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Onshore Oil and Gas Design Schedule Management Process Through Time-Impact Simulations Analyses

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Abstract: Korean oil and gas contractors have recently incurred significant losses due to improper engineering performance on EPC (engineering procurement and construction) projects in overseas markets. Several previous studies have verified the significant impact engineering has on EPC construction cost and project lifecycle. However, no literature has studied the time impact engineering has on EPC projects, representing a gap in the existing body of knowledge. To fill this gap, a Monte Carlo simulation was performed with the Pertmaster, Primavera risk analysis software for three sample onshore oil and gas projects. From said simulation of all major EPC critical activities, the authors found that the engineering phase is up to 10 times as impactful as the procurement and construction phases on the overall schedule duration. In assessing the engineering activities, the authors found the piping design activities to have the greatest impact on the overall schedule performance. Using these findings, the authors present a design schedule management process which minimizes the delays of project completion in EPC projects. Said process includes the following six steps: (1) Milestone management, (2) drawing status management, (3) productivity management of engineering, (4) interface management, (5) management of major vendor documents, and (6) work front management. The findings of this paper add to the body of knowledge by confirming the design phase to be the most impactful on the overall project schedule success. Furthermore, the presented design schedule management will aid industry with successfully executing the design phase in a timely manner, including examples from case study projects for a greater understanding.

Keywords: EPC; design management; scheduling analysis; Monte Carlo simulation; time-impact analysis; piping engineering; risk analysis

1. Introduction

The Korean oil and gas industry has suffered significant market difficulties recently due to a multitude of reasons. A downturn in demand due to falling oil prices, concentration on downstream versus upstream sectors, and a heavy dependency on the Middle East and Southeast Asia have all negatively impacted the industry. Furthermore, Korean oil and gas contractors have experienced a loss in profitability due to project management issues caused by executing Engineer, Procure, and Construct (EPC) megaprojects. This has mainly included inefficiencies of the project management system, errors in the design phase, and inefficiency of logistics management due to vendor departure. While all important areas of study, the design must be carried out precisely so that procurement and construction can proceed smoothly. Many EPC projects are fast-tracked with detailed design, procurement, and construction occurring concurrently. As such, the detailed design cannot be achieved properly, often damaging the project via schedule and/or cost impacts. Thus, this paper identifies the most impactful activities, developing a design management system to maximize engineering resources and minimize delays.

1.1. Existing Literature on Front-End Loading and EPC Scheduling

Existing literature has frequently emphasized the importance of front-end planning and front-end loading (FEL) as they relate to design excellence. Morgan identified the most impactful front-end planning, pre-EPC contract execution, factors that affect project management to maximize project efficiencies [1]. Van der Weijde analyzed the impact of front-end loading (FEL) on cost and schedule performance based on a holistic FEL literature review finding correlations between cost predictability, cost-effectiveness, schedule predictability, and schedule effectiveness [2]. Jergeas focused on the FEL 1, 2, and 3 planning phases in mega projects such as Alberta oil sands projects. They present the effort needed to deliver mega projects, provide schedule comparisons of key engineering milestones, and analyze scope changes and contingencies [3]. The Construction Industry Institute (CII) analyzed the effect of front-end schedule reduction by applying the Project Development Rating Index (PDRI) to evaluate project completeness [4]. Shlopak et al. addressed issues related to planning within the pre-contract phase and their impact on lean construction on shipbuilding projects [5]. Through case studies on the application of the FEL process on several mega shipbuilding projects, they present a FEL process tailored to the shipbuilding industry [5]. Through several case studies and subject matter experts, Baron presents the oil and gas design process as performed by the EPC contractor through the front-end engineering design (FEED) in great detail [6]. The examples in the literature presented above have all found the FEL process and activities, specifically the design/engineering activities, to have a significant impact on the life cycle performance of EPC projects.

To ensure EPC contractors maximize their design/engineering efficiencies, Merrow suggests owners perform extensive FEED activities to lessen the contractor's design burden [7]. The EPC technical committee of the Korea Plant Institute (KPI) finds design efficiencies to be most important in EPC fast track projects, often implemented in oil and gas projects [8]. However, many Korean EPC onshore and offshore oil and gas contractors have concentrated on achieving highly accurate field designs, leaving their FEED capability poorly developed compared to their global competitors [9,10]. Several studies have attempted to aid the EPC contractor's FEED efficiencies through schedule optimization. Yeo and Ning proposed an enhanced framework for procurement, combining the concepts of supply chain management and critical chain project management (CCPM) [11]. Their proposed framework widely accommodates cultural, process, and technical approaches. Jo et al. also used the CCPM to develop a schedule delay prevention method for piping construction, found to be essential for project success, incorporating material procurement processes [12]. Lee et al. utilized the Program Evaluation and Review Technique and Critical Path Method (PERT/CPM) and Monte Carlo simulations (MCS) for estimating the appropriate construction duration of coal-fired power plant projects at the planning stage or contracting stage [13].

Alternatively, there have been a number of research papers that utilize Last Planner System (LPS) as a means to maximize schedule efficiencies, though none explicitly discuss EPC projects. El-Sabek and McCabe [14] suggest a framework they developed for managing international megaprojects utilizing lean construction methods and LPS. They argue that the results, findings, and recommendations can be adopted to different types of projects that require integration of subprojects for the success of the project. Castillo et al. [15] found a positive relationship between the implementation level of LPS practices and project performance. The paper suggests potential interrelationships among project social network properties, LPS management practices, and project performance.

1.2. Existing Literature on Scheduling Risks on Infrastructure Construction

Along with proper planning, proper schedule risk management, assessment, and prevention processes can aid in the overall schedule success. Thus, many practitioners and researchers have applied the risk management approach to the assessment and prevention of construction schedule delay [16–20]. Mulholland and Christian [16] propose a system to estimate schedule risks at project initiation developed through subject matter expert knowledge, project-specific information, decision analysis techniques, and a resultant analytical model. Luu et al. applied the Bayesian belief network (BBN) to quantify the probability of construction project delays, identifying sixteen risk factors and eighteen cause-effect relationships through subject matter expert surveys and interviews [17]. Nasir et al. developed an 'Evaluating Risk in Construction–Schedule Model' to assist in the determination of the lower and upper activity duration values to be used on PERT and/or MCS schedule risk analyses [18]. Schatteman et al. [19] and Okmen and Oztas [20] have also presented integrated risk management models with correlated scheduling analyses, built off Nasir et al.'s findings. Specific to cost risks in Korean construction, Cha proposed a systematic approach to assessing the effects risk factors which have the greatest impact on the cost performance of EPC projects [21]. Kang et al. also aided international Korean contractors by analyzing the range of cost fluctuations per major risk factors experienced on all EPC stages on overseas plant projects [22]. From a broader perspective, the seminal Project Management Institute "Project Management Body of Knowledge 5th Edition" describes the relationship between risk, uncertainty, and cost/schedule throughout a project's life cycle [23].

Many researchers have used their identified risk factors to develop optimal risk responses such as schedule acceleration [24–26]. Al-Momani [24] and Khodakarami et al. [25] developed quantitative assessment models for construction schedule risk uncertainty. Al-Gahtani [26] proposed a mathematical model that works with the time-cost-trade-off method to estimate the increase in project risk caused by schedule acceleration. Alternatively, several researchers have studied the most common and impactful schedule risks, contractor resource constraints [27,28]. Omer and Cengiz considered fuzzy and crisp multi-mode resource-constrained project scheduling to minimize project duration [27]. Arashpour et al. developed an analytical model to define the optimal product sequencing to maximize production using optimization-based metaheuristics for off-site manufacturers of building elements [28].

