REASONS OF DELAYS IN STEEL CONSTRUCTION PROJECTS: AN APPLICATION OF A DELAY ANALYSIS METHODOLOGY

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ABSTRACT

REASONS OF DELAYS IN STEEL CONSTRUCTION PROJECTS:
AN APPLICATION OF A DELAY ANALYSIS METHODOLOGY

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Delay is one of the most common problems in the steel construction industry. At the time of bidding steel contractors plan tasks and assign resources according to the site visits, the information given in the contract and specifications related with the project. However, as the project progresses some conditions of the work may change. These changes may affect originally planned means and methods. Finally, the affected activities cause the project total cost and duration to increase. In steel construction projects, if not managed properly in accordance with the contract, changes are likely to result in claims between the project participants.

In this study, a delay analysis methodology which is based on time impact analysis is proposed. The aim of this methodology is to quantify impacts of work changes on the schedule and cost of steel construction projects and identify the responsible parties for these changes. A risk breakdown structure is presented to help decision-makers to identify probable sources of risk factors that usually result in time and cost overruns. The potential sources of change are categorized into 3 groups: contractor-related, owner-related and external factors. By using this structure, contractors may classify changes and assign the impacts of changes to the appropriate parties. The proposed methodology comprises of 3 steps: identification and quantification of delays, allocation of these delays to responsible parties and using TIA to calculate overall impact of changes on time and cost. The major benefits of this methodology are; a) its ability to handle and quantify changes in a step by step procedure, b) it provides a graphical representation of actual progress, and c) it helps decision-makers to give reliable decisions by monitoring the impact of changes during the project's life cycle. Construction professionals may use it to apportion impact of changes in a systematic and reliable way. Moreover, reports generated by using this methodology can provide evidence during the claim management process. An application of this methodology on a steel project demonstrates the superiority of the process in explaining the dynamic nature of changes and in apportioning the impacts between different parties in a systematic way.

Keywords : Steel Construction Projects, Delay Analysis, Time Impact Analysis, Risk Breakdown Structure, Delay.

ÖZ

ÇELİK KONSTRÜKSİYON PROJELERİNDEKİ GECİKMELERİN SEBEPLERİ:
BİR GECİKME ANALİZ YÖNTEMİNİN UYGULAMASI

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Gecikme, çelik konstrüksiyon endüstrisinde en çok rastlanan problemlerden biridir. Çelik Müteahhitleri teklif verme sırasında saha gezileri, sözleşmede verilen bilgiler ve projeyle ilgili şartnamelere göre görevleri planlar ve kaynakları tayin eder. Ancak, proje sürecinde işin bazı koşulları değişebilir. Bu değişiklikler orijinal olarak planlanmış kaynak ve yöntemleri etkileyebilir. Sonuç olarak, etkilenmiş aktiviteler proje toplam maliyetinin ve süresinin artmasına sebep olur. Çelik konstrüksiyon projelerinde, eğer düzgün bir şekilde ve sözleşmeye göre yönetilmezse, değişiklikler proje katılımcıları arasında ihtilaflara neden olabilmektedir.

Bu çalışmada, zaman etki analizine dayanan bir gecikme analizi yöntemi önerilmektedir. Bu yöntemin amacı iş değişikliklerinin çelik konstrüksiyon projelerinin süresi ve maliyeti üstündeki etkilerini hesaplamak ve bu

değişikliklerden sorumlu tarafları belirlemektir. Süre ve maliyet artışlarıyla sonuçlanan risk faktörlerinin kaynaklarını belirlemek için karar verme konumunda bulunan yetkililere yardımcı olmak amacıyla bir risk sınıflandırma yapısı sunulmuştur. Değişikliklerin potansiyel kaynakları 3 grupta sınıflandırılmıştır: müteahhitten kaynaklanan, işverenden kaynaklanan ve dış faktörler. Bu yapıyı kullanarak müteahhitler değişiklikleri sınıflandırabilir ve değişikliklerin etkilerini uygun taraflara atayabilir. Amaçlanan yöntem 3 basamaktan oluşmaktadır: gecikmeleri tanımlamak ve miktarlarını belirlemek, bu gecikmeleri sorumlu taraflara paylaştırmak ve Süre Etki Analizi kullanarak değişikliklerin süre ve maliyet üzerindeki toplam etkilerini hesaplamak. Bu yöntemin temel faydaları şunlardır; a) değişikliklerin proje üzerindeki etkisi adım adım ele alınır, b) gerçek süre değişimlerinin grafiksel olarak gözlemlenmesi sağlanır, ve c) karar mercilerinin proje süresi üzerindeki etkilerini izlemesi sağlanır. İnşaat profesyonelleri, bu yöntemi değişikliklerin etkilerini paylaştırmakta sistematik ve güvenilir bir şekilde kullanabilirler. İlave olarak, bu yöntemi kullanarak elde edilmiş olan raporlar talep yönetim sürecine kanıt sağlayabilirler. Bu yöntem bir çelik proje üzerinde uygulanarak, değişikliklerin dinamik doğası açıklanmaya ve sistematik bir şekilde farklı taraflar arasında değişikliklerin etkilerinin paylaştırılma yöntemi gösterilmeye çalışılmıştır.

