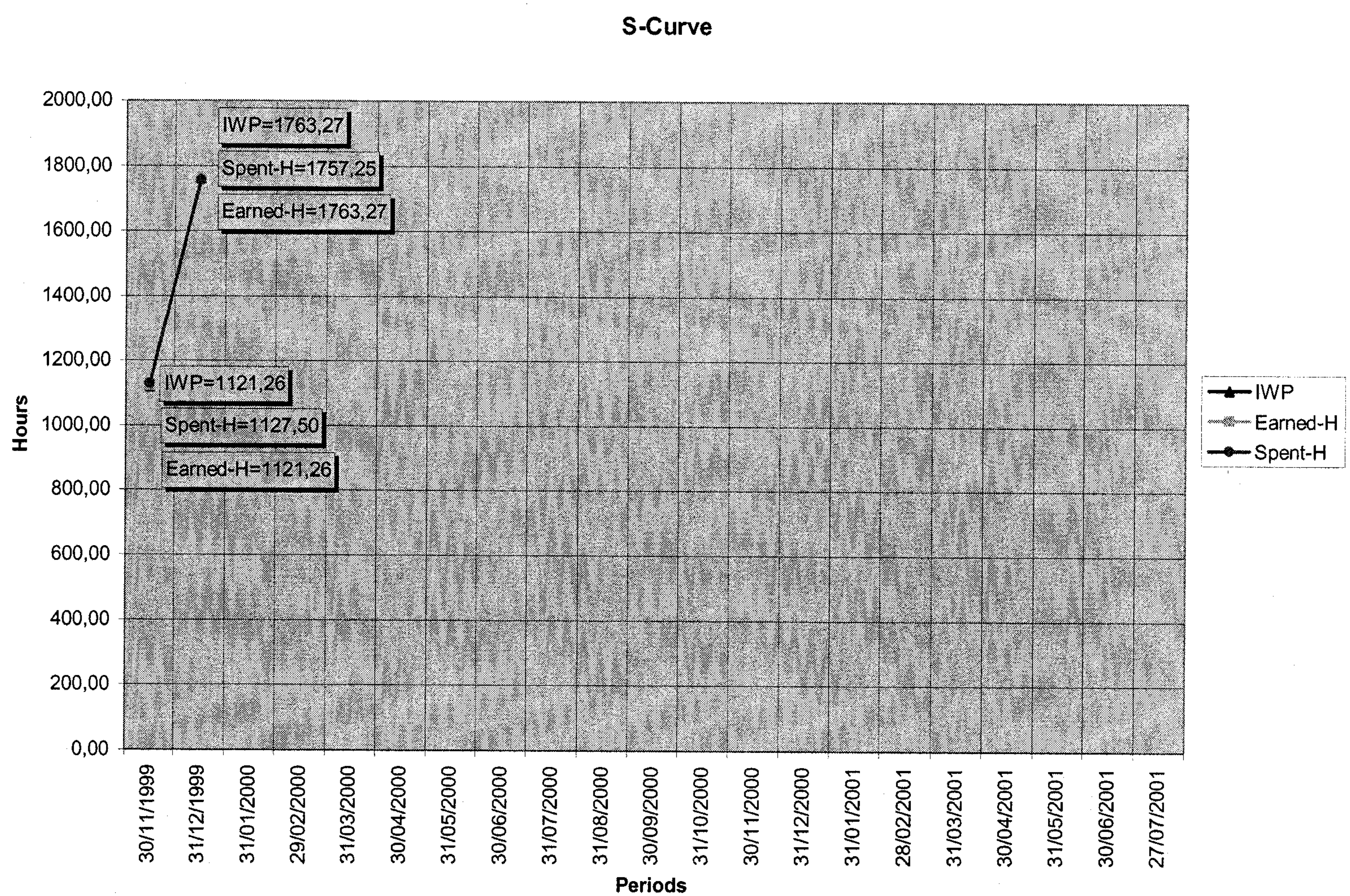
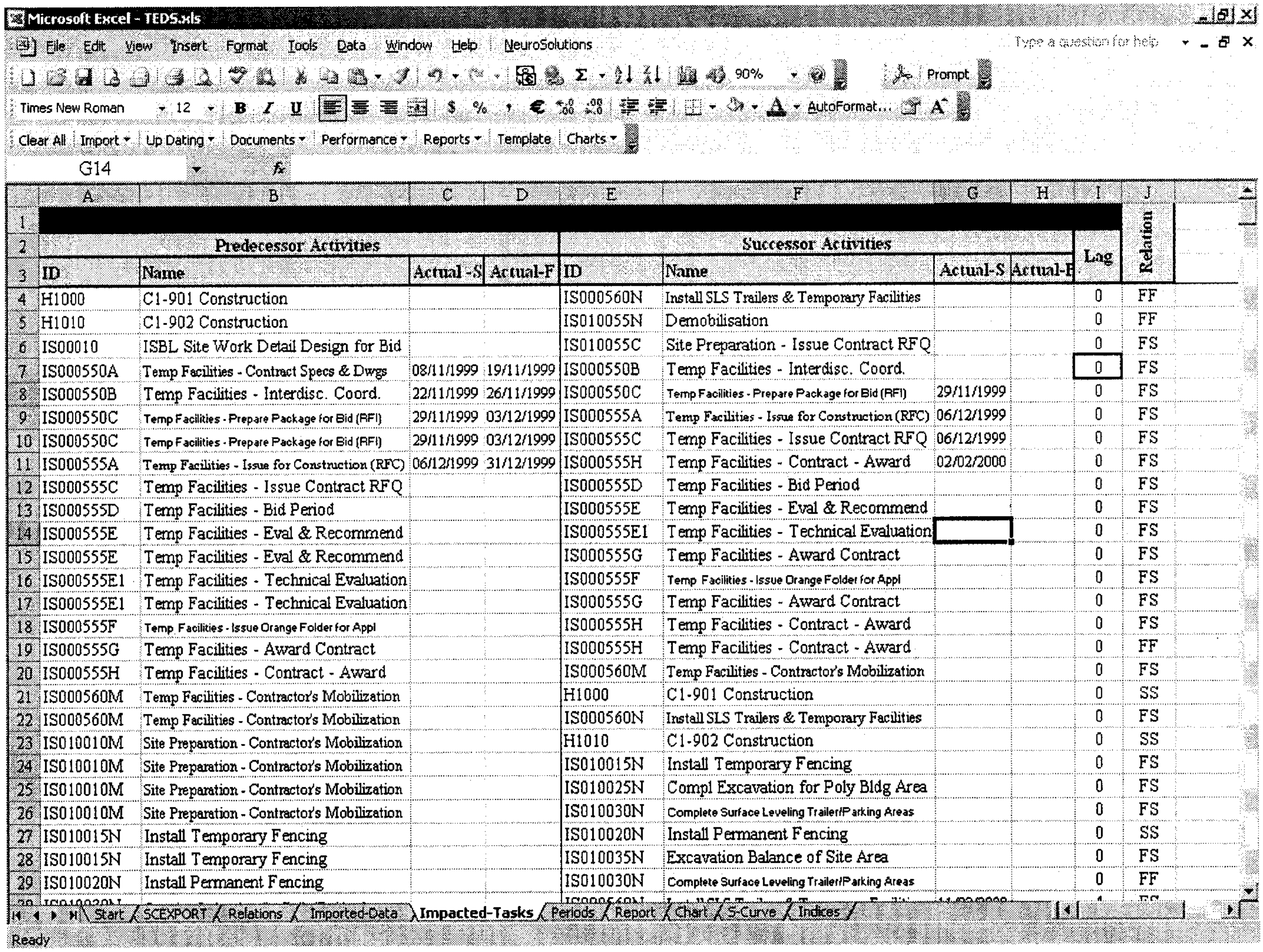


Fig.5. 18 S-Curve Report



Microsoft Excel - TEDS.xls

ID	Name	Actual -S	Actual-F	ID	Name	Actual-S	Actual-F	Lag	Relation
	Predecessor Activities				**Successor Activities**				
H1000	C1-901 Construction			IS000560N	Install SLS Trailers & Temporary Facilities			0	FF
H1010	C1-902 Construction			IS010055N	Demobilisation			0	FF
IS00010	ISBL Site Work Detail Design for Bid			IS010055C	Site Preparation - Issue Contract RFQ			0	FS
IS000550A	Temp Facilities - Contract Specs & Dwgs	08/11/1999	19/11/1999	IS000550B	Temp Facilities - Interdisc. Coord.			0	FS
IS000550B	Temp Facilities - Interdisc. Coord.	22/11/1999	26/11/1999	IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	29/11/1999		0	FS
IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	29/11/1999	03/12/1999	IS000555A	Temp Facilities - Issue for Construction (RFC)	06/12/1999		0	FS
IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	29/11/1999	03/12/1999	IS000555C	Temp Facilities - Issue Contract RFQ	06/12/1999		0	FS
IS000555A	Temp Facilities - Issue for Construction (RFC)	06/12/1999	31/12/1999	IS000555H	Temp Facilities - Contract - Award	02/02/2000		0	FS
IS000555C	Temp Facilities - Issue Contract RFQ			IS000555D	Temp Facilities - Bid Period			0	FS
IS000555D	Temp Facilities - Bid Period			IS000555E	Temp Facilities - Eval & Recommend			0	FS
IS000555E	Temp Facilities - Eval & Recommend			IS000555E1	Temp Facilities - Technical Evaluation			0	FS
IS000555E	Temp Facilities - Eval & Recommend			IS000555G	Temp Facilities - Award Contract			0	FS
IS000555E1	Temp Facilities - Technical Evaluation			IS000555F	Temp Facilities - Issue Orange Folder for Appl			0	FS
IS000555E1	Temp Facilities - Technical Evaluation			IS000555G	Temp Facilities - Award Contract			0	FS
IS000555F	Temp Facilities - Issue Orange Folder for Appl			IS000555H	Temp Facilities - Contract - Award			0	FS
IS000555G	Temp Facilities - Award Contract			IS000555H	Temp Facilities - Contract - Award			0	FF
IS000555H	Temp Facilities - Contract - Award			IS000560M	Temp Facilities - Contractor's Mobilization			0	FS
IS000560M	Temp Facilities - Contractor's Mobilization			H1000	C1-901 Construction			0	SS
IS000560M	Temp Facilities - Contractor's Mobilization			IS000560N	Install SLS Trailers & Temporary Facilities			0	FS
IS010010M	Site Preparation - Contractor's Mobilization			H1010	C1-902 Construction			0	SS
IS010010M	Site Preparation - Contractor's Mobilization			IS010015N	Install Temporary Fencing			0	FS
IS010010M	Site Preparation - Contractor's Mobilization			IS010025N	Compl Excavation for Poly Bldg Area			0	FS
IS010010M	Site Preparation - Contractor's Mobilization			IS010030N	Complete Surface Leveling Trailer/Parking Areas			0	FS
IS010015N	Install Temporary Fencing			IS010020N	Install Permanent Fencing			0	SS
IS010015N	Install Temporary Fencing			IS010035N	Excavation Balance of Site Area			0	FS
IS010020N	Install Permanent Fencing			IS010030N	Complete Surface Leveling Trailer/Parking Areas			0	FF