Many researchers and practitioners adopted probabilistic analysis approaches for scheduling analysis. Liu performed a holistic literature review, presenting the advantages and disadvantages of common construction schedule risk analysis methods used in the past several decades (i.e., CPM, PERT, MCS, BBN) [29]. Love et al. [30] used a 'best fit' probability distribution to ascertain the probability of schedule overruns, based on the schedule performance of 276 construction and engineering projects in Australia. Kirytopoulos et al. [31] argue that MC simulations generate better results than PERT and stress that accurate historical data and suitable distribution are the keys to achieving accurate activity duration estimating. A study by Aziz [32] mentioned software that can generate the expected project completion probability of a contract duration, called repetitive-projects evaluation and review technique (RPERT). Some researchers such as Ahong and Zhang [33], Sakka and El-sayegh [34], and Al-Gahtani [35] focused on the allocation and consumption of float in scheduling analysis, based on the application of PERT and/or MCS. More specifically, Ahong and Zhang's research proposed a method which calculates the noncritical path float through PERT analysis to identify scheduling uncertainties and reduce the misleading information. Their results showed the consistent path float under required completion probability and required duration [33]. Al-Gahtani introduced a total risk approach for float allocation among project parties to address the controversial issues in the schedule delay claims. They took into consideration the changes in float that may occur as a result of actions that delay or accelerate the project's schedule [35].

1.3. Point of Departure

As mentioned earlier, there have been many studies on the impact of detailed design on the project cost in EPC project execution. Although there have been some studies on the impact of the detailed design on the project schedule, none of them analyzed the time impact on EPC projects due to the detailed design delays utilizing simulation. Only the approximate schedule impact is analyzed based on the risks of the EPC stage [6]. This paper's findings most significantly build on Baron's presented oil and gas engineering guide, presenting specific examples of the proposed oil and gas engineering management process.

2. Data Collection and Research Methodology

The objective of this study is to investigate the impact design delays have on the schedule performance of an EPC oil and gas project. From these findings, the authors also propose a design management plan which best utilizes contractor resources in the engineering phase. A flow chart of the data collection and research methodology is shown below in Figure 1 and detailed in the following subsections.

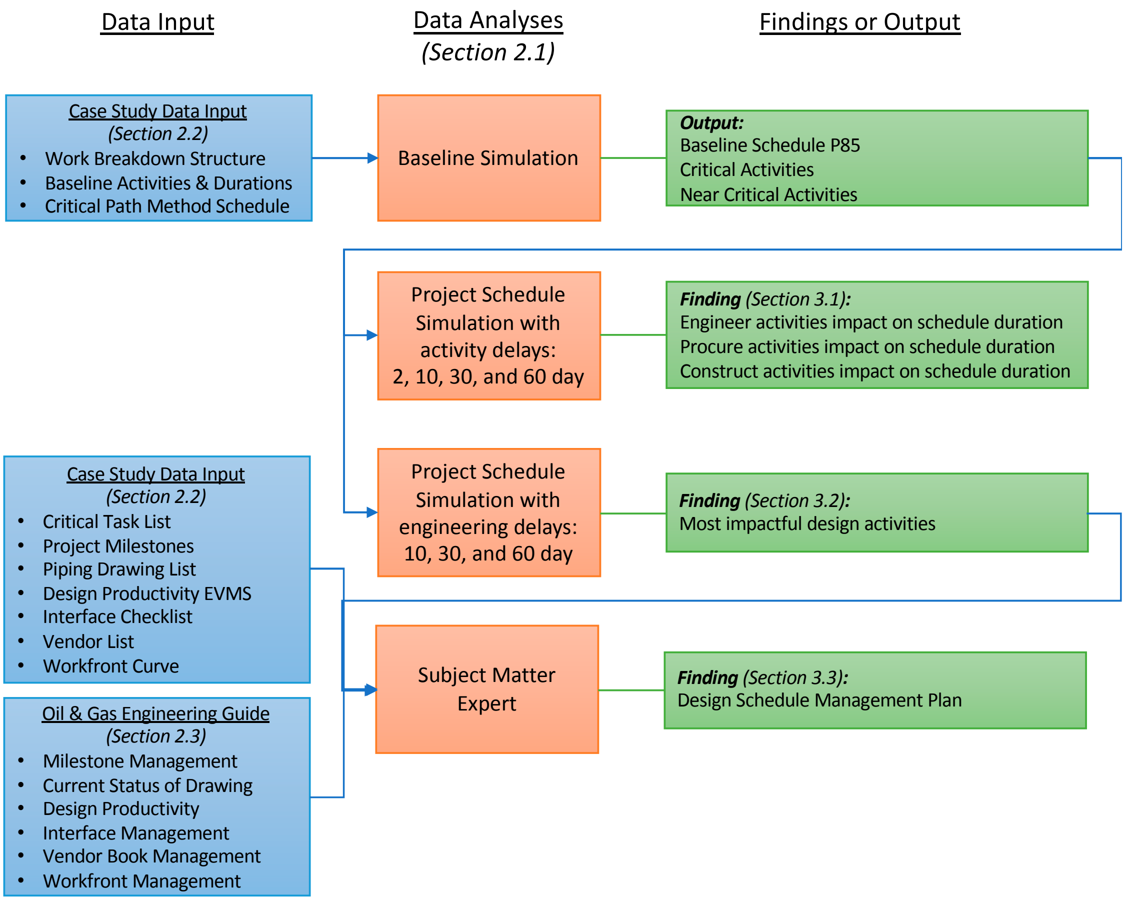

Figure 1. Data collection and research methodology flow chart.

2.1. Data Analyses

In order to find the EPC oil and gas activities that have the greatest impact on the project schedule, the authors used MCS analyses. To develop the template design schedule management plan for oil and gas projects, the authors relied on the findings of the MCS supported by subject matter experts. These data analyses methods are described in greater detail below.

2.1.1. Pertmaster Monte Carlo Schedule Simulations

This study performs MCS through the Primavera risk analysis add-on software, Pertmaster, to analyze the schedule and delay impacts. Pertmaster is a comprehensive risk management program with a methodology based on the Project Management Body of Knowledge outlined process. It is a schedule-based risk management tool that applies activity uncertainty and event risk to schedules created by process management such as PERT/CPM, MCS, and Latin Hypercube Simulation. For this study, the Pertmaster Monte Carlo analysis was performed to develop the baseline schedules along with simulating the impacts of the activity delays with the following processes and assumptions:

- The simulation is executed 1000 times for each activity.
- The period risk for each activity is entered as a triangular distribution (pessimistic, most likely, optimistic).
- The impact on the overall schedules is determined as a comparison of the baseline simulation and schedule simulation with delay P85 results. P85 means an 85% probability that the schedule will be completed. After a scheduling simulation, Primavera Risk Analysis can produce the expected completion date of various probabilities. However, in terms of reliability, it is said that the probability of project completion at 80~90% is realistic [36]. Therefore, the research team determined to use the median value of 85%.
- Baseline schedules for case studies were built based on the collected critical path method schedule, activities, and pessimistic, most likely, and optimistic durations. External risks, namely unforeseen risks, were not included in the baseline assessment.
- Project schedule simulation with activity delays was performed on two of the identified most impactful activities for each of the engineering, procurement, and construction from the critical path or near critical path. The near-critical path is defined as tasks with less than 30 days of float. The activities are given 2, 10, 30, and 60 delay days recording the impact on the overall project schedule. From the results, the authors compared which phase's delays (engineer, procure, or construct) have the most impact on the overall project schedule.
- Project schedule simulation with engineering delays was performed on the identified most impactful design activities on the critical path or near critical path. The activities are given 10, 30, and 60 delay days recording the impact on the overall project schedule. From the results, the authors compared which design activity's delays have the most impact on the overall project schedule.