Anahtar Kelimeler : Çelik Konstrüksiyon Projeleri, Gecikme Analizi, Zaman Etki Metodu, Risk Sınıflandırma Yapısı, Gecikme

To My Family

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LIST OF ABBREVIATIONS

CPM	Critical Path Method
CII	Construction Industry Institute
TIA	Time Impact Analysis
AIA	American Institute of Architects
P.H.	Pump House

CHAPTER 1

INTRODUCTION

1.1 Problem Statement

1.1.1 Background

Steel contractors bid for jobs based on the site visits, the information given in the contracts and specifications at the time of bidding. They plan tasks and assign resources for each task on the basis of such information. However, as projects progress, the scope of the work may change. These changes may include alterations on the sequence of work, design changes, or changes in the working conditions. Work changes may affect originally planned means and methods. As a consequence, they may impact the quantities and type of the resources required to perform the work, leading to significant changes in as-planned schedules.

The challenge is to quantify the net impacts caused by changes. Proper quantification of impacts solely introduced by changes is vital to all parties and to the success of a steel project. Failing to quantify net impacts due to changes may have adverse consequences that sometimes result in mediation, arbitration or litigation. Furthermore, the method of quantifying impacts should be acceptable to all parties involved. For the method to be acceptable to all parties involved, it should be capable of reflecting the reality to the extent that it can segregate the net impact merely due to changes.

Several techniques are employed by the industry to quantify the impacts of the changes. The most common technique is schedule analysis using Critical Path Method (CPM) which quantifies the time impacts of work changes. The time and motion method, expert opinion, industry standards and historical productivity data are among the tools that are used to quantify productivity-related impacts (Cushman and Carpenter 1990). However, there's no single method or panacea applicable to all kinds of problems that may be experienced in all kinds of projects.

Steel construction projects are subject to many risks that may lead to significant changes in as-planned schedules and original cost plans. A critical success factor in steel projects could be a method that's used to quantify impact of changes on time, cost and to apportion these impacts between project participants so that a fair risk allocation can be guaranteed. Significant risk exposure of contractors in steel projects necessitates a system/tool to quantify risk consequences and to prove the real impact of changes on project success so that claim management can be carried out successfully.

1.2 Purpose, Scope, Objectives

1.2.1 Purpose and Scope

Within the context of this research, a methodology for quantification of impacts in steel projects will be proposed. The overall purpose of this study is to explore and define the opportunities for using the proposed methodology in quantifying impacts of work changes on the schedule and cost of the steel construction projects and identifying the responsible parties for these changes.

A case study forms the application part of the work. The purpose of case study is to quantify impacts introduced via changes in a real steel construction project, and to illustrate the points of interest by using the proposed methodology.

The second chapter of this thesis entails a literature survey regarding the definitions of the terms mostly used in the delay analysis literature such as, types of delays, retrospective delay analysis techniques, effective documentation, claim settlement methods and construction claim process. The study then makes use of a project to fully discuss the points of interest. In this chapter**,** the study examines potential work changes in steel construction projects. Also, it is intended to find answers to the questions such as why and how work changes occur, what the sources of changes are , what the sources of delays and the tools to quantify delay impacts are. The third chapter introduces the proposed delay analysis methodology for steel construction projects. Disruptions affecting cost&time of a steel construction project, steps of the delay analysis are parts of this chapter. Finally, the proposed methodology is applied on a steel construction project and findings of the application are discussed.

1.3 Potential Benefits of This Research

The below points set forth what to expect from this methodology and how to make use of it as a tool:

- **Quantification:** The study addresses the benefits of using the proposed methodology, its capabilities and critical success factors that are important in quantifying impacts due to change
- **Visualization:** The study sets out benefits resulting from visualization of changes and impacts.
- **Evidence for Claims:** Study mentions benefits of using the proposed methodology while preparing claims.

It is anticipated that the output of the research may be valuable for practitioners who wish to use this methodology in quantifying impacts due to work changes. Any time-related claim situation needs to be resolved with regard to three basic elements of time impact: causation, liability, and damages. Causation deals with the identification and quantification of a schedule variance and its impact on the project; liability refers to the determination of the responsible party for the variance; and damages refer to the sharing of the loss. This study basically focuses on how to deal with delays occurring in steel construction projects, to identify and quantify the impacts of changes and to assign responsibilities for each delay. Thus, it can be used to evaluate causation, liability and damage in time-related claims. However, legal issues which are important while deciding on the “liability” are not discussed. Legal framework of delay claims is not within the context of this study.

CHAPTER 2

LITERATURE SURVEY

2.1 Brief Summary

The Construction Industry Institute (CII) has various publications on work changes, their impact and currently employed techniques to quantify the impacts. Publications about work changes and their impacts are based on the case studies and on the data collected from various projects. Below are brief summaries from some of the reports. There are also excerptions from the reports in the discussion of work changes and productivity issues in the following chapters. "The Impact of changes on Construction Cost and Schedule" (Cost and schedule Task 1990) gives an anatomy of changes. It encompasses the direct impacts of changes on cost and also gives list of the direct impact. The discussion extends to direct impacts of changes on schedule. Finally, the consequential impacts of changes are discussed and a Work Breakdown Structure is proposed to evaluate the effects of change. The publication concludes with a long list of recommendations and ideas.