Fig.5. 19 Impacted Activities Report Screen

Table 5. 10 Comparison of Results for Period# 2

Discipline Name	Commitment Package	%Complete		CPI		Variances(Hrs)	
		PM+	TEDS	PM+	TEDS	PM+	TEDS
Civil	C1-901	93.00	93.38	1.04	1.04	0.00	0.85
	C1-902	93.00	93.14	1.00	1.02	-2.00	0.95
	C1-903	0.00	0.00	-----	-----	0.00	0.00
Concrete	C2-902	-----	-----	-----	-----	0.00	0.00
	C2-903	-----	-----	-----	-----	0.00	0.00
Steel Structure	C3-902	-----	-----	-----	-----	0.00	0.00
	C3-903	-----	-----	-----	-----	0.00	0.00
Mechanical	P5-002	42.00	41.68	1.04	1.038	-2.00	5.04
	P5-006	45.00	45.00	1.01	1.007	-1.00	1.11
	C5-903	16.00	50.98	1.00	1.004	-2.00	2.33
Piping	C6-903	59.00	59.46	1.00	1.00	2.00	0.5
Electrical	C7-901	93.00	93.74	1.01	1.037	-4	0.26
Total Engineering Department			**38.24**	**0.99**	**0.994**	**-4.00**	**11.00**

As shown in Table 5.10, the results derived from of both models (**PM+** and **TEDS**) show close agreement. The results indicate the variance in hours at completion is varied. While in TEDS the variance in hours at completion equal to 11 hours, meaning the project is ahead of schedule, in PM+ the variance in hours at completion equal to -4 hours, meaning that the project is behind the schedule. This difference comes from the methods that are used to forecast hours to complete. While in PM+ the forecast hours to complete is estimated by engineers, in TEDS forecast hours to complete is calculated based on methods that introduced earlier in chapter 3.

In the presented case study, two periods have been entered into the models **TEDS** and **PM+**. The results derived from both models indicate a close agreement. From the illustrated results in Table 5.6 and Table 5.10, it is apparent that TEDS is capable of tracking and control engineering deliverables in the EPC projects. TEDS also has the capability of assisting the project management teams to identify the source of unacceptable performance, if any, since it provides diverse reports at different levels (deliverables' level, activity level and project level). And also it has the capability to demonstrate the impact of engineering deliverables on the project phases (procurement and construction) Indeed, TEDS employs two essential features: filtering and coloring techniques, which provide a high-degree of data manipulation.

5.10 Summary

This chapter has demonstrated through a set of training data that was extracted from an actual EPCM project the accuracy and functionality of TEDS. The project's characteristics are explained in this chapter. 12 out of 75 commitment packages have been selected to be processed into two models: PM+ (SNC-LAVAN management tool) and TEDS through two scenarios. A brief description of PM+ with its embedded modules is introduced. Then, processing the data on the two models is explained. Next, a number of reports are extracted from both models during two periods. The results obtained using TEDS are analyzed and compared to those generated by PM+. The comparison indicates close agreement between both modules and demonstrates the capability and functionality of TEDS.

Chapter VI– Summary and Concluding Remarks

6.1 Summering

This study focuses on tracking and controlling engineering deliverables in EPC projects. In this study, the current practices are described including a field study conducted by the author in collaboration with a leading industrial partner, SNC-LAVALIN, in the Canadian construction industry for an EPCM project. Then, the elements of the project control are explained. Next, a number of techniques that are used in this domain are reviewed. Integrated control is most desirable for it provides project management teams with useful and significant information. Therefore, it is important to construct a control system for engineering deliverables in EPC projects that has the following capabilities: tracking and controlling engineering deliverables individually, integrating the cost and schedule functions, determining the reason behind unacceptable performance explicitly and demonstrating the impact of engineering deliverables on other phases of the project. A methodology is presented in this study based on the earned value concept (U.S.A Department Of Energy, 1980), progress templates (SNC-LAVALIN 2006, Eldin 1991) and a set of developed algorithms.

The developed methodology was implemented in a computerized system using Microsoft Excel sheets in a Microsoft Windows XP environment. The developed system "Tracking Engineering Deliverables System (**TEDS)**" was coded utilizing Macros and Visual Basic Application programming language. The developed system, TEDS, has a number of interesting features that give the system a superiority over other control systems: 1) It is easy to use; 2) It integrates engineering deliverables with the project schedule; 3) it provides tabular and graphics reports; 4) It has many dropdown menus to facilitate its use; 5) It detects and identifies the roots of the unacceptable performance at the deliverables' level; and 6) It is a standalone system that can be used as an independent add-on utility to project management software "PM+" of an industrial partner.

To validate the functionality and accuracy of the developed system, TEDS, a training project "Poly", which was developed by SNC-LAVALIN, was utilized. The results derived from the system are compared to those derived from PM+ (SNC-LAVALIN). Based on this comparison, the following conclusions can be drawn:

1- The developed methodology is valid for EPC projects as it can integrate engineering deliverables into a project schedule.
2- The system demonstrates a high-degree of accuracy.
3- The system has the capability of identifying the reasons behind unacceptable performance (up to deliverable level), if any.
4- The system provides many reports at the summary and detailed levels, and graphical reports according to the project WBS.
5- The system has the capability of dealing with huge amounts of data effectively and easily as it utilizes filtering and coloring pattern techniques.

6.2 Recommendations for Future Work

This study presents an integrated control system for engineering deliverables in EPC projects. The system was implemented in the Microsoft Windows XP environment using Excel sheets; it can be expanded to accommodate other modules without changing or affecting its structure. The following recommendations are suggested for future research:

1) Expanding the document module to enable integration with other software such as AUTOCAD software to represent the deliverables in the system graphically.
2) Expanding the document module to enable tracking, controlling and measuring of crew productivity.
3) Expanding the document module to include indirect costs associated with engineering deliverables.
4) Expanding the document module to enable determining the effects of the scope change of the work in the engineering phase on the project.
5) Expanding the developed Impacted activity report to include other types of relation among project activities (start-start, start-finish, and finish- finish).
6) Developing a module to demonstrate the effect of changing the order in the construction and/or procurement phase on engineering phase.
7) Expanding the embedded database to include historical data of previously EPC projects.

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Appendix A

CASE STUDY

(Poly Project)

PERIOD No 1

01/11/1991 ~ 30/11/1999

TEDS REPORTS

Dynamic Report

1- Selection By: All Phases, all Disciplines, and all Commitment Packages.

Project Name	Poly.xls
Report Date	30/11/1999
Period Number	1

PHAS	DISC	CPKG	PPKG	Total-IWP	IWP	Earned-H	Spent-H	%Complete	CPI	FTC	BAC	Variance
C												
	41											
		C1-901										
			C1-901					0.00%	0.000	0.00	0.00	0.00
		C1-901 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
		C1-902										
			C1-902					0.00%	0.000	0.00	0.00	0.00
		C1-902 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
		C1-903										
			C1-903					0.00%	0.000	0.00	0.00	0.00
		C1-903 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
		C2-902										
			C2-902					0.00%	0.000	0.00	0.00	0.00
		C2-902 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	41 Total							**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**

42							
	C2-902						
		C2-902	0.00%	0.000	0.00	0.00	0.00
	C2-902 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C2-903						
		C2-903	0.00%	0.000	0.00	0.00	0.00
	C2-903 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
42 Total			**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43							
	C3-902						
		C3-902	0.00%	0.000	0.00	0.00	0.00
	C3-902 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C3-903						
		C3-903	0.00%	0.000	0.00	0.00	0.00
	C3-903 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43 Total			**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
45							
	C5-903						
		C5-903	0.00%	0.000	0.00	0.00	0.00
		P5-002	0.00%	0.000	0.00	0.00	0.00
	C5-903 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C5-905						
		C5-905	0.00%	0.000	0.00	0.00	0.00

		P5-006					0.00%	0.000	0.00	0.00	0.00
	C5-905 Total						0.00%	0.000	0.00	0.00	0.00
45 Total							**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
46											
	C6-903										
		C6-903					0.00%	0.000	0.00	0.00	0.00
	C6-903 Total						0.00%	0.000	0.00	0.00	0.00
46 Total							**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
C Total							**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
E											
41											
	C1-901										
		C1-901	22.00	13.92	13.92	13.50	63.27%	1.031	7.84	21.34	0.66
	C1-901 Total		22.00	13.92	13.92	13.50	63.27%	1.031	7.84	21.34	0.66
	C1-902										
		C1-902	497.00	355.28	355.28	357.00	71.48%	0.995	142.41	499.41	-2.41
	C1-902 Total		497.00	355.28	355.28	357.00	71.48%	0.995	142.41	499.41	-2.41
	C1-903										
		C1-903	213.00	0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
	C1-903 Total		213.00	0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
41 Total			**732.00**	**369.20**	**369.20**	**370.50**	**50.44%**	**0.996**	**364.08**	**734.58**	**-2.58**

42											
	C2-902										
		C2-902	784.00	0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
	C2-902 Total		**784.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C2-903										
		C2-903	200.00	0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
	C2-903 Total		**200.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
42 Total			**984.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43											
	C3-902										
		C3-902	620.00	0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
	C3-902 Total		**620.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C3-903										
		C3-903		0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
	C3-903 Total			**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43 Total			**620.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
45											
	C5-903										
		C5-903	530.00	173.84	173.84	173.00	32.80%	1.005	354.44	527.44	2.56
		P5-002	137.00	20.40	20.40	20.00	14.89%	1.020	114.31	134.31	2.69
	C5-903 Total		**667.00**	**194.24**	**194.24**	**193.00**	**29.12%**	**1.006**	**469.74**	**662.74**	**4.26**
	C5-905										
		P5-006	150.00	67.50	67.50	67.00	45.00%	1.007	81.89	148.89	1.11