2.1.2. Subject Matter Expert: Design Schedule Management Plan

From the simulations, the most impactful design activities are identified. From these findings, along with subject matter experts, the authors developed an oil and gas design schedule management plan. Said plan is based on the oil and gas engineering guide outline, defined in Section 2.3. Subject matter experts included the authors with about 12 years of industry/academic oil and gas experience on average.

2.2. Case Study Projects

To understand the impact the design phase has on EPC schedule performance, the authors collected data on three overseas onshore oil and gas EPC projects performed by a Korean company. Furthermore, the selected projects were all fast-tracked with minimal float so that any delays would directly impact the schedule performance. The three EPC project case studies performed for this study are defined in the following paragraphs.

Project 1 has 4400 activities with 8500 relationships. The work breakdown structure (WBS) of the project includes 3% milestone activities (0 duration activities that identify milestones such as design finish, substantial completion, etc.), 41% home office service, 12% manufacturing and delivery, and 44% construction. The home office service tasks were the focus and variable portion of the investigation and include engineering, procurement support services, subcontract management, and contracting. The identified critical activities for Project 1 include the process design basis, piping arrangement drawings in the engineering phase, tank setup, piping, painting, insulation, and commissioning in the construction phase. The baseline, non-delayed schedule results are shown below in Figure 2. As can be seen, there was an 85% chance that the project completion (P85) date was 2 July 2014, which equates to 55 months. Please note, this study assumes no delays were experienced for Projects 1 to 3 as they are outside of the focus of this study. The actual duration of Projects 1 to 3 was longer due to experiencing unforeseen events.

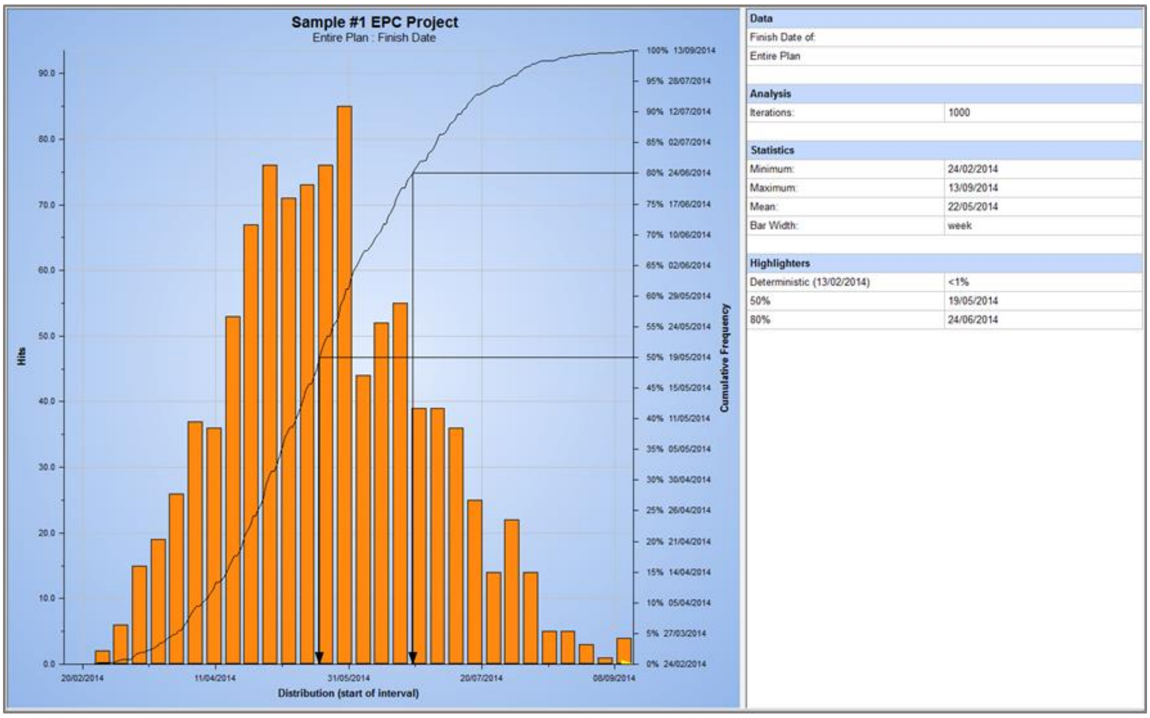

Figure 2. Case study 1 baseline project simulation result (non-delayed schedule).

Project 2 has 2100 activities with 3300 relationships. The WBS of the project includes: key milestones (2%); mobilization and project management (1%); engineering (45%); procurement, fabrication and transportation (44%); and construction and site installation, hook-up and tie-ins, pre-commissioning and commissioning, and demobilization (8%). The engineering tasks were the focus and variable portion of the investigation. Critical activities include main compressor package fabrication and procurement, module #1 fabrication and transportation, and central processing facility commissioning. The baseline, non-delayed schedule simulation result is shown below in Figure 3. The simulation P85 showed that the project completion date was 7 August 2014, which required a duration of 42 months.

Finally, project 3 has 4000 activities with 13,100 relationships. The WBS of the project includes 1% milestone and project management, 16% engineering, 29% procurement, 42% construction and commissioning, and 12% optional parts. The engineering tasks were the focus and variable portion of the investigation. Critical activities include process, piping, and instrument and control in the engineering phase, mechanical, electrical, and steel structure in the procurement phase, central processing facility, and underground piping offsite in the construction phase. The baseline, non-delayed schedule simulation result is shown below in Figure 4. The simulation P85 showed that the project completion date was 26 August 2017; therefore, requiring a duration of 42 months.

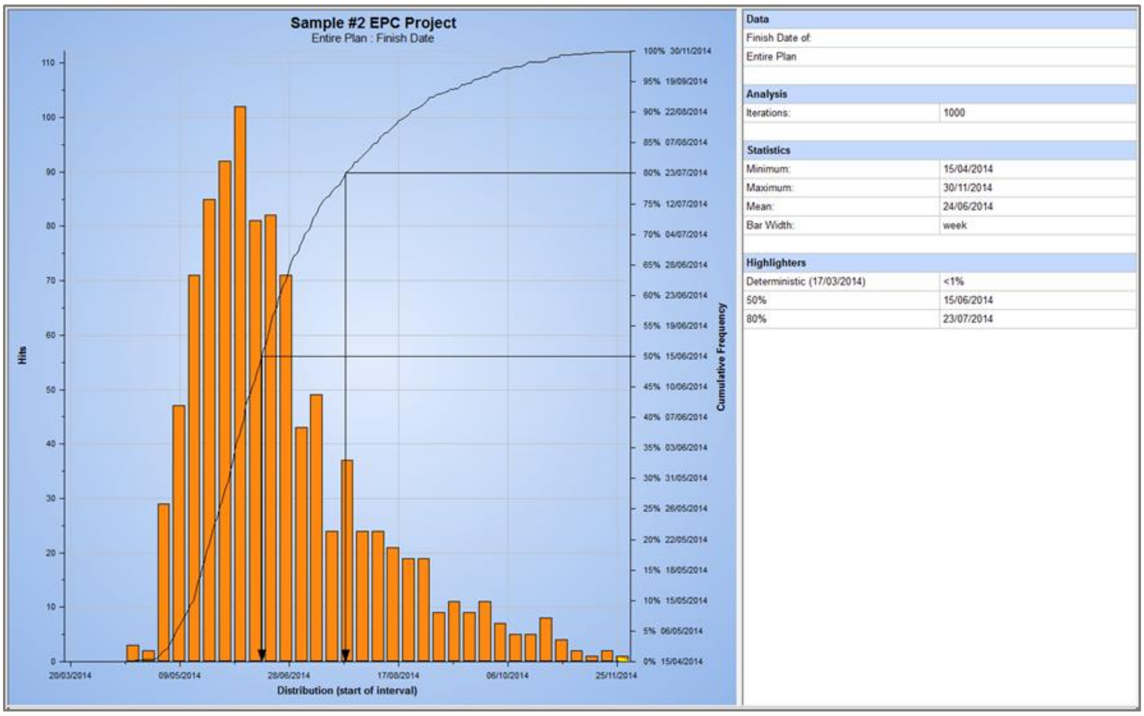

Figure 3. Case study 2 project simulation result (non-delayed schedule).