Hester, Kuprenas and Chang (1991) prepared a report on "Construction Changes and Change Order: Their Magnitude and Impact" to CII. The report introduces the change terminology and continues with a literature review. It discusses the legal issues regarding the changes as set forth in the contract and gives a list regarding the principal purposes of the change clauses. It also covers direct impacts, indirect impacts, impacts of multiple changes and compensability issues. Critical Path Method and Network Analysis are proposed to be used to quantify delays. The final section presents and illustrates an automated control system. The report includes four case studies.

Thomas and Napolitan (1994) prepared a report entitled as "The Effects of Changes on Labor Productivity: Why and How Much." The report introduces a literature review on changes. The literature review discusses categories of changes, quantification of the effects of changes and CII cost and schedule task force reports. The authors propose a conceptual model, Factor Model, to evaluate the impacts on labor productivity. They determine the factors affecting the labor productivity. The study continues with data collection and data processing methodologies. They use statistical methods to analyze the relationship between efficiency and the factors such as changes, rework and disruption. They also present a predictive model to estimate the effects on labor productivity. One of the conclusions suggests that there is a 30% loss of efficiency due to changes; however, the timing of the changes is a key issue that determines the loss of efficiency.

The tools to quantify the impacts of the changes are discussed under two categories: time related and productivity related. There is an extensive literature regarding the time related impact analysis tools. However, there are limited sources regarding the tools to quantify the productivity-related impacts. "Construction Scheduling: Preparation, Liability and Claims" (Wickwire, Driscoll and Hurlbut 1991) is a comprehensive source on the application of scheduling techniques in the analysis of delay claims. The authors present a discussion of the evolution of CPM from a scheduling tool to a delay analysis tool. The discussion also covers CPM's recognition by the courts. Different analysis methodologies are also introduced. The text also encompasses topics including legal aspects of schedule specifications, project record-keeping and calculation of the damages. "Construction Scheduling And The Law: Course Manuel" (Wickwire and Driscoll 1988) has almost similar content to (Wickwire et.al.1991). However, this document has important appendices like "Modification Impact Evaluation Guide" by the Department of Army. This guide is important in the sense that the proposed method is one of the first methods to recognize the nature of CPM as a dynamic tool. Bramble, D'onfrio and Stetson (1990) also devote a chapter in "Avoiding and Resolving Construction Claims". The authors present several uses of CPM for delay analysis and discuss their advantages and disadvantages through the examples. "Time Impact Analysis in Engineering & Contracting Projects: Industrial Case" (Paolo Sanvito et.al. 2004) focuses on claims concerning possible delays in completing project activities; delays stemming from disruption events. The paper describes the application of Time Impact Analysis (TIA) to an industrial case concerning the construction of a petrochemical plant in the Middle East. It also allows comparing a traditional "static" approach, based on the comparison between the "as planned" schedule and the current "as built" schedule, and the "dynamic" approach**,** typical of TIA by considering the event chain which has determined the current status of the project step by step. The paper points out the different results achieved by the two different approaches and the effectiveness of the latter approach in order to apportion rigorously both responsibility and corresponding penalties to each party involved in project completion delay.

The methodologies and tools to quantify the productivity related impacts are discussed in "Proving And Pricing Construction Claims" edited by Cushman and Carpenter (1990). The text presents several approaches and tools used under the heading of disruption, and the nature of disruption. Finally, it presents the approaches together with the tools to be employed in the analysis. Bramble, D'onfrio and Stetson (1990) discuss the impacts of different factors on labor productivity in "Avoiding and Resolving Construction Claims." They discuss the available methods, advantages as well as disadvantages of these methods.

2.2 Definitions

The commonly used terms in this study can be summarized as follows:

- *Change:* "A change is any modification to the contractual guidance provided to the constructor by the owner, owner's agent, or design engineer. Thus, it is encompasses changes in specifications, drawings and other written oral guidance" (Cost/Schedule controls Task Force 1990). A more specific definition of changes is "disturbances that interfere with the planned, orderly progression of work" (Cost/Schedule Controls Task Force 1990).
- *Disruption of work:* Any disturbance to the actual planned work or method of work is considered a disruption of a work (Hester, Kuprenas and Chang 1991)
- *Interference:* Any physical obstacle from other participants or a change hindering the progress of work is considered interference. (Hester, Kuprenas and Chang 1991)

- *Inefficiency:* Inefficiency is production by crews or equipment that is lower than their average. (Hester, Kuprenas and Chang 1991)
- *Ripple effects:* The consequential impact of change on other work items is defined as the ripple effect. (Hester, Kuprenas and Chang 1991)
- *Delay:* Act or event which extends time required to perform or complete work of the contract (James G. Zack, Jr.,2003)
- *Claim:* It is the position on the issue, the purpose behind the argument. (Scott T. and Soukup C., 1998)