		C5-905 Total		150.00	67.50	67.50	67.00	45.00%	1.007	81.89	148.89	1.11
	45 Total			**817.00**	**261.74**	**261.74**	**260.00**	**32.04%**	**1.007**	**551.57**	**811.57**	**5.43**
	46											
		C6-903										
			C6-903	1457.00	477.88	477.88	485.00	32.80%	0.985	993.71	1478.71	-21.71
		C6-903 Total		**1457.00**	**477.88**	**477.88**	**485.00**	**32.80%**	**0.985**	**993.71**	**1478.71**	**-21.71**
	46 Total			**1457.00**	**477.88**	**477.88**	**485.00**	**32.80%**	**0.985**	**993.71**	**1478.71**	**-21.71**
	47											
		C7-901										
			C7-901	20.00	12.44	12.44	12.00	62.20%	1.037	7.29	19.29	0.71
		C7-901 Total		**20.00**	**12.44**	**12.44**	**12.00**	**62.20%**	**1.037**	**7.29**	**19.29**	**0.71**
	47 Total			**20.00**	**12.44**	**12.44**	**12.00**	**62.20%**	**1.037**	**7.29**	**19.29**	**0.71**
E Total				**4630.00**	**1121.26**	**1121.26**	**1127.50**	**24.22%**	**0.994**	**3528.27**	**4655.77**	**-25.77**
P												
	41											
		C1-901										
			C1-901					0.00%	0.000	0.00	0.00	0.00
		C1-901 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
		C1-902										
			C1-902					0.00%	0.000	0.00	0.00	0.00
		C1-902 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**

	C1-903						
		C1-903	0.00%	0.000	0.00	0.00	0.00
	C1-903 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
41 Total			**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
42							
	C2-902						
		C2-902	0.00%	0.000	0.00	0.00	0.00
	C2-902 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C2-903						
		C2-903	0.00%	0.000	0.00	0.00	0.00
	C2-903 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
42 Total			**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43							
	C3-902						
		C3-902	0.00%	0.000	0.00	0.00	0.00
	C3-902 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C3-903						
		C3-903	0.00%	0.000	0.00	0.00	0.00
	C3-903 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43 Total			**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
45							
	C5-903						

		C5-903					0.00%	0.000	0.00	0.00	0.00
		P5-002					0.00%	0.000	0.00	0.00	0.00
		P5-014					0.00%	0.000	0.00	0.00	0.00
	C5-903 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C5-905										
		P5-006		0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
	C5-905 Total			**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
45 Total				**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
46											
	C6-903										
		C6-903					0.00%	0.000	0.00	0.00	0.00
	C6-903 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
46 Total							**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
P Total				**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
Grand Total			4630.00	1121.26	1121.26	1127.50	24.22%	0.994	3528.27	4655.77	-25.77

Activities Screen Report

Activity ID	Activity Description	Ph.	Disc.	PP	IWP	Spent H	Earned H	CPI	SPI	S-V	C-V	T-V	F/ Day	FTC cost	F/ Date	IWP Total
H1000	C1-901 Construction	C	41	C1-901												
H1010	C1-902 Construction	C	41	C1-902												
IS00010	ISBL Site Work Detail Design for Bid	E	41	C1-902												
IS000550A	Temp Facilities - Contract Specs & Dwgs	E	41	C1-901	3.80	3.50	3.80	1.09	1.00	0.00	9.00	-9.00	0	0.00	19/11/1999	
IS000550B	Temp Facilities - Interdisc. Coord.	E	41	C1-901	7.00	7.00	7.00	1.00	1.00	0.00	0.00	0.00	0	0.00	26/11/1999	
IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	E	41	C1-901	3.12	3.00	3.12	1.04	1.00	0.00	3.60	-3.60	3	0.00	03/12/1999	22
IS000555A	Temp Facilities - Issue for Construction (RFC)	E	41	C1-901												
IS000555C	Temp Facilities - Issue Contract RFQ	P	41	C1-901												
IS000555D	Temp Facilities - Bid Period	P	41	C1-901												
IS000555E	Temp Facilities - Eval & Recommend	P	41	C1-901												
IS000555E1	Temp Facilities - Technical Evaluation	P	41	C1-901												
IS000555F	Temp Facilities - Issue Orange Folder for Appl	P	41	C1-901												
IS000555G	Temp Facilities - Award Contract	P	41	C1-901												
IS000555H	Temp Facilities - Contract - Award	P	41	C1-901												
IS000560M	Temp Facilities - Contractor's Mobilization	C	41	C1-901												
IS000560N	Install SLS Trailers & Temporary Facilities	C	41	C1-901												
IS010010M	Site Preparation - Contractor's Mobilization	C	41	C1-902												
IS010015N	Install Temporary Fencing	C	41	C1-902												
IS010020N	Install Permanent Fencing	C	41	C1-902												
IS010025N	Compl Excavation for Poly Bldg Area	C	41	C1-902												
IS010030N	Complete Surface Leveling Trailer/Parking Areas	C	41	C1-902												
IS010035N	Excavation Balance of Site Area	C	41	C1-902												
IS010040N	Demolition & Install Underground Piping System	C	41	C1-902												
IS010045N	Backfill Site to Required Elevation	C	41	C1-902												
IS010050A	Site Preparation - Contract Specs & Dwgs	E	41	C1-902	98.60	97.00	98.60	1.02	1.00	0.00	48.00	-48.00	-1	0.00	19/11/1999	

IS010050B	Site Preparation - Interdisc. Coord.	E	41	C1-902	196.40	201.00	196.40	[redacted]	1.00	0.00	-138.00	138.00	0	0.00	26/11/1999	
IS010050C	Site Preparation - Prepare Package for Bid (RFI)	E	41	C1-902	60.28	59.00	60.28	1.02	1.00	0.00	38.40	-38.40	3	0.00	03/12/1999	497
IS010050N	Prepare & Finish Surface Drainage	C	41	C1-902												
IS010055A	Site Preparation - Issue for Construction (RFC)	E	41	C1-902												
IS010055C	Site Preparation - Issue Contract RFQ	P	41	C1-902												
IS010055D	Site Preparation - Bid Period	P	41	C1-902												
IS010055E	Site Preparation - Eval & Recommend	P	41	C1-902												
IS010055G	Site Preparation - Award Contract	P	41	C1-902												
IS010055H	Site Preparation - Contract - Award	P	41	C1-902												
IS010055N	Demobilisation	C	41	C1-902												
OS00540	Laboratory - Install Plumbing & Piping	C	46	C6-903												
OS00950	WWT - Install Mech Equip. Services & Piping	C	45	C5-905												
OS010050A	OSBL Foundations - Contract Specs & Dwgs	E	42	C2-902	0.00	0.00	0.00									784
OS010050B	OSBL Foundations - Interdisc. Coord.	E	42	C2-902												
OS010050C	OSBL Foundations - Prepare Package for Bid (RFI)	E	42	C2-902												
OS010055A	OSBL Foundations - Issue for Construction (RFC)	E	42	C2-902												
OS010055C	OSBL Foundations - Issue Contract RFQ	P	42	C2-902												
OS010055D	OSBL Foundations - Bid Period	P	42	C2-902												
OS010055E	OSBL Foundations - Commercial Evaluation	P	42	C2-902												
OS010055E1	OSBL Foundations - Technical Evaluation	P	42	C2-902												
OS010055F	OSBL Founds - Issue Orange Folder for Approval	P	42	C2-902												
OS010055G	OSBL Foundations - Award Contract	P	42	C2-902												
OS010055H	OSBL Foundations - Contract - Award	P	42	C2-902												
OS010060M	OSBL Foundations - Contractor's Mobilization	C	42	C2-902												
OS010060N	Utility Building - Foundations	C	42	C2-902												
OS010065N	Laboratory - Civil Foundations	C	42	C2-902												
OS010070N	Material Handling Fnds	C	41	C2-902												
OS013050A	Site Prep South - Contract Specs & Dwgs	E	41	C1-903	0.00	0.00	0.00									213
OS013050B	Site Prep South - Interdisc. Coord.	E	41	C1-903												

OS013050C	Site Prep South - Prepare Package for Bid (RFI)	E	41	C1-903												
OS013055A	Site Prep South - Issue for Construction (RFC)	E	41	C1-903												
OS013055C	Site Prep South - Issue Contract RFQ	P	41	C1-903												
OS013055D	Site Prep South - Bid Period	P	41	C1-903												
OS013055E	Site Prep South - Commercial Evaluation	P	41	C1-903												
OS013055E1	Site Prep South - Technical Evaluation	E	41	C1-903												
OS013055F	Site Prep South - Iss Orange Folder for Approval	P	41	C1-903												
OS013055G	Site Prep South - Award Contract	P	41	C1-903												
OS013055H	Site Prep South - Contract - Award	P	41	C1-903												
OS013060M	Site Prep South - Contractor's Mobilization	C	41	C1-903												
OS013060N	Site Prep South - Sleeve U/G Piping & level	C	41	C1-903												
OS020050A	Piperack & HTM Fnds - Contract Specs & Dwgs	E	42	C2-903	0.00	0.00	0.00									200
OS020050B	Piperack & HTM Fnds - Interdisc. Coord.	E	42	C2-903												
OS020050C	Piperack & HTM Fnds - Prep Package for Bid (RFI)	E	42	C2-903												
OS020055A	Piperack & HTM Fnds - Iss for Construction (RFC)	E	42	C2-903												
OS020055C	Piperack & HTM Fnds - Issue Contract RFQ	P	42	C2-903												
OS020055D	Piperack & HTM Foundations - Bid Period	P	42	C2-903												
OS020055E	Piperack & HTM Fnds - Commercial Evaluation	P	42	C2-903												
OS020055E1	Piperack & HTM Fnds - Technical Evaluation	P	42	C2-903												
OS020055F	Piperack & HTM Fnds - Iss Orange Folder for Appl	P	42	C2-903												
OS020055G	Piperack & HTM Fnds - Award Contract	P	42	C2-903												
OS020055H	Piperack & HTM Fnds - Contract - Award	P	42	C2-903												
OS020060M	Piperack & HTM Fnds - Contractor's Mobilization	C	42	C2-903												
OS020060N	Piperacks - Foundations	C	42	C2-903												
OS031050A	Stor & Util Bldg Steel - Contract Specs & Dwgs	E	43	C3-902	0.00	0.00	0.00									620
OS031050B	Stor & Util Bldg Steel - Interdisc. Coord.	E	43	C3-902												
OS031050C	Stor & Util Bldg Steel - Prep Pkg for Bid (RFI)	E	43	C3-902												
OS031055A	Stor & Util Bldg Steel - Iss for Construct (RFC)	E	43	C3-902												
OS031055C	Stor & Util Bldg Steel - Issue Contract RFQ	P	43	C3-902												