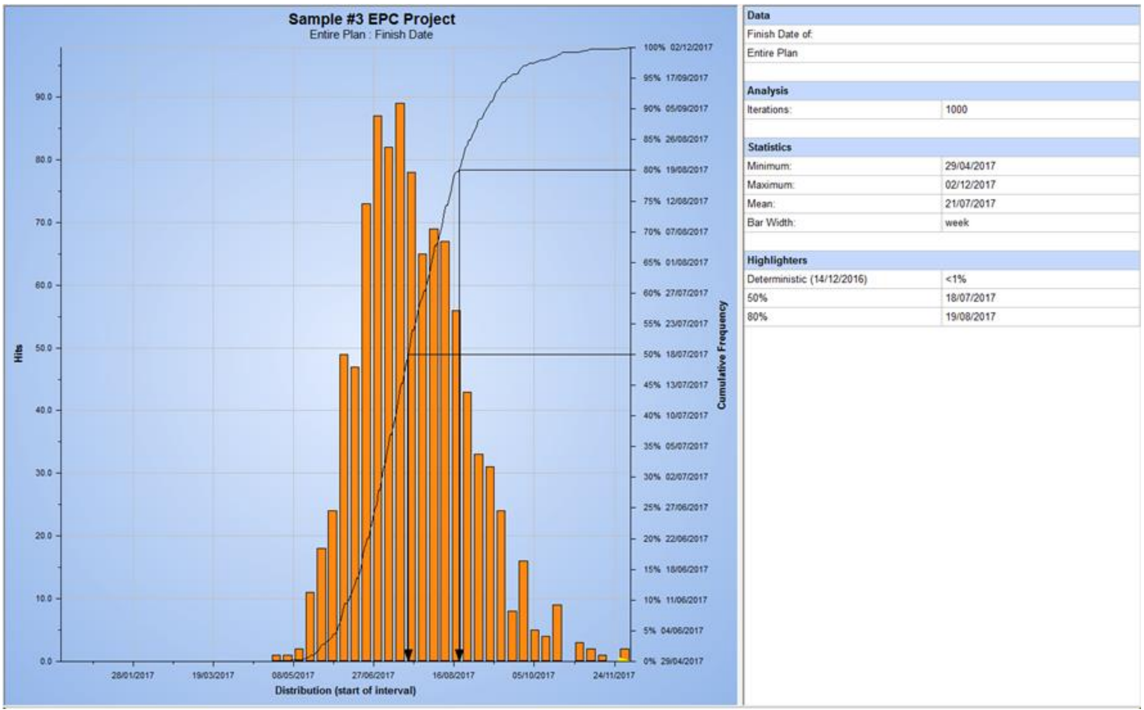

Figure 4. Case study 3 project simulation result (Non-delayed schedule).

From the CII PDRI, the authors identified eleven task types for industrial projects. Tables 1 and 2 show the percentage of items in the critical and near critical paths of the three case study projects. As can be seen, the piping tasks have the highest frequency of being on the critical and near critical paths of the eleven tasks. As such, the piping design has the most significant impact on the schedule.

The near critical paths are also shown as, when delays occur, said activities have a high probability of affecting the schedule, becoming critical activities.

Table 1. Percentage of task type in the critical path (CP) of the Sample engineering procurement and construction (EPC) Projects.

Task Type	Critical Path (%)			
	Case Study 1	Case Study 2	Case Study 3	Average
Process	38%	2%	16%	18%
Civil	38%	12%	-	17%
Building	-	-	-	-
HVAC *	-	3%	-	1%
Fire Fighting	-	-	-	-
Steel Structure	-	8%	21%	9%
Mechanical	-	13%	14%	9%
Piping	26%	24%	35%	28%
Electrical	-	16%	8%	8%
Instrument and Control	-	23%	6%	10%
Health and Safety	-	-	-	-
Sum	100%	100%	100%	100%

* HVAC = Heating, Ventilation, and Air Conditioning.

Table 2. Percentage of task type in the near critical path (NCP) of the Sample EPC Projects.

Task Type	Near Critical Path (%)			
	Case Study 1	Case Study 2	Case Study 3	Average
Process	5%	2%	11%	6%
Civil	29%	12%	-	14%
Building	-	-	-	-
HVAC *	2%	3%	2%	2%
Fire Fighting	-	-	-	-
Steel Structure	2%	8%	6%	5%
Mechanical	12%	13%	47%	24%
Piping	27%	24%	22%	24%
Electrical	12%	16%	5%	11%
Instrument and Control	11%	23%	8%	14%
Health and Safety	-	-	-	-
Sum	100%	100%	100%	100%

* HVAC = Heating, Ventilation, and Air Conditioning.

2.3. Oil and Gas Engineering Guide

Baron developed an oil and gas engineering guide, detailing a suggested methodology to manage the design portion of a project [6]. The authors use said guide's suggested outline to present a proposed critical and near critical path design management plan. Said proposed management plan uses the oil and gas suggested outline as follows [6]:

- Milestone Management
- Current Status of Drawing Export
- Design Productivity Management
- Interface Management with other design types
- Vendor Print Management
- Work front Management

3. Findings

The findings are presented as follows: Project schedule simulation with EPC activity delays, project schedule simulation with engineering delays, and design schedule management plan.

3.1. Project Schedule Simulation with EPC Activity Delays

Table 3 shows the results of the project simulation, increasing the two most impactful engineer, procure, and construct activities (total six activities) by 2, 10, 30, and 60 days. EPC delay results for each sample project. As can be seen, the engineering activities' delays have up to 10 times the impact of the procurement and construction activities. When two or ten days are delayed from each engineering, procurement, and construction activities, the delay impact was negligible. However, with 30- and 60-days delay, the delay impact was significant. These findings confirm that the engineering activity schedule impacts are greater than that of procurement and construction. Based on these findings, the authors next investigated the tasks in the design that have the most significant impacts on the overall schedule.

Table 3. Project schedule simulation with phase activity delay results.

Case Study No.	Phase E = Engineering P = Procure C = Construction	Delay Impact Per Phase			
		2 Days	10 Days	30 Days	60 Days
1	E	Minimal Impact	3 days delay	17.5 days delay	54.5 days delay
	P	Minimal Impact	No delay	1.8 days delay	7.3 days delay
	C	Minimal Impact	No delay	1.8 days delay	7.3 days delay
2	E	Minimal Impact	Minimal Impact	2.5 days delay	28 days delay
	P	Minimal Impact	Minimal Impact	2.5 days delay	12 days delay
	C	Minimal Impact	Minimal Impact	2.5 days delay	12 days delay
3	E	Minimal Impact	Minimal Impact	12.5 days delay	42.5 days delay
	P	Minimal Impact	Minimal Impact	4.5 days delay	24 days delay
	C	Minimal Impact	Minimal Impact	4.5 days delay	24 days delay

3.2. Project Schedule Simulation with Engineering Activity Delays

Table 4 summarizes the results of delaying the engineering activities by 10, 30, and 60 days. Shown are the design activities with significant delays and minor delays. As can be seen, a relatively large delay occurs with the piping activity in most cases. In the case studies 1 and 3, the process activity also has a relatively big delay impact. The possible reason for this is that the process is closely related to the piping. Piping's significance will be presented in greater detail in the discussion section of this paper.