2.2.1 Why and How Work Changes Occur

Steel construction projects can hardly be performed as they were planned. This is due to existence of various parties and resources employed in a steel construction project. Most of the changes are due to participants and agents, physical conditions, a contract and resources. The participants are owner, contractor, and third parties. Resources include material, labor, equipment, capital and time. Mostly these factors bear uncertainties from the beginning of the project until the end. It is not always possible to foresee design omissions until construction starts, or to predict whether the owner will change his mind regarding a work item. No one can guarantee physical conditions such as those in the subsurface. The quantities in the contract are just estimates and they can either increase or decrease. Estimates just form a baseline regarding the quantities. Resources, being scarce, require a fine-tuned scheduling. However, there will always be problems or delays for either two parties**,** contractor/owner-furnished equipment or materials. The uncertainties will be discussed in the forthcoming sections. Contract packages limit these uncertainties to an extent by establishing a baseline and setting forth the rules to manage the uncertainties in case they arise. Contractors rely on the contractual documents as a baseline**,** plan their operations and resource flows, and establish their schedule and budget. Nevertheless, these uncertainties will cause changes and as-planned operations will not take place as they are planned. This situation is described in the Construction Industry Institute's publication as follows;

Initial guidance comes to the contractor in the form of a contract package. This package is the basis for the contractor's bid or proposal. The contractor will have developed project schedules, budgets, and a variety of detailed implementation plans using this guidance. Obviously, any change to the original guidance can be expected to alter the contractor's plans (Cost/Schedule Task Force 1990).

2.2.2 Sources of Changes

Uncertainties and management of multiple parties and resources in steel construction and construction projects are general reasons that give rise to specific changes. There have been many studies to identify the causes of changes. Table 2.2.2.1 is from the study entitled as 'Construction Changes and Change Orders: Their Magnitude and Impact.' This table lists the sources of changes from six different reports. Hester et al. (1991) point**s** out that although the project types in the reports vary, sources of changes tend to be similar.

Table 2.2.2.1 Sources of changes (Hester et al. 1991)

Report Type	Sources of Changes
A	Clarifications of work
	Additional work
	Changed site conditions
	Substitutions
B	Ambiguous specification; omissions in specifications
	Design errors
	Change in scope
	Differing site conditions
	Delays
	Improper actions by contracting officer
C	Faulty contract documents
	Deficient site investigation
	Substandard work
	Delays
D	Poor plans and specifications
	Change in scope
	Unforeseen conditions
	Owner-caused delays
	Lack of knowledge
E	Gaps in contract documents
	Increased scope
	Project rhythm interrupted
F	Design error
	Discretionary changes
	Differing site conditions
	Value engineering resulted changes
	Mandatory changes

REPORT TITLES

A. Management of Environmental Protection Agency Projects by Local Grantees, June 1982. - Hester, et al.

B. Air Force Construction Contract Disputes: An analysis, September 1992- Merrill (ed.)

C. Comparative Analysis of Time and Schedule Performance on Highway Construction Projects, July 1985. – Thomas, et al.

D. The Cause and Effects of Change Orders on the Construction Process, Georgia Institute of Technology, 1981. – Rowland.

E. Change Orders' Impacts on Construction Cost and Schedule, AAEC, 1980. – Suhanic.

F. Construction Claims: Frequency and Severity, ASCE Journal of CM, 1985. – Diekmann.

Another category regarding the origins of changes is based on the party that has initiated the change. Owner's change requests may include scope changes, design changes, schedule changes and materials changes. Designers may also initiate changes to incorporate the owner's change requests, to correct their design, or to improve functionality in the design. A detailed list regarding types and origins of changes is given in Table 2.2.2.2. This table also gives a list of specific types of changes.

2.2.3 Why Work Changes are Important

Changes are important for various reasons. They introduce flexibility to projects, resulting in better products. However, equally important, they lead to serious impacts on project performance, resulting in increased project cost and extended project duration. In addition, they may cause disputes that may result in litigation.

Table 2.2.2.2 Matrix of types and origins of changes (Thomas&Napolitan 1994)

Types of Changes	Originating or Responsible Party				
	Outside	**Engineer**	**Owner**	**Contractor**	**Vendor**
Omissions		*			
Engineering Errors		*			
Design Changes		*			
Unforeseen Conditions	*				
Change in Work Sequence		*	*	*	
Schedule Change		*	*	*	
Specification Change		*			
Vendor Change		*			
Process Change		*	*		
Aesthetic Change			*		
Operations Directed Change			*		
Value Engineering		*		*	
Cost Reduction Change		*	*	*	
Constructability Change		*		*	
Intended Use Change		*	*		
Regulatory Change	*				
Concept Change		*	*		
Scope Change			*		
Design Evaluation Change		*			
Safety/Insurance Change (Design)		*			
Change in Available Resources	*				
Force Major	*				
Mobilization Delay			*		
Quantity Change		*			
Code change	*				
Material Availability	*				
Seasonal Work Change		*	*		
Accident-Change in Safety Appr.Const.	*				
Work Rules (Labor)				*	
Work Rules (Operations)			*		
Failure to Perform		*	*	*	*
Late Issue of Design		*			
Late Receipt of Equipment		*	*	*	*
Change in Timing of Vendor Drw. Appr.		*	*		
Late Procurement Activities		*	*	*	*
Change in Access to Work Area			*		
Change in Raw Materials			*		
As-build Used for Design was Incorrect				*	
Change in Engineering Support to Const.		*			

2.2.3.1 Benefits

No one can argue about the benefits of changes. They are contractual tools to handle uncertainties in the contract and dynamics of projects. For example, if a certain condition stipulated in the contract is found to be different on site, a change in the contract will settle this problem. Changes are also tools to meet changes in owner's needs like the type of a material. Contractors can propose value-engineering changes. Obviously, all of these features of changes lead to an improved product. Of course, there is usually a price associated with these changes.