OS031055D	Stor & Util Bldg Steel - Bid Period	P	43	C3-902												
OS031055E	Stor & Util Bldg Steel - Commercial Evaluation	P	43	C3-902												
OS031055E1	Stor & Util Bldg Steel - Technical Evaluation	P	43	C3-902												
OS031055F	Stor & Util Bldg St - Iss Orange Folder for Appl	P	43	C3-902												
OS031055G	Stor & Util Bldg Steel - Award Contract	P	43	C3-902												
OS031055H	Stor & Util Bldg Steel - Contract - Award	P	43	C3-902												
OS031055I	Utility Bldg Structural Steel Fab & Deliver	P	43	C3-902												
OS031055I1	Storage Bldg Struct. Steel Fab & Deliver	P	43	C3-902												
OS031060M	Stor & Util Bldg Steel - Contractor Mobilize	C	43	C3-902												
OS031060N	Storage Building - Erect Structural Steel	C	43	C3-902												
OS031065N	Utility Building - Erect Struct Steel	C	43	C3-902												
OS032050A	Piperack & HTM Steel - Contract Specs & Dwgs	E	43	C3-903	0.00	0.00	0.00									
OS032050B	Piperack & HTM Steel - Interdisc. Coord.	E	43	C3-903												
OS032050C	Piperack & HTM Steel - Prep Pkage for Bid (RFI)	E	43	C3-903												
OS032055A	Piperack & HTM Steel- Iss for Construction -RFC	E	43	C3-903												
OS032055C	Piperack & HTM Steel - Issue Contract RFQ	P	43	C3-903												
OS032055D	Piperack & HTM Steel - Bid Period	P	43	C3-903												
OS032055E	Piperack & HTM Steel - Commercial Evaluation	P	43	C3-903												
OS032055E1	Piperack & HTM Steel - Technical Evaluation	P	43	C3-903												
OS032055F	Piperack & HTM Steel- Iss Orange Folder.	P	43	C3-903												
OS032055G	Pipierack & HTM Steel - Award Contract	P	43	C3-903												
OS032055H	Piperack & HTM Steel - Contract - Award	P	43	C3-903												
OS032055I	Piperacks - Struct Steel Fabricate & Deliver	P	43	C3-903												
OS032060M	Piperack & HTM Steel - Contractor's Mobilization	C	43	C3-903												
OS032060N	Piperacks - Erect Piperack Steel	C	43	C3-903												
OS0510230N	Utility Building-Install Equipment & Services	C	45	C5-903												
OS059030A	OSBL Mech Installation - Contract Specs & Dwgs	E	45	C5-903	173.84	173.00	173.84	1.00	1.00	0.00	25.20	-25.20	43	0.00	28/01/2000	530
OS059030B	OSBL Mech Installation - Interdisc. Coord.	E	45	C5-903												
OS059030C	OSBL Mech Install- Prepare Package for Bid -RFI	E	45	C5-903												

OS0590310M	OSBL Mech Installati - Contractor's Mobilization	C	45	C5-903												
OS0590315N	Utility Building - Inst Demin Water Equip & Pipg	C	45	C5-903												
OS0590320N	Utility Building-Inst Chilled Water Equip & Pipg	C	45	C5-903												
OS0590325N	Utility Building-Inst Material Handling Blowers	C	45	C5-903												
OS0590335N	PTA Unloading Install Equipment	C	45	C5-903												
OS0590340N	PTT Car Loading Install Equipment	C	45	C5-903												
OS0590345N	Laboratory-Install Mech Bldg Services Equipment	C	45	C5-903												
OS0590350N	Laboratory - Install Laboratory Equipment	C	45	C5-903												
OS0590355N	PDO Storage Install Pumps & Piping	C	45	C5-903												
OS059035A	OSBL Mech Install - Issue for Construction (RFC)	E	45	C5-903												
OS059035C	OSBL Mech Installation - Issue Contract RFQ	P	45	C5-903												
OS059035D	OSBL Mech Installation - Bid Period	P	45	C5-903												
OS059035E	OSBL Mech Installation - Commercial Evaluation	P	45	C5-903												
OS059035E1	OSBL Mech Installation - Technical Evaluation	P	45	C5-903												
OS059035F	OSBL Mech Install - Iss Orange Folder for Appl	P	45	C5-903												
OS059035G	OSBL Mech Installation - Award Contract	P	45	C5-903												
OS059035H	OSBL Mech Installation - Contract - Award	P	45	C5-903												
OS063050A	OSBL Piping - Contract Specs & Dwgs	E	46	C6-903	477.88	485.00	477.88	[redacted]	1.00	0.00	-213.60	213.60	23	0.00	31/12/1999	1457
OS063050B	OSBL Piping - Interdisc. Coord.	E	46	C6-903												
OS063050C	OSBL Piping - Prepare Package for Bid (RFI)	E	46	C6-903												
OS063055A	OSBL Piping - Issue for Construction (RFC)	E	46	C6-903												
OS063055C	OSBL Piping - Issue Contract RFQ	P	46	C6-903												
OS063055D	OSBL Piping - Bid Period	P	46	C6-903												
OS063055E	OSBL Piping - Commercial Evaluation	P	46	C6-903												
OS063055E1	OSBL Piping - Technical Evaluation	P	46	C6-903												
OS063055F	OSBL Piping - Issue Orange Folder for Approval	P	46	C6-903												
OS063055G	OSBL Piping - Award Contract	P	46	C6-903												
OS063055H	OSBL Piping - Contract - Award	P	46	C6-903												
OS063060M	OSBL Piping - Contractor's Mobilization	C	46	C6-903												

OS500205A	Pumps - Eng. Specs	E	45	C5-903	20.40	20.00	20.40	1.02	1.00	0.00	12.00	-12.00	8	0.00	10/12/1999	137
OS500205B	Pumps - Interdisc Coord.	E	45	C5-903												
OS500205C	Pumps - RFI Issued by Eng.	E	45	C5-903												
OS500210C	Pumps - RFQ Issued.	P	45	C5-903												
OS500210D	Pumps - Bid Period/Bid Rec'd.	P	45	C5-903												
OS500210E	Pumps - Commercial Evaluation.	P	45	C5-903												
OS500210E1	Pumps - Technical Evaluation	E	45	C5-903												
OS500210F	Pumps - Issue P.O. Folder for Appr.	P	45	C5-903												
OS500210G	Pumps - Award Purchase Order	P	45	C5-903												
OS500210G1	Pumps - Purchase Order Award	P	45	C5-903												
OS500210H	Pumps - 1st Vend Dwgs Rec.	P	45	C5-903												
OS500210H1	Pumps - Cert Vend Dwg Appr.	P	45	C5-903												
OS500210I	Pumps - Vend Dwg Appr.	E	45	C5-903												
OS500210J	Pumps - Fabricate.	P	45	C5-903												
OS500210N	Pumps - Deliver.	C	45	C5-903												
OS500610A	WWT - Prepare Performance Spec (RFI)	E	45	C5-905	67.50	67.00	67.50	1.01	1.00	0.00	15.00	-15.00	0	0.00	12/11/1999	150
OS500610C	WWT - RFQ Issued.	P	45	C5-905	0.00	0.00	0.00								19/11/1999	
OS500610D	WWT - Bid Period/Bid Rec'd.	P	45	C5-905											30/11/1999	
OS500610E	WWT - Commercial Evaluation.	P	45	C5-905												
OS500610E1	WWT - Technical Evaluation	E	45	C5-905												
OS500610F	WWT - Issue P.O. Folder for Appr.	P	45	C5-905												
OS500610G	WWT- Award Purchase Order	P	45	C5-905												
OS500610G1	WWT - Purchase Order Award	P	45	C5-905												
OS500610H1	WWT - Vendor Prepare Design Drawings	P	45	C5-905												
OS500610H2	WWT - Vendor Design Review	E	45	C5-905												
OS500610H3	WWT - Vendor Place Equipment Orders	P	45	C5-905												
OS500610H4	WWT - 1st Vend Equipment Dwgs Rec.	P	45	C5-905												
OS500610I	WWT - 1st Vendor Equipment Dwg Appr.	E	45	C5-905												
OS500610J	WWT - Fabricate WWT Equipment.	P	45	C5-905												

OS500610N	WWT - Deliver.	C	45	C5-905												
OS500620H	WWT - Cert Vend Dwg Appr.	P	45	C5-905												
OS501410N	Rail Car Weight Scale - Deliver.	P	45	C5-903												
IS47901A	Temp Facilities-Elec-Contract Specs & Dwgs	E	47	C7-901	4.00	4.00	4.00	1.00	1.00	0.00	0.00	0.00	0	0.00	19/11/1999	20
IS47901B	Temp Facilities-Elect- Interdisc. Coord.	E	47	C7-901	6.20	6.00	6.20	1.03	1.00	0.00	6.00	-6.00	0	0.00	26/11/1999	
IS47901C	Temp Facilities-Elect-Prepare Package for Bid (RFI)	E	47	C7-901	2.24	2.00	2.24	1.12	1.00	0.00	7.20	-7.20	3	0.00	03/12/1999	

PM+ REPORT

PM

IM001 PREV

SUMMARY WORK HOUR ANALYSIS BY DEPARTMENT/DISCIPLINE/IWP

Project: CM006 : Copy of CM004 (1) concordia

Client: Typical Client

Scope of report for IWP: 4% and Task: All Tasks

SNC·LAVALIN

Report date: 2006-08-18

Time: 23:22:36

Period Start: 1988-11-01

Period End: 1988-11-30

Department / Discipline / Internal Work Package (IWP)		Control Budget		Allocated Budget (wkhrs)					Earned(wkhrs)			Actual (wkhrs)		Forecast					Budget
		Disc.	IWP	Original (A)	Approved (B)	Transfer (C)	Revised (D=A+B+C)	Pending (E)	Revised (F)	Pending (G)	Total (H=F+G)	Period (I)	To-Date (J)	FTC (K)	Final (L=J+K)	CPI (M=H/J)	Earned (%) (N=H/(D+E))	Compl. (%) (O=J/L)	Var. (P=D-L)
4	**ENGINEERING**																		
4-0	**ENGINEERING MANAGEMENT**																		
40-01	*Engineering Manager*		780	780	0	0	780	0	16	0	16	15	15	765	780	1.04	2	2	0
40-02	*Environmental Engineer*		650	650	0	0	650	0	20	0	20	19	19	630	649	1.03	3	3	1
Subtotal Discipline: 4-0		1,430	1,430	1,430	0	0	1,430	0	35	0	35	34	34	1,395	1,429	1.03	2	2	1
4-1	**CIVIL**																		
41-0000	*General*		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
41-1901	*Install temporary Fcality*		22	22	0	0	22	0	14	0	14	14	14	8	22	1.03	63	63	1
41-1902	*Site Preparation & Underground Services*		497	497	0	0	497	0	353	0	353	357	357	140	497	0.99	71	72	0
41-1903	*Site Preparation Work Under R/R & South*		213	213	0	0	213	0	0	0	0	0	0	213	213	0.00	0	0	0
41-1904	*Railroad*		174	174	0	0	174	0	0	0	0	0	0	174	174	0.00	0	0	0
41-1906	*Roads & Container Storage Area Paving*		157	157	0	0	157	0	0	0	0	0	0	157	157	0.00	0	0	0
Subtotal Discipline: 4-1		1,063	1,063	1,063	0	0	1,063	0	367	0	367	371	371	692	1,063	0.99	35	35	1
4-2	**CONCRETE ENGINEERING**																		
42-0000	*General*		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
42-2902	*OSBL Founds - Utility, Lab,El & Mat Han*		784	784	0	0	784	0	0	0	0	0	0	784	784	0.00	0	0	0
42-2903	*New Piperack & HTU Foundations*		616	616	0	0	616	0	0	0	0	0	0	616	616	0.00	0	0	0
42-2905	*Miscellaneous Concrete Works*		207	207	0	0	207	0	0	0	0	0	0	207	207	0.00	0	0	0
Subtotal Discipline: 4-2		1,507	1,607	1,607	0	0	1,607	0	0	0	0	0	0	1,607	1,607	0.00	0	0	0
4-3	**STRUCTURAL**																		
43-0000	*General*		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
43-3902	*Utility Bids & Lab Structural Steel*		620	620	0	0	620	0	0	0	0	0	0	620	620	0.00	0	0	0
Subtotal Discipline: 4-3		620	620	620	0	0	620	0	0	0	0	0	0	620	620	0.00	0	0	0