Table 4. Project schedule simulation with design activity delays.

Case Study No.	Result Analysis			
	Delay Classification	10 Days Delay	30 Days Delay	60 Days Delay
1	Major	Piping	Process, Piping	Process, Piping
	Minor	Process, Civil	Civil	Civil
2	Major	-	Piping	Piping
	Minor	Process, Piping, Installation, Steel Structure	Process, Piping, Installation, Civil, Steel Structure	Process, Installation, Civil, Steel Structure
3	Major	-	Process, Piping	Process, Piping
	Minor	Process, Steel Structure, Piping, Electrical	Steel Structure, Electrical	Steel Structure, Electrical

3.3. Design Schedule Management Plan

From the above findings and oil and gas engineering guide [6], the authors developed a design schedule management plan for power plant projects. This is detailed below using case study project 1 examples and the following sections: Milestone management, current status of the drawing, design productivity, interface management, vendor print management, and work front management. Prior to executing a design schedule management plan, the industry representative should compile a list of critical and near critical path tasks based on the baseline schedule. The critical path tasks are those on the path with a total float of 0 whose delays directly affect the completion date. The near critical tasks are those with 30 days or less of total float which have the potential to become critical since they have little float. The near critical task 30 delineation can be modified according to industry management. Figure 5 below shows task groups by the lengths of the total float for the critical and near critical path.

Activity Name	Total Float	Original Duration	BL1 Start	Early Start	BL1 Finish	Early Finish
Critical & Near Critical						
1st Critical Path						
Home Office Engineering Organization	0	19	2009-12-14	2009-12-14	2010-01-11	2010-01-11
Process Flow Diagram (IFR)	0	42	2010-01-07	2010-01-07	2010-03-10	2010-03-10
Process Flow Diagram (IFD)	0	63	2010-03-11	2010-03-11	2010-06-10	2010-06-10
Engineering Design Basis	0	60	2010-01-07	2010-01-07	2010-04-05	2010-04-05
1st Near Critical Path						
GENERAL PLOT PLAN (IFA)	1	26	2010-02-24	2010-02-24	2010-04-01	2010-04-01
MTO For Fitting (CS) (1st BM) (PU-008)	4	1	2010-03-11	2010-03-11	2010-03-11	2010-03-11
MTO For Fitting (CS) (2nd BM) (PU-008)	4	1	2010-05-19	2010-05-19	2010-05-19	2010-05-19
2nd Near Critical Path						
MTO For PIPE SUPPORT MATERIAL 1ST (PU-	6	1	2010-06-03	2010-06-03	2010-06-03	2010-06-03
P&ID :PROCESS & UTILITY (IFA)	6	35	2010-03-11	2010-03-11	2010-04-28	2010-04-28
Process Data Sheet : INSTRUMENT (IFR)	6	42	2010-03-23	2010-03-23	2010-05-20	2010-05-20
PROJECT SPECIFICATION (IFR)	7	82	2010-01-07	2010-01-07	2010-05-06	2010-05-06
MTO For Pipe (CS) (1st BM) (PU-007)	9	1	2010-03-08	2010-03-08	2010-03-08	2010-03-08
MTO For Pipe (SS) (1st BM) (PU-010)	9	1	2010-05-27	2010-05-27	2010-05-27	2010-05-27
3rd Near Critical Path						
MTO For Ball Valve (1st BM) (PU-004)	11	1	2010-06-01	2010-06-01	2010-06-01	2010-06-01
MTO For Butterfly Valve (1st BM) (PU-005)	11	1	2010-06-01	2010-06-01	2010-06-01	2010-06-01
Process Data Sheet : COMPRESSOR PACKAG	15	96	2010-01-12	2010-01-12	2010-06-01	2010-06-01
MECHNICAL DATASHEET : COMPRESSOR PA	15	19	2010-02-02	2010-02-02	2010-03-03	2010-03-03
4th Near Critical Path						
MTO for Tank Material 1st	17	22	2010-03-16	2010-03-16	2010-04-14	2010-04-14
MTO for Tank Material 2nd	17	10	2010-04-15	2010-04-15	2010-04-28	2010-04-28
MTO for Tank Material 3rd	17	18	2010-04-29	2010-04-29	2010-05-26	2010-05-26
Process Data Sheet : TANK (IFR)	17	16	2010-01-14	2010-01-14	2010-02-04	2010-02-04
MECHANICAL DATASHEET : TANK (IFR)	17	52	2010-01-28	2010-01-28	2010-04-14	2010-04-14
PROJECT SPECIFICATION (IFR)	17	45	2010-02-03	2010-02-03	2010-04-09	2010-04-09
CALCULATION (IFA)	17	27	2010-04-12	2010-04-12	2010-05-19	2010-05-19
MTO For Pipe (CS) (2nd BM) (PU-007)	20	1	2010-05-19	2010-05-19	2010-05-19	2010-05-19
PROJECT SPECIFICATION (IFR)	20	49	2010-01-20	2010-01-20	2010-04-01	2010-04-01
MECHNICAL DATASHEET : FLARE SYSTEM (I	20	22	2010-04-02	2010-04-02	2010-05-03	2010-05-03
5th Near Critical Path						
GENERAL PLAN (IFR)	22	99	2010-01-07	2010-01-07	2010-06-01	2010-06-01
PROJECT SPECIFICATION (IFR)	24	49	2010-01-20	2010-01-20	2010-04-01	2010-04-01
6th Near Critical Path						
Utility Flow Diagram (IFR)	26	37	2010-03-11	2010-03-11	2010-04-30	2010-04-30
MECHNICAL DATASHEET : COMPRESSOR PA	30	57	2010-03-04	2010-03-04	2010-05-25	2010-05-25
MECHNICAL DATASHEET : COMPRESSOR PA	30	5	2010-05-26	2010-05-26	2010-06-01	2010-06-01

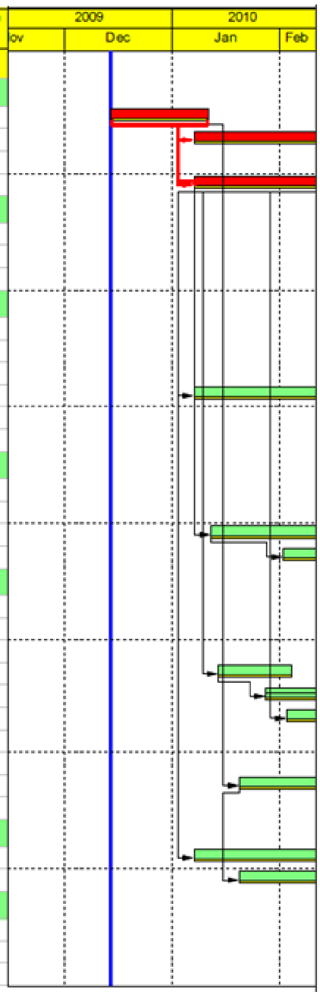

Figure 5. Case study project 1 critical and near critical path task list. (Note for abbreviations: IfA = Issue for Approval; IfD = Issue for Design; IfR = Issue for Review; MTO = Material Take Off; P&ID = Ping and Instrumentation Drawing).