2.2.3.2 Impacts on Project

Changes in any planned activity will cause a disturbance and require the rearrangement or review of the existing plan under the recent developments. Given the complex, multi-party and multi-resource nature of the steel construction, it is not difficult to perceive the impacts of changes on projects.

Impacts of a change are defined as the net effects of the change on the project performance. Numerous studies have been done to identify the impacts of changes, relationships between change and its impacts, and true consequences of changes in terms of cost and time (Cost/Schedule Controls Task Force 1990; Hester et al. 1991; Thomas and Napolitan 1994; Project Change Management Team 1995; Ibbs and Allen 1995). Table 2.2.3.1 shows impacts on cost and schedule from four different reports. Changes have direct and indirect impacts on the project performance.

2.2.3.2.1 Direct Impacts

Direct impacts are impacts of changes that appear in immediate activities of the changed work. These impacts can easily be linked to the change in most cases. Nevertheless, closer analysis and supervision of the impacted activities are required to identify these impacts. Moreover, the true consequences such as quantification of the impacts solely due to changes are not easy and require additional data storing and analysis.

A summary from CII publication concerning direct impacts on project cost due to changes while a work is in progress are given below (Cost/Schedule Control Task Force 1990):

- *Productivity degradation:* Production will be lowered due to interruptions. The magnitude of the impact is the function of the required degree of concentration for the changed work, type of the required resources, total number of interruptions, elapsed time since the last interruption, expectation of interruption, source of the interruption and, finally, whether workers agree with the change.
- *Delays:* Additional and different types of materials may be required and this may take some time.
- *Equipment and labor in tearing out completed work:* Removal of the completed work may require additional equipment and labor.

- *Materials wasted in rework:* Changes may necessitate removing some contractor-furnished material. This may result in waste of materials.
- *Nonproductive periods during redirection of work:* Reorganization of the crew may take some periods of nonproductive times.
- *Recovery scheduling:* Overtime and multiple shifts may be required to meet deadlines in the project.

Each of these items will be a burden to the project in terms of additional cost and time. Furthermore, these impacts will also cause secondary impacts on other activities.

2.2.3.2.2 Indirect Impacts

Indirect impacts known as consequential or ripple effects, are those resulting from the direct impacts and are experienced by other activities either concurrently or later in the project. The identification and proof of these types of impacts are more difficult since this time a logical link with the impact of the change should be established. However, they are equally important and should be included in an analysis.

Indirect impacts of changes are summarized from CII publication (Cost/Schedule Control Task Force 1990):

- *Productivity degradation in succeeding sequential activities:* There is a tendency that the lowered productivity will adversely affect the succeeding activity.
- *Productivity degradation of adjacent concurrent activity:* Interruption in one activity will have impacts on the adjacent activities. The affected crews will reflect their idleness to the surrounding work area.
- *Increased overhead costs:* First, additional supervision will be needed. Also, a delay in completion time will increase overhead costs.
- *Extended project time:* A critical activity may be affected and the project duration may be extended. Constructive acceleration will occur in case the owner fails to recognize the extension; hence, the contractor should claim the incurred costs.
- *Crash scheduling cost:* In order to meet project completion time, schedule compression may be required. This necessitates overtime and multiple shifts which are not so efficient.
- *Changes to subcontracts:* Any change will be reflected in the work performed by subcontractors. When this happens, they will request price and schedule adjustment.
- *Time-value of capital employed:* Changes may require purchasing some additional materials. The money would be used somewhere else or earn interest.
- *Change of work to a different working period:* Sometimes, delays caused by changes may push the working time to another working period. This working period may not be convenient in

terms of weather conditions and cause disturbance like the erection of steel construction moving into the winter.

2.2.4 Types of Disruptions

The potential of changes to cause dispute can be seen from the list given in Table 2.2.4. This table is arranged based on responses to a survey of state transportation agencies and contractors. The table clearly shows that most of the dispute types involve:

- Changes, or
- Impacts of changes like the items listed under the heading "Delay/Impact", or
- Other dispute types, which may be considered change sources like the items listed under the headings "Design/Engineering Defects" and "Differing Site Conditions".

Disputes also have considerable impacts and require additional efforts of parties to settle them. When they escalate to claims and litigation, those litigation impacts may be heavier than the impacts of changes.