IM001 PREV

SUMMARY WORK HOUR ANALYSIS BY DEPARTMENT/DISCIPLINE/IWP

Project: CM005 : Copy of CM004 (1) concordia

Client: Typical Client

Scope of report for IWP: 4%   and Task: All Tasks

SNC·LAVALIN

Report date: 2005-08-18

Time: 23:22:35

Period Start: 1998-11-01

Period End: 1998-11-30

Department / Discipline / Internal Work Package (IWP)		Control Budget		Allocated Budget (wkhrs)					Earned(wkhrs)			Actual (wkhrs)		Forecast					Budget
		Disc.	IWP	Original (A)	Approved (B)	Transfer (C)	Revised (D=A+B+C)	Pending (E)	Revised (F)	Pending (G)	Total (H=F+G)	Period (I)	To-Date (J)	FTC (K)	Final (L=J+K)	CPI (M=H/J)	Earned (%) (N=H/(D+E))	Compl. (%) (O=J/L)	Var. (P=D-L)
4	ENGINEERING																		
4-4	ARCHITECTURE																		
44-0000	General		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
44-4902	Arch Siding Util/Elec,Lab,Matl/Han& Store		365	365	0	0	365	0	0	0	0	0	0	365	365	0.00	0	0	0
44-4906	Arch Util/Elec,Lab,Matl/Han Finishes		247	247	0	0	247	0	0	0	0	0	0	247	247	0.00	0	0	0
44-4907	Service Doors		297	297	0	0	297	0	0	0	0	0	0	297	297	0.00	0	0	0
Subtotal Discipline: 4-4		909	909	909	0	0	909	0	0	0	0	0	0	909	909	0.00	0	0	0
4-5	MECHANICAL																		
45-0000	General		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
45-2902	OSBL Founds - Utility, Lab, El & Matl Han		477	477	0	0	477	0	0	0	0	0	0	477	477	0.00	0	0	0
45-6002	Pumps		137	137	0	0	137	0	20	0	20	20	20	116	136	1.02	15	15	1
45-6006	Waste water treatment package		150	150	0	0	150	0	58	0	68	57	57	82	149	1.01	45	45	1
45-6007	PTT Car Loading Equipment Package		169	169	0	0	169	0	0	0	0	0	0	169	169	0.00	0	0	0
45-6011	Safety Showers & Eye Wash		75	75	0	0	75	0	0	0	0	0	0	75	75	0.00	0	0	0
45-6013	Car Pullers CANCELLED		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
45-6014	Rail Car Weigh Scale		10	10	0	0	10	0	0	0	0	0	0	10	10	0.00	0	0	0
45-6903	Install OSBL Mechanical Equipment		1,693	1,693	0	0	1,693	0	174	0	174	173	173	1,520	1,693	1.00	10	10	0
45-6904	HVAC Install UTIL,Lab,Storage &CntRooms		594	594	0	0	594	0	0	0	0	0	0	594	594	0.00	0	0	0
45-6906	Field Erected Tanks & Silos		60	60	0	0	60	0	0	0	0	0	0	60	60	0.00	0	0	0
45-6907	Plumbing & Safety Showers		490	490	0	0	490	0	0	0	0	0	0	490	490	0.00	0	0	0
45-6908	Fire Protections Systems Installation		316	316	0	0	316	0	0	0	0	0	0	316	316	0.00	0	0	0
Subtotal Discipline: 4-5		4,171	4,171	4,171	0	0	4,171	0	262	0	262	260	260	3,909	4,169	1.01	6	6	2
4-8	PIPING																		
48-0000	General		160	160	0	0	160	0	0	0	0	0	0	160	160	0.00	0	0	0

PM

M001 PREV

SUMMARY WORK HOUR ANALYSIS BY DEPARTMENT/DISCIPLINE/IWP

Project: CM005 : Copy of CM004 (1) concordia

Client: Typical Client

Scope of report for IWP: 4% and Task: All Tasks

SNC·LAVALIN

Report date: 2005-08-18

Time: 23:22:35

Period Start: 1999-11-01

Period End: 1999-11-30

Department / Discipline / Internal Work Package (IWP)		Control Budget		Allocated Budget (wkhrs)					Earned(wkhrs)			Actual (wkhrs)		Forecast					Budget
		Disc.	IWP	Original (A)	Approved (B)	Transfer (C)	Revised (D=A+B+C)	Pending (E)	Revised (F)	Pending (G)	Total (H=F+G)	Period (I)	To-Date (J)	FTC (K)	Final (L=J+K)	CPI (M=H/J)	Earned (%) (N=H/(D+E))	Compl. (%) (O=J/L)	Var. (P=D-L)
4	ENGINEERING																		
4-8	PIPING																		
46-6002	Manual Valves		120	120	0	0	120	120	0	0	0	0	0	120	120	0.00	0	0	0
46-6901	Coastal Piping Modifications & Tie - ins		50	50	0	0	50	0	0	0	0	0	0	50	50	0.00	0	0	0
46-6902	OSBL Piperack Piping Installation		1,380	1,380	0	0	1,380	0	0	0	0	0	0	1,380	1,380	0.00	0	0	0
46-6903	OSBL Piping Installation		1,537	1,537	0	0	1,537	0	476	0	476	485	485	1,063	1,548	0.98	31	31	-11
46-6906	Piping & Equipment Insulation		100	100	0	0	100	0	0	0	0	0	0	100	100	0.00	0	0	0
Subtotal Discipline: 4-8		3,347	3,347	3,347	0	0	3,347	120	476	0	476	485	485	2,873	3,358	0.98	14	14	-11
4-7	ELECTRICAL																		
47-0000	General		630	430	0	0	430	0	0	0	0	0	0	430	430	0.00	0	0	0
47-1901	Install Temporary Facilities(Electrical)		20	20	0	0	20	0	12	0	12	12	12	8	20	1.04	62	60	0
47-1902	Site Preparation & Underground Services		140	140	0	0	140	0	0	0	0	0	0	140	140	0.00	0	0	0
47-2902	OSBL Founds - Utility, Lab, El & Matl Han		50	50	0	0	50	0	0	0	0	0	0	50	50	0.00	0	0	0
47-7902	OSBL Electrical &Instrument Installation		2,800	1,860	0	0	1,860	0	0	0	0	0	0	1,860	1,860	0.00	0	0	0
Subtotal Discipline: 4-7		3,640	3,640	2,500	0	0	2,500	0	12	0	12	12	12	2,488	2,500	1.04	0	0	0
Subtotal Department: 4		16,787	16,787	15,647	0	0	15,647	120	1,152	0	1,152	1,162	1,162	14,493	15,655	0.99	7	7	-8
Total :		16,787	16,787	15,647	0	0	15,647	120	1,152	0	1,152	1,162	1,162	14,493	15,655	0.99	7	7	-8

Page 3 of 3

PERIOD No 2

01/12/1991 ~ 31/12/1999

TEDS REPORTS

Dynamic Report

1- Selection By: All Phases, all Disciplines, and all Commitment Packages

Project Name	Poly.xls
Report Date	31/12/1999
Period Number	2

PHAS	DISC	CPKG	PPKG	Total-IWP	IWP	Earned-H	Spent-H	%Complete	CPI	FTC	BAC	Variance
C												
	41											
		C1-901										
			C1-901					0.00%	0.000	0.00	0.00	0.00
		C1-901 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
		C1-902										
			C1-902					0.00%	0.000	0.00	0.00	0.00
		C1-902 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
		C1-903										
			C1-903					0.00%	0.000	0.00	0.00	0.00
		C1-903 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
		C2-902										
			C2-902					0.00%	0.000	0.00	0.00	0.00
		C2-902 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**

41 Total			**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
42							
	C2-902						
		C2-902	0.00%	0.000	0.00	0.00	0.00
	C2-902 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C2-903						
		C2-903	0.00%	0.000	0.00	0.00	0.00
	C2-903 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
42 Total			**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43							
	C3-902						
		C3-902	0.00%	0.000	0.00	0.00	0.00
	C3-902 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C3-903						
		C3-903	0.00%	0.000	0.00	0.00	0.00
	C3-903 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43 Total			**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
45							
	C5-903						
		C5-903	0.00%	0.000	0.00	0.00	0.00
		P5-002	0.00%	0.000	0.00	0.00	0.00
	C5-903 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**

		C5-905										
			C5-905					0.00%	0.000	0.00	0.00	0.00
			P5-006					0.00%	0.000	0.00	0.00	0.00
		C5-905 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	45 Total							**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	46											
		C6-903										
			C6-903					0.00%	0.000	0.00	0.00	0.00
		C6-903 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	46 Total							**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
C Total								**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
E												
	41											
		C1-901										
			C1-901	22.00	20.54	20.54	19.75	93.38%	1.040	1.40	21.15	0.85
		C1-901 Total		**22.00**	**20.54**	**20.54**	**19.75**	**93.38%**	**1.040**	**1.40**	**21.15**	**0.85**
		C1-902										
			C1-902	497.00	462.89	462.89	462.00	93.14%	1.002	34.05	496.05	0.95
		C1-902 Total		**497.00**	**462.89**	**462.89**	**462.00**	**93.14%**	**1.002**	**34.05**	**496.05**	**0.95**
		C1-903										
			C1-903	213.00	0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00