3.3.1. Milestone Management

The first step in design schedule management is to identify and monitor target major milestones in the critical and near critical path. Figure 6, below, is an example milestone management checklist from project case study 1. As can be seen, there is a planned, forecasted, and actual date of completion with a variance calculation ([plan - forecast]/plan). The benefit of milestone management is that it is simple and clear, and a good method to set and achieve goals.

MILESTONE CHECK LIST						
NO.	MILESTONE DESCRIPTION	Plan	Forecast	Actual	Variance (Plan - Forecast)	REMARKS
DETAILED ENGINEERING						
1	Complete HAZOP Review with reports	2010-07-30	2010-08-29	2010-07-30	30	Not Achieved
2	Complete Engineering (90%)	2010-12-31	2011-02-11	2010-12-31	42	Not Achieved
3	Issue Process P&IDs for Approval	2010-04-30	2010-04-30	2010-04-30	0	Achieved
4	Issue Process P& IDs for Design	2010-08-27	2010-09-26	2010-08-27	30	Not Achieved
5	Issue Utility P&IDs for Approval	2010-05-28	2010-06-07	2010-06-07	10	Achieved
6	Issue Utility P&IDs for Design	2010-09-24	2010-11-05	2010-09-24	42	Not Achieved
7	Issue majority of Utility P&IDs for Construction (95%)	2011-01-28	2011-03-11	2011-01-28	42	Not Achieved
8	Issue Plot Plans for Approval	2010-05-28	2010-06-07	2010-05-28	10	Achieved
9	Issue Plot Plans for Design	2010-08-27	2010-09-26	2010-08-27	30	Not Achieved
10	Issued Plot Plans for Construction	2010-10-29	2010-12-10	2010-10-29	42	Not Achieved
11	Issue Preliminary Interface Hydraulics – Issued for Approval	2010-05-28	2010-06-07	2010-05-28	10	Achieved
12	Issue Final Interface Hydraulics - Issued for Design	2010-10-29	2010-12-10	2010-10-29	42	Not Achieved
13	Majority of Underground Piping General Arrangement Drawings Issued for Construction (60%)	2010-07-30	2010-08-29	2010-07-30	30	Not Achieved
14	Majority of Above Ground Piping General Arrangement Drawings Issued for Construction (60%)	2010-05-28	2010-06-27	2010-05-28	30	Not Achieved
15	All Underground services Drawings Issued for Construction	2010-08-27	2010-09-26	2010-08-27	30	Not Achieved
16	Balance of Underground Piping General Arrangement Drawings Issued for Construction	2010-08-27	2010-09-26	2010-08-27	30	Not Achieved
17	Complete GADs and Isometrics - MODEL	2010-12-31	2011-02-11	2010-12-31	42	Not Achieved
18	Issue First MTO Piping Bulks (65%)	2010-04-30	2010-05-05	2010-04-30	5	Achieved
19	All Piping Tie-in Drawings Issued for Construction	2010-12-31	2011-02-11	2010-12-31	42	Not Achieved
20	Majority of Above Ground Piping Large Bore Isometrics, 2" and Above, Issued for Fabrication (60%)	2010-11-26	2011-01-07	2010-11-26	42	Not Achieved

Figure 6. Sample milestone checklist. (Note for abbreviations: GAD = General Arrangement Drawing; HAZOP = Hazard and Operability (study)).

3.3.2. Current Status of Drawing

The most important measure of the progress of the design progress is the date of the drawing release. This is important as it is the step required to begin owner approval and directly correlated to the construction start. The release schedule of the drawings that constitute the critical and near critical paths are to be monitored. This document allows for weekly progress updates and proactive countermeasures if/when delays in anticipated completion occur. Figure 7 depicts the piping drawing list from case study project 1 and includes information of the drawings, target schedule, expected schedule, and percentage of progress.

PIPING DOCUMENT LIST

Document No.	Doc. Class	Document Title	P/F/A	Study, rough draft	Issued for Review	COMPANY comments incorporated	Final approval by COMPANY	Issued for Design	Issued for Construction	% Progress
Plot Plan & Key Plan										
Plot Plan										
PU-D-1000	1	Plot Plan - Key Plan - Plot Plan	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1001	1	Plot Plan - K.O. Drum LLP Flare	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1002	1	Plot Plan - Propylene Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1003	1	Plot Plan - Gasoline - 91 Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1004	1	Plot Plan - Gasoline - 95 Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1005	1	Plot Plan - Gasoline - 98 Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1006	1	Plot Plan - Bunker Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1007	1	Plot Plan - Jet Fuel Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1008	1	Plot Plan - Alkylate Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1009	1	Plot Plan - Crude Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1010	1	Plot Plan - Crude Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1011	1	Plot Plan - Gasoil Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1012	1	Plot Plan - Naphtha Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1013	1	Plot Plan - Dosing & Blending System	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1014	1	Plot Plan - Whole Cracked Naphtha Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1015	1	Plot Plan - SR Atmospheric Residue Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%
PU-D-1016	1	Plot Plan - SR Light Gasoil Storage Tank	P	1-Mar-10	1-Apr-10	28-May-10	1-Jul-10	29-Jul-10	28-Oct-10	90.00%
			F	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	
			A	1-Mar-10	9-Apr-10	20-May-10	5-Aug-10	5-Aug-10	29-Oct-10	90.00%

Figure 7. Sample list of drawing release status.

3.3.3. Design Productivity Management

The next step in the design schedule management is assessing the engineering productivity. As can be seen in Figure 8, a sample design productivity management curve, the actual progress, productivity index, and cumulative productivity index are calculated. The productivity index is calculated as the number of drawings completed per time, as follows:

$$\text{Productivity Index} = \frac{\text{number of drawings}}{\text{working time of design staff (hours)}}$$

Productivity trends of drawings are managed on a weekly basis. If/when trends change, the identification of causes is required to resolve them. By managing the efficiency of resources for the output of drawings, it is possible to prevent the delays of detailed design progress in advance. Figure 8 is an example of a detailed design productivity management curve showing the drawing productivity and the progress of detailed design in weekly units.

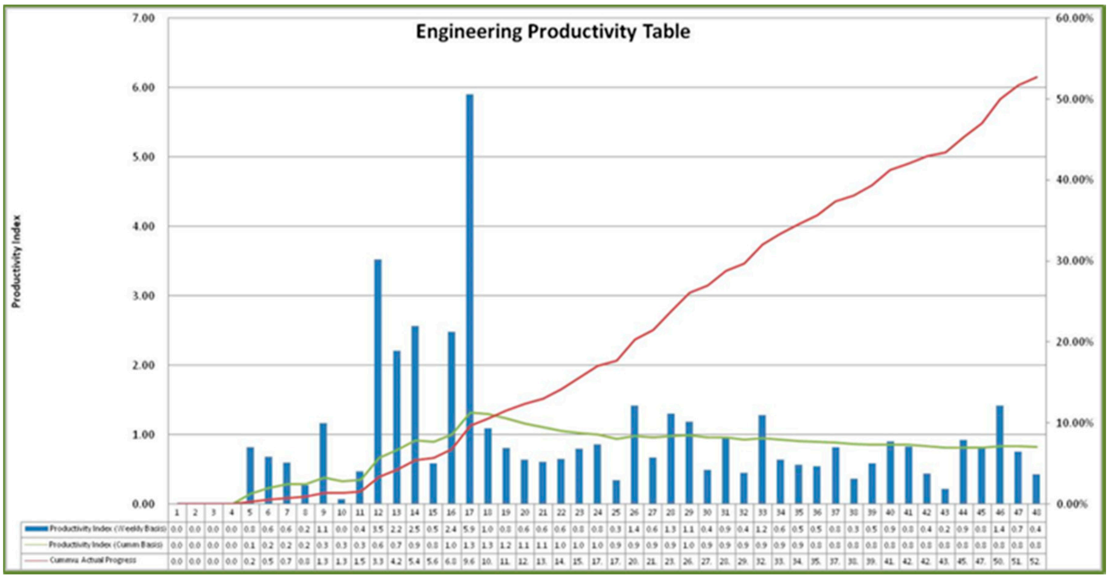

Figure 8. Case study project 1 sample detailed design productivity management curve.