Table 2.2.4 Types of Disputes (Bramble and Cipollini 1995)

Changes

- Estimated quantity variations
- Extra work/scope of work
- Agency changes
- Disputes directed changes/change orders
- Constructive changes
- Cumulative changes
- Contract interpretation
- Higher performance standards
- Over inspection
- Alignment changes

Design Engineering Defects

- Design errors
- Design omissions
- Plan revisions
- Layout errors
- Dimension problems

Differing Site Conditions

- Differing geotechnical conditions
- Soil settlement
- Mislocated utilities
- Hazardous material
- Incorrect as-built dimensions
- Environmental conditions

Third part Actions/Inactions

- Governmental actions
- Strikes
- Utility relocation delay
- Right-of-way/easement disputes
- Work of previous or adjacent contractor
- Transportation delays
- Acts of god
- Weather
- Third party permits

Delay Impact

- Project delay
- Suspension
- Acceleration
- Lost labor productivity/inefficiency

Contractor Management and Performance Problem

- Inadequate staffing
- Equipment failures
- Poor planning
- Work quality/defective work
- Subcontractor defaults
- Labor productivity/inefficiency

Site Access or Site Management Failures

- Right-of-way delays
- Restricted or denied site access
- Traffic control problems

2.2.5 Tools to Quantify Delay Impacts

Schedule analysis are successfully applied both to recognize delays and to quantify the net impacts of delays on a project. Bar Charts and Critical Path Methods are the basic tools that are used in the analysis.

2.2.5.1 Bar Charts

Bar charts are time-scaled drawn charts to show duration, start and finish times of project activities. Bar charts are one of the first tools in work scheduling. They were introduced by Henry L.Gannt and Frederick W. Taylor in the early 1900s. This was the most common tool for planning and scheduling until 1957 (Wickwire, Driscoll and Hurlbut 1991). Bar charts are visually effective in communicating a schedule. However, this effectiveness diminishes as projects become complex. This might not have been a problem in the past, but today bar charts can only be used to depict the summarized schedule of a project or a fragment from a schedule.

Bar charts have various limitations. Wickwire et.al. (1991) give a detailed list of bar charts disadvantages:

1. Size limits a bar chart in what it can graphically present
2. Bar charts do not show the interrelationships or interdependencies of one bar to another

3. Bar charts do not show the available float or contingency time, nor can they show the delay impact of one bar on another
4. Bar charts are not capable of accurately distributing or controlling manpower and project costs.
5. Adding more detail to the bar chart makes it harder to read, understand, and maintain.

As a result, bar charts cannot depict the logical relationship among activities.

2.2.5.2 Critical Path Method (CPM)

The Critical Path Method (CPM) is originally a planning, scheduling and controlling tool in project management. Proper use of this tool facilitates the completion of projects in a timely manner. Wickwire et.al. (1991) defines CPM as "A graphic representation of the planned sequence of activities that shows the interrelationships and interdependencies of the elements composing a project."

E.I.Du Pont de Nemours Company in conjunction with UNIVAC Applications Research Center of Remington Rand developed the Critical Path Methods between 1956 and 1958. CPM was not widely used until late 1960s and early 1970s (Callahan, Quackenbush and Rowing 1992). Despite the fact that CPM was intended as a planning tool, later another feature of CPM was exposed: it can be well applied to prove delay claims. This results primarily from CPM's capability to depict the picture of the project and changes. Now it is possible "to deal with previously illusive question of concurrent delay, on and off critical path and the difficult question of cause, effect and liability." (Wickwire and Smith 1974)

2.3 Types of Delays

According to the American Institute of Architects (AIA) general conditions of contract, classic delays occur when a period of uselessness and/or idleness is imposed upon the construction work. Such delays can be classified as:

1. Excusable/compensable
2. Excusable/noncompensable
3. Non-excusable

Excusable/compensable delays are not caused by the contractor but by the owner. The reasons for such delays may be the following;

- Owner's delay in providing access to site
- Change in scope of work or in construction detail
- Failure on the part of the owner to approve shop drawings, schedules, and material on time
- Suspension of work or wrongful termination by the owner
- Failure on the part of the owner to properly coordinate multiple contractors
- Nonpayment of the contractor
- Unnecessary interference by the owner

- Delay in receiving design or owner-furnished material in time
- Defects in plans and specifications
- Improper or delayed issue of change orders
- Inadequate information and supervision by the owner

In delays that are excusable/compensable, the contractor is allowed for time extension and extra cost for the losses. For example, if a change due to owner in the design occurs after an element of construction is performed, requiring crews to go back, remove and replace the element of construction, this type of delay becomes an excusable/compensable delay.

Excusable/noncompensable delays are caused by events that are beyond the contractor's and owner's control. For example;

- Extreme weather
- Fire
- Flood
- Strikes
- Lockouts
- Vandalism
- War
- Epidemics
- Damage**,** caused by parties other than the contractor or the owner

- Prices of some materials shooting up or the constructed project being devalued
- Government actions and inactions regarding ordinances, construction law, and etc.

Such delays are usually provided in the contract under *force majeure* events. When not provided, the claimant may be liable if the party against whom the claim is brought has possibly and reasonably foreseen these causes. For example, in the case of the Arundel Corp. versus United States, the situation was a delay due to an act of nature. Before the contract was executed, a hurricane set up currents that scoured a channel and removed a large amount of material that was to be dredged. The amount to be dredged was reduced, and the contractor filed a claim on increased overhead per unit to be removed. The court ruled since this was an act of God, neither party was liable to the other (O'Brien 1976).