	C1-903 Total		**213.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
41 Total			**732.00**	**483.43**	**483.43**	**481.75**	**66.04%**	**1.003**	**247.71**	**729.46**	**2.54**
42											
	C2-902										
		C2-902	784.00	0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
	C2-902 Total		**784.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C2-903										
		C2-903	200.00	0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
	C2-903 Total		**200.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
42 Total			**984.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43											
	C3-902										
		C3-902	620.00	0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
	C3-902 Total		**620.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C3-903										
		C3-903		0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
	C3-903 Total			**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43 Total			**620.00**	**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
45											
	C5-903										
		C5-903	530.00	270.19	270.19	269.00	50.98%	1.004	258.67	527.67	2.33

		P5-002	137.00	57.10	57.10	55.00	41.68%	1.038	76.96	131.96	5.04
	C5-903 Total		**667.00**	**327.29**	**327.29**	**324.00**	**49.07%**	**1.010**	**336.30**	**660.30**	**6.70**
	C5-905										
		P5-006	150.00	67.50	67.50	67.00	45.00%	1.007	81.89	148.89	1.11
	C5-905 Total		**150.00**	**67.50**	**67.50**	**67.00**	**45.00%**	**1.007**	**81.89**	**148.89**	**1.11**
45 Total			**817.00**	**394.79**	**394.79**	**391.00**	**48.32%**	**1.010**	**418.16**	**809.16**	**7.84**
46											
	C6-903										
		C6-903	1457.00	866.30	866.30	866.00	59.46%	1.000	590.50	1456.50	0.50
	C6-903 Total		**1457.00**	**866.30**	**866.30**	**866.00**	**59.46%**	**1.000**	**590.50**	**1456.50**	**0.50**
46 Total			**1457.00**	**866.30**	**866.30**	**866.00**	**59.46%**	**1.000**	**590.50**	**1456.50**	**0.50**
47											
	C7-901										
		C7-901	20.00	18.75	18.75	18.50	93.74%	1.013	1.24	19.74	0.26
	C7-901 Total		**20.00**	**18.75**	**18.75**	**18.50**	**93.74%**	**1.013**	**1.24**	**19.74**	**0.26**
47 Total			**20.00**	**18.75**	**18.75**	**18.50**	**93.74%**	**1.013**	**1.24**	**19.74**	**0.26**
E Total			**4630.00**	**1763.27**	**1763.27**	**1757.25**	**38.08%**	**1.003**	**2856.95**	**4614.20**	**15.80**
P											
41											
	C1-901										
		C1-901					0.00%	0.000	0.00	0.00	0.00

	C1-901 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C1-902						
		C1-902	0.00%	0.000	0.00	0.00	0.00
	C1-902 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C1-903						
		C1-903	0.00%	0.000	0.00	0.00	0.00
	C1-903 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
41 Total			**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
42							
	C2-902						
		C2-902	0.00%	0.000	0.00	0.00	0.00
	C2-902 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C2-903						
		C2-903	0.00%	0.000	0.00	0.00	0.00
	C2-903 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
42 Total			**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43							
	C3-902						
		C3-902	0.00%	0.000	0.00	0.00	0.00
	C3-902 Total		**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C3-903						

		C3-903					0.00%	0.000	0.00	0.00	0.00
	C3-903 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
43 Total							**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
45											
	C5-903										
		C5-903					0.00%	0.000	0.00	0.00	0.00
		P5-002					0.00%	0.000	0.00	0.00	0.00
		P5-014					0.00%	0.000	0.00	0.00	0.00
	C5-903 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
	C5-905										
		P5-006		0.00	0.00	0.00	0.00%	0.000	0.00	0.00	0.00
	C5-905 Total			**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
45 Total				**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
46											
	C6-903										
		C6-903					0.00%	0.000	0.00	0.00	0.00
	C6-903 Total						**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
46 Total							**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
P Total				**0.00**	**0.00**	**0.00**	**0.00%**	**0.000**	**0.00**	**0.00**	**0.00**
Grand Total			**4630.00**	**1763.27**	**1763.27**	**1757.25**	**38.08%**	**1.003**	**2856.95**	**4614.20**	**15.80**

Activities Screen Report

Activity Code	Activity Description	PH.	DIS.	PPKG	IWP	Spent Hours	Earned Hours	%Com	CPI	SPI	S-V	C-V	T-V	FTC Days	FTC-Cost	Forecasted Date	Total IWP
1000		C	46	C6-903													
H1000	C1-901 Construction	C	41	C1-901													
H1010	C1-902 Construction	C	41	C1-902													
IS00010	ISBL Site Work Detail Design for Bid	E	41	C1-902													
IS000550A	Temp Facilities - Contract Specs & Dwgs	E	41	C1-901	3.80	3.50	3.80	17.27	1.09	1.00	0.00	9.00	-9.00	0.00	0.00	19/11/1999	
IS000550B	Temp Facilities - Interdisc. Coord.	E	41	C1-901	7.00	7.00	7.00	31.82	1.00	1.00	0.00	0.00	0.00	0.00	0.00	26/11/1999	
IS000550C	Temp Facilities - Prepare Package for Bid (RFI)	E	41	C1-901	7.80	7.50	7.80	35.45	1.04	1.00	0.00	9.00	-9.00	0.00	0.00	03/12/1999	22
IS000555A	Temp Facilities - Issue for Construction (RFC)	E	41	C1-901	1.94	1.75	1.94	8.83	1.11	1.00	0.00	5.79	-5.79	10.00	0.00	14/01/2000	
IS000555C	Temp Facilities - Issue Contract RFQ	P	41	C1-901													
IS000555D	Temp Facilities - Bid Period	P	41	C1-901													
IS000555E	Temp Facilities - Eval & Recommend	P	41	C1-901													
IS000555E1	Temp Facilities - Technical Evaluation	P	41	C1-901													
IS000555F	Temp Facilities - Issue Orange Folder for Appl	P	41	C1-901													
IS000555G	Temp Facilities - Award Contract	P	41	C1-901													
IS000555H	Temp Facilities - Contract - Award	P	41	C1-901													
IS000560M	Temp Facilities - Contractor's Mobilization	C	41	C1-901													
IS000560N	Install SLS Trailers & Temporary Facilities	C	41	C1-901													
IS010010M	Site Preparation - Contractor's Mobilization	C	41	C1-902													
IS010015N	Install Temporary Fencing	C	41	C1-902													
IS010020N	Install Permanent Fencing	C	41	C1-902													
IS010025N	Compl Excavation for Poly Bldg Area	C	41	C1-902													

IS010030N	Complete Surface Leveling Trailer/Parking Areas	C	41	C1-902													
IS010035N	Excavation Balance of Site Area	C	41	C1-902													
IS010040N	Demolition & Install Underground Piping Systems	C	41	C1-902													
IS010045N	Backfill Site to Required Elevation	C	41	C1-902													
IS010050A	Site Preparation - Contract Specs & Dwgs	E	41	C1-902	98.60	97.00	98.60	19.84	1.02	1.00	0.00	48.00	-48.00	0.00	0.00	19/11/1999	
IS010050B	Site Preparation - Interdisc. Coord.	E	41	C1-902	196.40	201.00	196.40	39.52	[redacted]	1.00	0.00	-138.00	138.00	0.00	0.00	26/11/1999	
IS010050C	Site Preparation - Prepare Package for Bid (RFI)	E	41	C1-902	150.70	150.00	150.70	30.32	1.00	1.00	0.00	21.00	-21.00	0.00	0.00	03/12/1999	497
IS010050N	Prepare & Finish Surface Drainage	C	41	C1-902													
IS010055A	Site Preparation - Issue for Construction (RFC)	E	41	C1-902	17.19	14.00	17.19	3.46	1.23	1.00	0.00	95.56	-95.56	10.00	0.00	14/01/2000	
IS010055C	Site Preparation - Issue Contract RFQ	P	41	C1-902													
IS010055D	Site Preparation - Bid Period	P	41	C1-902													
IS010055E	Site Preparation - Eval & Recommend	P	41	C1-902													
IS010055G	Site Preparation - Award Contract	P	41	C1-902													
IS010055H	Site Preparation - Contract - Award	P	41	C1-902													
IS010055N	Demobilisation	C	41	C1-902													
OS00540	Laboratory - Install Plumbing & Piping	C	46	C6-903													
OS00950	WWT - Install Mech Equip. Services & Piping	C	45	C5-905													
OS010050A	OSBL Foundations - Contract Specs & Dwgs	E	42	C2-902	0.00	0.00	0.00	0.00									784
OS010050B	OSBL Foundations - Interdisc. Coord.	E	42	C2-902													
OS010050C	OSBL Foundations - Prepare Package for Bid (RFI)	E	42	C2-902													
OS010055A	OSBL Foundations - Issue for Construction (RFC)	E	42	C2-902													
OS010055C	OSBL Foundations - Issue Contract RFQ	P	42	C2-902													
OS010055D	OSBL Foundations - Bid Period	P	42	C2-902													
OS010055E	OSBL Foundations - Commercial Evaluation	P	42	C2-902													
OS010055E1	OSBL Foundations - Technical Evaluation	P	42	C2-902													

OS010055F	OSBL Founds - Issue Orange Folder for Approval	P	42	C2-902													
OS010055G	OSBL Foundations - Award Contract	P	42	C2-902													
OS010055H	OSBL Foundations - Contract - Award	P	42	C2-902													
OS010060M	OSBL Foundations - Contractor's Mobilization	C	42	C2-902													
OS010060N	Utility Building - Foundations	C	42	C2-902													
OS010065N	Laboratory - Civil Foundations	C	42	C2-902													
OS010070N	Material Handling Fnds	C	41	C2-902													
OS013050A	Site Prep South - Contract Specs & Dwgs	E	41	C1-903	0.00	0.00	0.00	0.00									213
OS013050B	Site Prep South - Interdisc. Coord.	E	41	C1-903													
OS013050C	Site Prep South - Prepare Package for Bid (RFI)	E	41	C1-903													
OS013055A	Site Prep South - Issue for Construction (RFC)	E	41	C1-903													
OS013055C	Site Prep South - Issue Contract RFQ	P	41	C1-903													
OS013055D	Site Prep South - Bid Period	P	41	C1-903													
OS013055E	Site Prep South - Commercial Evaluation	P	41	C1-903													
OS013055E1	Site Prep South - Technical Evaluation	E	41	C1-903													
OS013055F	Site Prep South - Iss Orange Folder for Approval	P	41	C1-903													
OS013055G	Site Prep South - Award Contract	P	41	C1-903													
OS013055H	Site Prep South - Contract - Award	P	41	C1-903													
OS013060M	Site Prep South - Contractor's Mobilization	C	41	C1-903													
OS013060N	Site Prep South - Sleeve U/G Piping & level	C	41	C1-903													
OS020050A	Piperack & HTM Fnds - Contract Specs & Dwgs	E	42	C2-903	0.00	0.00	0.00	0.00									200
OS020050B	Piperack & HTM Fnds - Interdisc. Coord.	E	42	C2-903													
OS020050C	Piperack & HTM Fnds - Prep Package for Bid (RFI)	E	42	C2-903													
OS020055A	Piperack & HTM Fnds - Iss for Construction (RFC)	E	42	C2-903													
OS020055C	Piperack & HTM Fnds - Issue Contract RFQ	P	42	C2-903													