3.3.4. Interface Management

Many of the design details have an impact on multiple design packages. Therefore, design progress requires an assessment of the design interface rather than singular designs and design teams. The checklist for necessary data and cooperation with the team of other design types is to be created and managed to complete the design work of the critical and near critical path list. Figure 9 is an example interface checklist for the major drawings of the case study 1 project.

3.3.5. Vendor Print Management

Design development can be carried out only when vendors of the devices and equipment provide crucial information in a timely manner. A list of major vendor prints is to be created and managed. Major vendor prints are identified as payment milestones when a purchase order is placed with vendors. Figure 10 is an example list of major vendor prints from the case study 1 project. According to each device and equipment, the list of major vendor prints, the schedule of the submission and its status, and the person in charge are provided.

3.3.6. Work Front Management

Work front refers to the predecessor to execute follow-up work. The work front of construction work can include manpower, equipment, materials, etc. In contrast, the construction drawing release status should be managed before the time of construction to prevent construction delay. Work front management items are mainly bulk construction items such as foundation, steel frame installation, piping spool, piping installation, and electric instrumentation cable. Figure 11 shows the work front curve for the installation of the ground piping, which compares the current state of isometric drawing versus the amount of installed ground piping so that the status of the isometric drawings can be managed.

IFC Outstanding status Report

Discipline	Total	Approved	Out standing	Drawing Title	CP/NCP	EA	Action Disc	In Charge	Target Date	Forecast Date
Piping	612	151	461	Above Ground - General Arrangement Drawing	Critical	304	Mechanica	K.K.S	12-Jun-10	2010-06-02
							Civil	H.W.S	7-Jun-10	2010-05-28
							Process	L.D.W	18-Jun-10	2010-06-12
				Under Ground - General Arrangement Drawing	Critical	161	Civil	H.W.S	10-Jul-10	2010-06-18
							Electrical	S.W.K	10-Jun-10	2010-05-31
							Fire Frighti	L.Y.K	1-Jun-10	2010-06-01
				Location Plan for Utility Station	Near Critical	30	Process	L.D.W	12-Jun-10	2010-06-12
							Mechanica	K.K.S	24-Jun-10	2010-06-20
				Plot Plan	Near Critical	29	Process	L.D.W	14-Jun-10	2010-06-12
							Mechanica	K.K.S	5-Jun-10	2010-06-13
Inst.	50	48	2	Logic	Near Critical	2	Process	L.D.W	7-Jun-10	2010-06-12
							Piping	M.S.S	9-Jun-10	2010-05-30
Total	**662**	**199**	**463**			**61**				

Figure 9. Case study 1 sample interface checklist with other design types. (Note for abbreviations: CP = Critical Path; EA = Each; IFC = Issue for Construction; NCP = Near Critical Path).

MAJOR VENDOR PRINT STATUS

MR No.	MR Description	Major VP	Date	Status	In Charge	1st Target Date	Remark
Rotating Equipment							
MR-MK-001	Compressor Package	P&ID - LUBE_OIL_CONSOLE_TRAIN_A	21-Dec-10	approved	K.H.S		
DR		P&ID - LUBE_OIL_CONSOLE_TRAIN_B/C	21-Dec-10	approved	K.H.S		
		P&ID - LUBE_OIL_SYSTEM_TRAIN_A	21-Dec-10	approved	K.H.S		
		P&ID - LUBE_OIL_SYSTEM_TRAIN_BC	21-Dec-10	approved	K.H.S		
		P&ID - GAS_SEAL_SYSTEM	21-Dec-10	approved	K.H.S		
		GA - COMPRESSOR_DRIVEN_SKID_Train_A	24-Jun-11	approved	K.H.S		
		GA - COMPRESSOR_DRIVEN_SKID_Train_BC	24-Jun-11	approved	K.H.S		
		GA - Motor	26-Oct-11	approved	K.H.S	2011-8-31	
		GA - Transformer	13-Mar-12	approved	K.H.S	2011-8-31	
		GA - ACS panel	23-Mar-11	approved	K.H.S		
		Datasheet - Propylene Compressor K-001A/B/C	26-Oct-11	approved	K.H.S	2011-8-31	
		Datasheet - Transformer	24-Nov-11	approved	K.H.S	2011-8-31	
		Datasheet - VSD	14-Jan-11	approved	K.H.S		
		Performance Curves - Propylene Compressor K-001A/B/C	20-Sep-10	approved	K.H.S		
		TEMPERATURE VIBRATION_COMPR_TRAIN_A	18-Feb-11	approved	K.H.S		
		TEMPERATURE VIBRATION_COMPR_TRAIN_BC	18-Feb-11	approved	K.H.S		
	Compressor Package	ELECTRICAL_SYSTEM_SINGLE_LINE_DIAGRAM	16-Aug-11	approved	K.H.S	2011-8-31	
		VSD Functional Description	14-Jan-11	approved	K.H.S		
		Description CCC Control System	11-Dec-11	approved	K.H.S	depend on Vendor	
		Cross Sectional Drawing	2011-07-06	approved	K.H.S		
	Turbine	General Arrangement-Gear Box	23-Mar-11	approved	K.H.S		
		General Arrangement-Lube Oil System	23-Mar-11	approved	K.H.S		
		General Arrangement-Seal Oil Console	23-Mar-11	approved	K.H.S		
MR-MG-001 FL	API 610 Pumps (Horizontal Pumps)	G.A Drawing w/Nozzle F&M/ Outline/ Piping Layout	15-Aug-12	approved	K.H.S	2011-9-30	
		Pump Datasheets	15-Aug-12	approved	K.H.S	2011-9-30	
		Performance Curves	15-Aug-12	approved	K.H.S	2011-9-30	
		Motor Datasheets	13-Aug-12	approved	K.H.S	2011-9-30	
MR-MG-004 SP	API 675 Pumps (Diaphragm Pumps)	General Arrangement	16-Aug-11	information only	L.D.K	2011-8-31	
		Pump Datasheets	2-Nov-11	approved	L.D.K	2011-8-31	
		Performance Curves	20-Nov-11	approved	L.D.K	2011-8-31	
		Motor Datasheets	24-Nov-11	approved	L.D.K	2011-8-31	
MR-MG-005	API 676 Pumps (Portable Gear Pumps)	General Arrangement	21-Nov-11	approved	L.D.K	2011-7-29	
PK		Pump Datasheets	15-Nov-11	approved	L.D.K	2011-7-29	
		Performance Curves	15-Nov-11	approved	L.D.K	2011-7-29	
		Motor Datasheets	21-Nov-11	approved	L.D.K	2011-7-29	
MR-MG-011 RY	Non-API Pump (Pnuematic Drum Pump)	General Arrangement	15-Jun-11	approved	L.D.K	-	
		Pump Datasheets	15-Jun-11	approved	L.D.K	-	
MR-MV-001 MX	Side-Entry Tank Mixers	General Arrangement	11-Jul-12	approved	K.H.S	2011-9-30	
		Mixer Datasheets	27-May-12	approved	K.H.S	2011-9-30	
		Motor Datasheets	28-May-12	approved	K.H.S	2011-9-30	
MR-MZ-100	E.O.T Cranes	General Arrangement	30-Jan-12	approved	K.H.S	depend on PO	
KH		Datasheets	27-Feb-12	approved	K.H.S	depend on PO	
5578-E4-1045-MR-MA-001	LLP Flare System	LLP Flare Stack General Arrangement Drawing	18-Nov-12	comment as note	L.D.K	2011-9-30	
HC		Flare Data Sheet	18-Nov-12	comment as note	L.D.K	2011-9-30	
		WIRING DIAGRAM FOR FFG PANEL	19-Nov-12	comment as note	L.D.K	2011-9-30	
		P&ID	19-Nov-12	comment as note	L.D.K	2011-9-30	

Figure 10. Case study 1 sample major vendor print list. (Note for abbreviations: ACS = Automatic Control Service; CCC = Compressor Controls Corporation; FFG = Flame Front Generator; GA = General Arrangement; PO = Purchasing Order; VSD = Variable Speed Drive).