Non-excusable delays are due to the contractor's inefficiency. The owner has the right to charge the contractor liquidated damages for such delays in the total project duration. Reasons for these delays maybe;

- Shortage of qualified workers, technical personnel, or material
- Delay in producing design if it is a design-construct job
- Failure to coordinate the work, i.e., deficient planning, scheduling, and supervision
- Delay caused by one of the subcontractors
- Defective work that has to be redone
- Slow mobilization

- Low contractor productivity
- Accidents

Depending on the timing of the events, delays can further be classified at activity level as:

1. Independent delays
2. Concurrent delays
3. Serial delays

An Independent delay is the one that occurs independently of any other delay and has no effect on any other activity in the project. It is relatively easy to identify the delay, to establish its effects on total project duration, and to allocate cost burdens to the parties involved**.**

Concurrent delays occur when the overall delay is caused by several factors, some of which are within the owner's responsibility and some others are within the contractor's responsibility. The overlapping nature of the events makes it difficult to discern what proportion of the overall delay is the party's responsibility.

Serial delays occur when a series of delays are linked together. For instance, if an owner's representative delays the review of shop drawings, and this delay causes the project to drift into a strike or severe weather, then the court may find the owner**,** liable for the total serial delay resulting from the initial incremental one.

2.4 Retrospective Delay Analysis Techniques

Delay is one of the most common problems in the steel construction industry. There are several methods for computing activity delays and assessing their contribution to project delay. Common delay analysis methods are based on critical path method (CPM) techniques and are performed by contrasting the as-planned and as-built schedules (Kraiem and Diekmann 1987; Trauner 1990). A delay of an activity on the critical path delays the completion of the project. However, the critically of individual activities in a CPM network changes from day to day due to delays and accelerations in construction (Arditi and Robinson 1995). Therefore, extra effort is required on the part of managers to update the as-planned schedule with daily as-built information (Kallo 1996)

Research efforts have contributed to the development of computer-based systems for delay analysis. Alkass et al. (1995) developed a computer-aided construction delay analysis system. Diekmann and Kim (1992) developed an expert system named Super Change to advise inexperienced site engineers about the legal consequences of construction disputes so as to reduce potential claims. Yates (1993) presented a construction decision support system for delay analysis with the capability of determining possible causes for project delays, and suggesting alternative courses of action to prevent further delays. A multimedia system for construction delay management is discussed by Abudayyeh (1997).

Since its foundation in 1983, the Society of Construction Law has worked to promote for the public benefit education, study and research in the field of construction law and related subjects (including adr, arbitration and adjudication), both in the UK and overseas. (http://www.scl.org.uk/index.php). In the society of

Construction Law Delay and Disruption Protocol, four retrospective analysis techniques are referred, as follows (Peter Barnes, 2003);

1. As-Planned v As-Built
2. Impacted As-Planned
3. Collapsed As-Built
4. Time Impact Analysis

2.4.1 As-Planned v As-Built

This method compares the duration of an As-planned activity (or the duration of all As-planned activities) on the original programme with the as-built duration for that same activity (or those same activities) on the as-built programme.

The difference in time between the duration on the As-built programme and the duration on the As-planned programme is taken as the period of delay to which a Contractor is entitled to an extension of time as a result of an excusable delay event (or delay events) (otherwise known as Employer delay events).

To make this method work effectively**,** the activity or activities need to be clearly on the critical path. Besides, the delay event or events need to be clearly identified and there should be no other delay events to the activities in question that are non-excusable delay events (otherwise known as Contractor delay events)

The method is inexpensive to use, simple to use and understand but no detailed analysis is possible. It can only be used on the most simple construction projects. It cannot deal with (a) the issue of concurrent or parallel delays, (b) the matter of consequential delay or re-sequencing of works, or (c) the effects of mitigation and/or acceleration measures.

2.4.2 Impacted As-Planned

This method adds an identified excusable delay event (or events), either as a separate activity (or activities), or onto the duration of an existing activity (or activities), into the As-planned programme. The duration of the activity is derived (where possible) from the resource allowances on the As-planned programme.

The As-planned programme with the delay event (or events) incorporated is then re-run, to show a resultant revised completion date on what is then called the Impacted As-planned programme. The period between the completion date shown on the As-planned programme and the one shown on the Impacted As-planned programme, is taken as the period of delay to which a contractor is entitled to an extension of time as a result of an excusable delay event (or events) (otherwise known as employer delay events).

To make this method work effectively, a simple contract or, in the case of more complex projects, delay events that occur only over limited periods or where the As-planned programme has been affected by a limited number of delays is only needed. Besides, an accurate and realistic As-planned programme and sufficient details on the As-planned programme to allow a reasonable estimate to be made of the resources necessary (based upon the allowances included in the As-planned programme) to access the time to be added for the task resulting from the excusable event (or events) are needed.

For this method, As-built information is not needed at all. As the As-planned Impacted programme rarely bears any relationship with what actually happened on site, it can be used to illustrate areas where the contractor took acceleration measures (or conversely where the contractor's actions were deleterious).However, this method is a very theoretical method, relies heavily on the As-planned programme, and can show misleading results if the As-planned programme is incorrect (either in terms of durations for activities or in respect of logic linking). Also, as the As-planned impacted programme rarely bears any relationship with what actually happened on site, it is difficult to use the results to ascertain a contractor's actual extension of time entitlement. If records are available for an As-built programme, then it is unlikely that a tribunal will accept this theoretical method as a basis for assessing a contractor's extension of time entitlement.

2.4.3 Collapsed As-Built

Collapsed As-built method involves removing from the As-built programme identifying excusable delays to show what the completion date would have been if those delay events had not occurred.