OS020055D	Piperack & HTM Foundations - Bid Period	P	42	C2-903													
OS020055E	Piperack & HTM Fnds - Commercial Evaluation	P	42	C2-903													
OS020055E1	Piperack & HTM Fnds - Technical Evaluation	P	42	C2-903													
OS020055F	Piperack & HTM Fnds - Iss Orange Folder for Appl	P	42	C2-903													
OS020055G	Piperack & HTM Fnds - Award Contract	P	42	C2-903													
OS020055H	Piperack & HTM Fnds - Contract - Award	P	42	C2-903													
OS020060M	Piperack & HTM Fnds - Contractor's Mobilization	C	42	C2-903													
OS020060N	Piperacks - Foundations	C	42	C2-903													
OS031050A	Stor & Util Bldg Steel - Contract Specs & Dwgs	E	43	C3-902	0.00	0.00	0.00	0.00									620
OS031050B	Stor & Util Bldg Steel - Interdisc. Coord.	E	43	C3-902													
OS031050C	Stor & Util Bldg Steel - Prep Pkg for Bid (RFI)	E	43	C3-902													
OS031055A	Stor & Util Bldg Steel - Iss for Construct (RFC)	E	43	C3-902													
OS031055C	Stor & Util Bldg Steel - Issue Contract RFQ	P	43	C3-902													
OS031055D	Stor & Util Bldg Steel - Bid Period	P	43	C3-902													
OS031055E	Stor & Util Bldg Steel - Commercial Evaluation	P	43	C3-902													
OS031055E1	Stor & Util Bldg Steel - Technical Evaluation	P	43	C3-902													
OS031055F	Stor & Util Bldg St - Iss Orange Folder for Appl	P	43	C3-902													
OS031055G	Stor & Util Bldg Steel - Award Contract	P	43	C3-902													
OS031055H	Stor & Util Bldg Steel - Contract - Award	P	43	C3-902													
OS031055I	Utility Bldg Structural Steel Fab & Deliver	P	43	C3-902													
OS031055I1	Storage Bldg Struct. Steel Fab & Deliver	P	43	C3-902													
OS031060M	Stor & Util Bldg Steel - Contractor Mobilize	C	43	C3-902													
OS031060N	Storage Building - Erect Structural Steel	C	43	C3-902													
OS031065N	Utility Building - Erect Struct Steel	C	43	C3-902													
OS032050A	Piperack & HTM Steel - Contract Specs & Dwgs	E	43	C3-903	0.00	0.00	0.00	0.00									

OS032050B	Piperack & HTM Steel - Interdisc. Coord.	E	43	C3-903													
OS032050C	Piperack & HTM Steel - Prep Pkage for Bid (RFI)	E	43	C3-903													
OS032055A	Piperack & HTM Steel- Iss for Construction (RFC)	E	43	C3-903													
OS032055C	Piperack & HTM Steel - Issue Contract RFQ	P	43	C3-903													
OS032055D	Piperack & HTM Steel - Bid Period	P	43	C3-903													
OS032055E	Piperack & HTM Steel - Commercial Evaluation	P	43	C3-903													
OS032055E1	Piperack & HTM Steel - Technical Evaluation	P	43	C3-903													
OS032055F	Piperack & HTM Steel- Iss Orange Folder for Appl	P	43	C3-903													
OS032055G	Pipierack & HTM Steel - Award Contract	P	43	C3-903													
OS032055H	Piperack & HTM Steel - Contract - Award	P	43	C3-903													
OS032055I	Piperacks - Struct Steel Fabricate & Deliver	P	43	C3-903													
OS032060M	Piperack & HTM Steel - Contractor's Mobilization	C	43	C3-903													
OS032060N	Piperacks - Erect Piperack Steel	C	43	C3-903													
OS0510230N	Utility Building-Install Equipment & Services	C	45	C5-903													
OS059030A	OSBL Mech Installation - Contract Specs & Dwgs	E	45	C5-903	270.19	269.00	270.19	50.98	1.00	1.00	0.00	35.70	-35.70	20.00	0.00	28/01/2000	530
OS059030B	OSBL Mech Installation - Interdisc. Coord.	E	45	C5-903													
OS059030C	OSBL Mech Install- Prepare Package for Bid (RFI)	E	45	C5-903													
OS0590310M	OSBL Mech Installati - Contractor's Mobilization	C	45	C5-903													
OS0590315N	Utility Building - Inst Demin Water Equip & Pipg	C	45	C5-903													
OS0590320N	Utility Building-Inst Chilled Water Equip & Pipg	C	45	C5-903													
OS0590325N	Utility Building-Inst Material Handling Blowers	C	45	C5-903													
OS0590335N	PTA Unloading Install Equipment	C	45	C5-903													
OS0590340N	PTT Car Loading Install Equipment	C	45	C5-903													
OS0590345N	Laboratory-Install Mech Bldg Services Equipment	C	45	C5-903													

OS0590350N	Laboratory - Install Laboratory Equipment	C	45	C5-903													
OS0590355N	PDO Storage Install Pumps & Piping	C	45	C5-903													
OS059035A	OSBL Mech Install - Issue for Construction (RFC)	E	45	C5-903													
OS059035C	OSBL Mech Installation - Issue Contract RFQ	P	45	C5-903													
OS059035D	OSBL Mech Installation - Bid Period	P	45	C5-903													
OS059035E	OSBL Mech Installation - Commercial Evaluation	P	45	C5-903													
OS059035E1	OSBL Mech Installation - Technical Evaluation	P	45	C5-903													
OS059035F	OSBL Mech Install - Iss Orange Folder for Appl	P	45	C5-903													
OS059035G	OSBL Mech Installation - Award Contract	P	45	C5-903													
OS059035H	OSBL Mech Installation - Contract - Award	P	45	C5-903													
OS063050A	OSBL Piping - Contract Specs & Dwgs	E	46	C6-903	866.30	866.00	866.30	59.46	1.00	1.00	0.00	9.00	-9.00	0.00	0.00	31/12/1999	1457
OS063050B	OSBL Piping - Interdisc. Coord.	E	46	C6-903													
OS063050C	OSBL Piping - Prepare Package for Bid (RFI)	E	46	C6-903													
OS063055A	OSBL Piping - Issue for Construction (RFC)	E	46	C6-903													
OS063055C	OSBL Piping - Issue Contract RFQ	P	46	C6-903													
OS063055D	OSBL Piping - Bid Period	P	46	C6-903													
OS063055E	OSBL Piping - Commercial Evaluation	P	46	C6-903													
OS063055E1	OSBL Piping - Technical Evaluation	P	46	C6-903													
OS063055F	OSBL Piping - Issue Orange Folder for Approval	P	46	C6-903													
OS063055G	OSBL Piping - Award Contract	P	46	C6-903													
OS063055H	OSBL Piping - Contract - Award	P	46	C6-903													
OS063060M	OSBL Piping - Contractor's Mobilization	C	46	C6-903													
OS500205A	Pumps - Eng. Specs	E	45	P5-002	30.80	30.00	30.80	22.48	1.03	1.00	0.00	24.00	-24.00	0.00	0.00	10/12/1999	137
OS500205B	Pumps - Interdisc Coord.	E	45	P5-002	0.00	0.00	0.00	0.00								17/12/1999	
OS500205C	Pumps - RFI Issued by Eng.	E	45	P5-002	26.30	25.00	26.30	19.20	1.05	1.00	0.00	39.00	-39.00	0.00	0.00	24/12/1999	

OS500210C	Pumps - RFQ Issued.	P	45	P5-002													
OS500210D	Pumps - Bid Period/Bid Rec'd.	P	45	P5-002													
OS500210E	Pumps - Commercial Evaluation.	P	45	P5-002													
OS500210E1	Pumps - Technical Evaluation	E	45	P5-002													
OS500210F	Pumps - Issue P.O. Folder for Appr.	P	45	P5-002													
OS500210G	Pumps - Award Purchase Order	P	45	P5-002													
OS500210G1	Pumps - Purchase Order Award	P	45	P5-002													
OS500210H	Pumps - 1st Vend Dwgs Rec.	P	45	P5-002													
OS500210H1	Pumps - Cert Vend Dwg Appr.	P	45	P5-002													
OS500210I	Pumps - Vend Dwg Appr.	E	45	P5-002													
OS500210J	Pumps - Fabricate.	P	45	P5-002													
OS500210N	Pumps - Deliver.	C	45	P5-002													
OS500610A	WWT - Prepare Performance Spec (RFI)	E	45	P5-006	67.50	67.00	67.50	45.00	1.01	1.00	0.00	15.00	-15.00	0.00	0.00	12/11/1999	150
OS500610C	WWT - RFQ Issued.	P	45	P5-006	0.00	0.00	0.00	0.00								19/11/1999	
OS500610D	WWT - Bid Period/Bid Rec'd.	P	45	P5-006												30/11/1999	
OS500610E	WWT - Commercial Evaluation.	P	45	P5-006													
OS500610E1	WWT - Technical Evaluation	E	45	P5-006													
OS500610F	WWT - Issue P.O. Folder for Appr.	P	45	P5-006													
OS500610G	WWT- Award Purchase Order	P	45	P5-006													
OS500610G1	WWT - Purchase Order Award	P	45	P5-006													
OS500610H1	WWT - Vendor Prepare Design Drawings	P	45	P5-006													
OS500610H2	WWT - Vendor Design Review	E	45	P5-006													
OS500610H3	WWT - Vendor Place Equipment Orders	P	45	P5-006													
OS500610H4	WWT - 1st Vend Equipment Dwgs Rec.	P	45	P5-006													
OS500610I	WWT - 1st Vendor Equipment Dwg Appr.	E	45	P5-006													
OS500610J	WWT - Fabricate WWT Equipment.	P	45	P5-006													