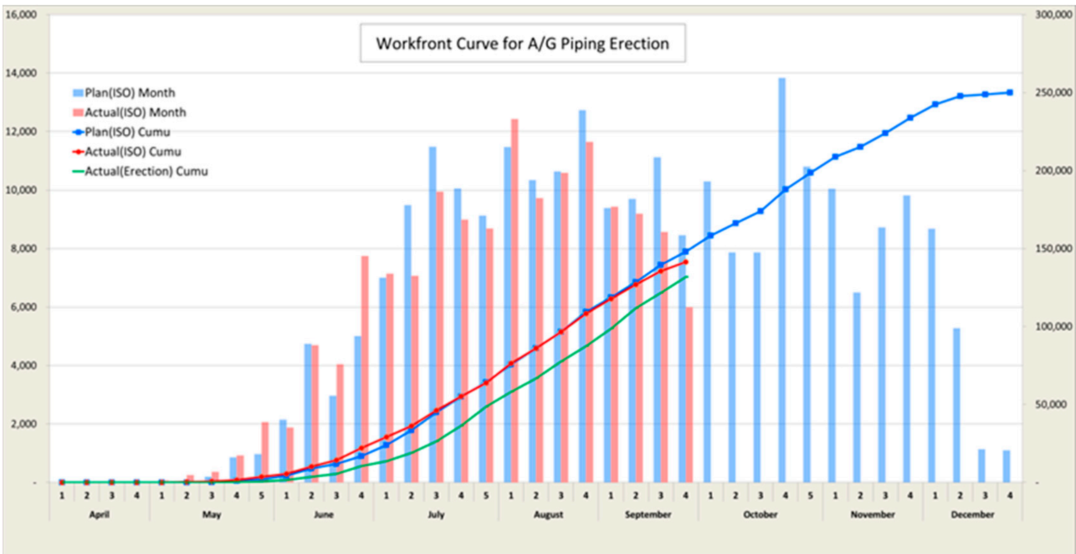

Figure 11. Sample work front management curve. (Note for acronym: ISO = Isometric).

4. Conclusions and Discussion

4.1. Study Conclusions

This study analyzed the impact the engineering phase has on the success of EPC projects. When projects are well-defined and well-focused in the early stage of the project, the chances of project success increase. To succeed, contractors need to properly execute the design phase through adequate resource allocation and design management. A Monte Carlo simulation was conducted using the Primavera Risk Analysis software, Pertmaster, for three sample EPC onshore oil and gas project schedules. To ascertain which stage of the EPC affects the project schedule most, the research team delayed the critical activities of engineering, procurement, and construction for 2, 10, 30, and 60 days, recording the estimated impact on the project completion date, respectively. The results of the simulation showed the design phase to be most impactful on the project schedule success. While two- or ten-day delays did not have much impact on the project schedule, 30- or 60-day delays have a significant impact on the project schedule, having up to 10 times the impact of the procurement and construction activities. As such, the most impactful tasks in the engineering phase were identified by delaying tasks in the critical path or near critical path. The results of the simulation confirmed that piping design work had the largest impact on the detailed design and hence, the project completion date. The reason for the above simulation results is that the detailed design has a lot of data to be exchanged among other types of work, so the work route is much more complicated than procurement or construction work. The influence of the engineering phase on the project schedule suggests that the front end of the EPC project should be managed very closely from the early stage of the project.

The authors also presented design schedule management processes milestone management, current status of the drawing export, detailed design productivity management, interface management with other detailed design types, vendor print management, and work front management. This is described in detail below:

1. ***The design schedule milestone management*** process identifies and monitors target major milestones in the critical and near critical path. The project team identifies the planned, forecasted, and actual date of completion with a variance calculation ([plan – forecast]/plan). This process provides a simple, low resource intense method to set and achieve goals.
2. ***The drawing release status*** monitoring is arguably the most important measure of the design progress as is the date of drawing release. This is because these are the dates which begin owner approval and are directly finish-start correlated to construction starting. In this process, only the most important drawing release dates (critical and near critical on CPM) are monitored. The project team is expected to perform weekly progress updates and proactive countermeasures as required.
3. ***Detailed design productivity*** is presented as a curve which tracks the actual progress, productivity index (number of drawings/working hours of design staff), and cumulative productivity index. This curve is also expected to be managed on a weekly basis with issues identified proactively (negative changes in trends), along with the related solutions. Productivity trends of drawings are managed on a weekly basis. By performing these assessments, the project team may prevent delays associated with poor design productivity.
4. ***Design interface management*** process monitors the interdependency of multiple design packages. This is performed with a checklist of required data, external team cooperation, and desired completion dates. This document ensures no drawing process stagnates due to teams not understanding or adequately preparing for their required input.
5. ***Vendor management*** is required to monitor the vendors' crucial device and equipment specification submittal progress. This is monitored through a simple table which includes a list of required vendor drawings, desired date, and status. This document ensures no drawing process

stagnates due to not receiving vendor information. The authors suggest major vendor prints be identified as payment milestones for vendor purchase orders to ensure timely submittals.

6. ***Work front management*** ensures that drawings are completed well ahead of construction. As most EPC projects include overlapping design and construction activities, it can be easy for detailed design teams to lose track of construction progress and allow construction activities to run out of designed work. This, of course, would be extremely detrimental to schedule performance. As such, work front management provides designers with a simple design versus a construction comparative graph comparing the current state of isometric drawing versus the amount installed.

4.2. Limitations and Future Research

The sample EPC project schedule used for the simulation in this study is limited to a total of three onshore oil and gas EPC project schedules due to limited projects with relevant data. As such, the research team could only analyze the approximate trend of the time effect on the schedule of the EPC task. If more EPC projects can be analyzed through schedule samples, it is possible to analyze the time effect and cost effect of each type of EPC project through various simulations. The findings of this work can be improved in the future. Therefore, it is expected that research on resource management of detailed design will be possible. Building on the findings of the activities which are most impactful to schedule performance, future research will also include methods to avoid schedule delays for overseas oil and gas projects. Future research utilizing LPS may be possible for qualitative analysis. However, securing a sufficient number of sample projects that adopt LPS and analyzing the results quantitatively may still be challenging.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

CII	Construction Industry Institute
CPM	Critical Path Methods
EPC	Engineering, Procurement and Constriction
EVMS	Earned Value Management System
FEED	Front-End Design
FEL	Front-End Loading
KPI	Korea Plant Institute
LPS	Last Planner System
PDRI	Project Development Rating Index
P&ID	Ping and Instrumentation Drawing
PERT	Program Evaluation and Review Technique

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