OS500610N	WWT - Deliver.	C	45	P5-006													
OS500620H	WWT - Cert Vend Dwg Appr.	P	45	P5-006													
OS501410N	Rail Car Weight Scale - Deliver.	P	45	P5-014													
IS47901A	Temp Facilities-Elec-Contract Specs & Dwgs	E	47	C7-901	4.00	4.00	4.00	20.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	19/11/1999	20
IS47901B	Temp Facilities-Elect- Interdisc. Coord.	E	47	C7-901	6.20	6.00	6.20	31.00	1.03	1.00	0.00	6.00	-6.00	0.00	0.00	26/11/1999	
IS47901C	Temp Facilities-Elect-Prepare Package for Bid (RFI)	E	47	C7-901	5.60	5.50	5.60	28.00	1.02	1.00	0.00	3.00	-3.00	0.00	0.00	03/12/1999	
IS47901D	Temp Facilities-Elect-Issue for Construction (RFC)	E	47	C7-901	2.95	3.00	2.95	14.74	[illegible]	1.00	0.00	-1.56	1.56	10.00	0.00	14/01/2000	

PM+ REPORT

IM001

SUMMARY WORK HOUR ANALYSIS BY DEPARTMENT/DISCIPLINE/IWP

Project: CM005 - Copy of CM004 (1) concordia

Client: CLTYPE - Typical Client

Scope of report for IWP: 4% and Task: All Tasks

SNC·LAVALIN

Report date: 2005-10-12

Time: 22:59:26

Period Start: 2000-01-01

Period End: 2000-01-31

Department / Discipline / *Internal Work Package (IWP)* / Task Code - Description		Control Budget Disc.	Control Budget IWP	Allocated Budget (wkhrs) Original (A)	Approved (B)	Transfer (C)	Revised (D=A+B+C)	Pending (E)	Earned(wkhrs) Revised (F)	Pending (G)	Total (H=F+G)	Actual (wkhrs) Period (I)	To-Date (J)	Forecast FTC (K)	Final (L=J+K)	CPI (M=H/J)	Earned (%) (N=H/(D+E))	Compl. (%) (O=J/L)	Budget Var. (P=L-D)
4 ENGINEERING																			
4-0 ENGINEERING MANAGEMENT																			
40-01	*Engineering Manager*		780	780	0	0	780	0	16	0	16	0	15	765	780	1.04	2	2	0
40-02	*Environmental Engineer*		650	650	0	0	650	0	20	0	20	0	19	630	649	1.03	3	3	-1
Subtotal Discipline: 4-0		1,430	1,430	1,430	0	0	1,430	0	35	0	35	0	34	1,395	1,429	1.03	2	2	-1
4-1 CIVIL																			
41-0000	*General*		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
41-1901	*Install temporary Fcality*		22	22	0	0	22	0	20	0	20	0	20	2	21.75	1.04	93	91	-0
41-1902	*Site Preparation & Underground Services*		497	497	0	0	497	0	462	0	462	0	462	33	495	1.00	93	93	-2
41-1903	*Site Preparation Work Under R/R & South*		213	213	0	0	213	0	0	0	0	0	0	213	213	0.00	0	0	0
41-1904	*Railroad*		174	174	0	0	174	0	0	0	0	0	0	174	174	0.00	0	0	0
41-1905	*Roads & Container Storage Area Paving*		157	157	0	0	157	0	0	0	0	0	0	157	157	0.00	0	0	0
Subtotal Discipline: 4-1		1,063	1,063	1,063	0	0	1,063	0	483	0	483	0	462	579	1,061	1.00	45	45	-2
4-2 CONCRETE ENGINEERING																			
42-0000	*General*		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
42-2002	*OSBL Founds - Utility, Lab,El & Matl Han*		784	784	0	0	784	0	0	0	0	0	0	784	784	0.00	0	0	0
42-2003	*New Piperack & HTM Foundations*		616	616	0	0	616	0	0	0	0	0	0	616	616	0.00	0	0	0
42-2005	*Miscellaneous Concrete Works*		207	207	0	0	207	0	0	0	0	0	0	207	207	0.00	0	0	0
Subtotal Discipline: 4-2		1,607	1,607	1,607	0	0	1,607	0	0	0	0	0	0	1,607	1,607	0.00	0	0	0

Variance calculations for the column (P) are inverted from SNC-LAVALIN methodology. In this report, positive results are overruns and negative are underruns.

SUMMARY WORK HOUR ANALYSIS BY DEPARTMENT/DISCIPLINE/IWP

Project: CM005 - Copy of CM004 (1) concordia

Client: CLTYPE - Typical Client

Scope of report for IWP: 4% and Task: All Tasks

SNC·LAVALIN

Report date: 2005-10-12
Time: 22:53:26
Period Start: 2000-01-01
Period End: 2000-01-31

Department Discipline Internal Work Package (IWP) Task Code	Description	Control Budget Disc.	Control Budget IWP	Allocated Budget (wkhrs) Original (A)	Approved (B)	Transfer (C)	Revised (D=A+B+C)	Pending (E)	Earned(wkhrs) Revised (F)	Pending (G)	Total (H=F+G)	Actual (wkhrs) Period (I)	To-Date (J)	Forecast FTC (K)	Final (L=J+K)	CPI (M=H/J)	Earned (%) (N=H/(D+E))	Compl. (%) (O=J/L)	Budget Var. (P=L-D)
4	**ENGINEERING**																		
4-3	**STRUCTURAL**																		
43-0000	General		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
43-3902	Utility Blds & Lab Structural Steel		620	620	0	0	620	0	0	0	0	0	0	620	620	0.00	0	0	0
Subtotal Discipline: 4-3		620	620	620	0	0	620	0	0	0	0	0	0	620	620	0.00	0	0	0
4-4	**ARCHITECTURE**																		
44-0000	General		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
44-4002	Arch Siding Util/Elec,Lab,MatlHan& Store		365	365	0	0	365	0	0	0	0	0	0	365	365	0.00	0	0	0
44-4006	Arch Util/Elec,Lab,MatlHan Finishes		247	247	0	0	247	0	0	0	0	0	0	247	247	0.00	0	0	0
44-4007	Service Doors		297	297	0	0	297	0	0	0	0	0	0	297	297	0.00	0	0	0
Subtotal Discipline: 4-4		909	909	909	0	0	909	0	0	0	0	0	0	909	909	0.00	0	0	0
4-5	**MECHANICAL**																		
45-0000	General		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
45-2002	OSBL Founds - Utility, Lab,El & Matl Han		477	477	0	0	477	0	0	0	0	0	0	477	477	0.00	0	0	0
45-5002	Pumps		137	137	0	0	137	0	57	0	57	0	55	80	135	1.04	42	41	-2
45-5006	Waste water treatment package		150	150	0	0	150	0	68	0	68	0	67	82	149	1.01	45	45	-1
45-5007	PTT Car Loading Equipment Package		169	169	0	0	169	0	0	0	0	0	0	169	169	0.00	0	0	0
45-5011	Safety Showers & Eye Wash		75	75	0	0	75	0	0	0	0	0	0	75	75	0.00	0	0	0
45-5013	Car Pullers CANCELLED		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0	0
45-5014	Rail Car Weigh Scale		10	10	0	0	10	0	0	0	0	0	0	10	10	0.00	0	0	0

Variance calculations for the column (P) are inverted from SNC-LAVALIN methodology. In this report, positive results are overruns and negative are underruns.

IM001

SUMMARY WORK HOUR ANALYSIS BY DEPARTMENT/DISCIPLINE/IWP

Project: CM005 - Copy of CM004 (1) concordia

Client: CLTYPE - Typical Client

Scope of report for IWP: 4% and Task: All Tasks

SNC·LAVALIN

Report date: 2005-10-12

Time: 22:59:26

Period Start: 2000-01-01

Period End: 2000-01-31

Department / Discipline / Internal Work Package (IWP) / Task Code	Description	Control Budget Disc.	Control Budget IWP	Allocated Budget (wkhrs) Original (A)	Approved (B)	Transfer (C)	Revised (D=A+B+C)	Pending (E)	Earned(wkhrs) Revised (F)	Pending (G)	Total (H=F+G)	Actual (wkhrs) Period (I)	To-Date (J)	Forecast FTC (K)	Final (L=J+K)	CPI (M=H/J)	Earned (%) (N=H/(D+E))	Compl. (%) (O=J/L)	Budget Var. (P=L-D)
4	ENGINEERING																		
4-5	MECHANICAL																		
45-5903	Install OSBL Mechanical Equipment		1,693	1,693	0	0	1,693	0	270	0	270	0	269	1,422	1691	1.00	16	16	-2
45-5904	HVAC Install UTIL,Lab,Storage		594	594	0	0	594	0	0	0	0	0	0	594	594	0.00	0	0	0
45-5906	Field Erected Tanks & Silos		60	60	0	0	60	0	0	0	0	0	0	60	60	0.00	0	0	0
45-5907	Plumbing & Safety Showers		490	490	0	0	490	0	0	0	0	0	0	490	490	0.00	0	0	0
45-5908	Fire Protections Systems Installation		316	316	0	0	316	0	0	0	0	0	0	316	316	0.00	0	0	0
Subtotal Discipline: 4-5		4,171	4,171	4,171	0	0	4,171	0	395	0	395	0	391	3,775	4,166	1.01	9	9	-5
4-6	PIPING																		
46-0000	General		160	160	0	0	160	0	0	0	0	0	0	160	160	0.00	0	0	0
46-6002	Manual Valves		120	120	0	0	120	0	0	0	0	0	0	120	120	0.00	0	0	0
46-6901	Coastal Piping Modifications & Tie - Ins		50	50	0	0	50	0	0	0	0	0	0	50	50	0.00	0	0	0
46-6902	OSBL Piperack Piping Installation		1,380	1,380	0	0	1,380	0	0	0	0	0	0	1,380	1380	0.00	0	0	0
46-6903	OSBL Piping Installation		1,537	1,457	0	0	1,457	0	866	0	866	0	866	593	1459	1.00	59	59	2
46-6908	Piping & Equipment Insulation		100	100	0	0	100	0	0	0	0	0	0	100	100	0.00	0	0	0
Subtotal Discipline: 4-6		3,347	3,347	3,267	0	0	3,267	0	866	0	866	0	866	2,403	3,269	1.00	27	26	2
4-7	ELECTRICAL																		
47-0000	General		530	430	0	0	430	0	0	0	0	0	0	430	430	0.00	0	0	0
47-1901	Install Temporary Facilities(Electrical)		20	20	0	0	20	0	19	0	19	0	19	2	20.5	1.01	93	90	1
47-1902	Site Preparation & Underground Services		140	140	0	0	140	0	0	0	0	0	0	140	140	0.00	0	0	0

Variance calculations for the column (P) are inverted from SNC-LAVALIN methodology. In this report, positive results are overruns and negative are underruns.