The period between the completion date on the As-built programme and the completion date on the collapsed As-built programme, is considered the period of delay to which a contractor is entitled to an extension of time as a result of an excusable delay event (or events) (otherwise known as employer delay events)

To make this method work**,** an accurate As-built programme and clear identification of delay events are needed.

As this method is based upon the As-built programme, there is certainty that the outcome coincides with the events on site. It is easy to understand but the removal of rare arbitrarily established delays from the As-built programme can conceal the actual effect of the contractor's delays, and cannot allow for (a) the issue of concurrent or parallel delays, (b) the matter of the re-sequencing of the works, or (c) the effects of mitigation and/or acceleration measures. The re-creation of a critical path following the removal of delay events may not be the same as the critical path that actually has existed at the time of delay event since the process involves the re-construction of the as-built logic. In respect of both of the above items, criticisms may be made of the subjective approach that must be used.

2.4.4 Time Impact Analysis

Time impact analysis can be considered under two headings, i.e. Window analysis and Snapshot analysis. A snapshot analysis is used primarily only in the event of contemporaneous extension of time award. Window analysis is based on the analysis of the effects of delay events over the entire length of a project by looking at the events which have affected progress within 'windows' of the contract period sequentially. The duration of each window is not predetermined, but is frequently taken as one month. At the end of each window**,** the As-planned programme is updated to take account of any delaying inefficiency which is the contractor's risk, any necessary logic or duration revisions because of mitigation measures undertaken, together with all excusable and/or compensable events during the period since the last update. The closing of a window in this way forms an as-built programme at the end of that window which effectively becomes the As-planned programme for the next window in sequence.

At the end of each window a projection is made for the completion date. At the end of the last window, a final revised completion date which, when compared to the original As-planned completion date, indicates the extension of time entitlement of the contractor is provided.

To make this method effectively, when used retrospectively accurate information at the time of the windows must be available. Besides, an accurate As-planned programme that reflects all of the activities to have been included within the original programme is needed.

This method is the one recommended within the Society of Construction Law Delay and Disruption Protocol. In each window, there are relatively few activities to be analyzed (as compared to the over-all programme) and therefore the delay analysis becomes easier. It is the best technique to determine the amount of extension time that the contractor should have been granted at the time that an excusable risk occurred. However, for the application of this method, accurate progress information at the time of the windows must be available, or else, the analysis will not be properly or accurately completed. The less accurate the programme and available progress information is, the more likely it is to obtain inaccurate results which require to be amended by manipulating any obvious errors in the original As-planned programme.

To come to a conclusion, there seems to be some unnecessary confusion regarding the various delay analysis techniques. They are all relatively simple to understand in principle, but (in some cases) they are perhaps rather more difficult to operate in practice. Each of the technique has its own strengths and weaknesses, but in reality the delay analysis to be used is often not dictated by the appropriateness of the technique itself but by factors such as, the relevant conditions of contract, the nature of the causative events, the value of the dispute, the time available, the records available, the programme information available, the programmer's skill level and familiarity with the project.

2.5 Effective Documentation

An accurate delay analysis cannot be made without proper documentation. In order to quantify impacts, documentation is necessary to show when the disruption occur and how it affected both time and cost.

Effective documentation is the result of following simple guidelines and maintaining organizational discipline. Typically, completing paperwork on a construction project becomes burdensome, so this is the point at which the discipline plays a role. The profitability of the project could be directly impacted by effective documentation or lack of it.

Guidelines:

Project managers must establish a minimum checklist of records for retention. A standardized format or outline for the organization of files to be kept is beneficial to the maintenance of effective documentation. The following are the types of records that should be included in a well-organized filing system:

- The original estimate, with all data upon which it is based
- The contract and other legal documents
- Correspondence (including any pre-contract correspondence)
- Meeting minutes
- Daily logs or diaries
- Weekly/monthly reports
- Photographs
- Engineering drawings
- Engineering calculations
- Quality control/quality assurance records
- Other technical information
- Schedules and other planning documents
- Procurement/purchasing records
- Cost and financial reports
- Payroll and personnel records

- Equipment assignment and utilization records

The checklist can be tailored to suit the requirements of any company and further individualized for each project. Additional recommendations relative with effective documentation follow: The Original Contract, subcontracts, change orders, and any other legal documents pertinent to projects should be kept in locked, fireproof filing cabinets or safes. Correspondence may be the most important record. Firstly, letters must be written when it is required:

- to record the compliance with the contract (as with contractually required submittals and reports)
- to confirm verbal requests or instructions
- to report unforeseen events or conditions
- to record your disagreement with a statement or position taken in writing by the other side
- to give timely notice of a request for additional time or compensation

All original incoming and outgoing correspondence is generally kept in a chronological file or files. These are control files to be protected from removal.

On all but the smallest projects, subject files are usually created with photocopies for easy reference to specific commercial or technical subjects, like "Insurance" or "Pipelines." Many companies have replaced subject files with computerized indices and in some systems; much of the correspondence itself is retrievable via the computer. Daily logs or diaries record:

- the day's work activities and production
- quantities where applicable
- milestone events
- weather
- any conditions or events that affect production

If planned operations are prevented, delayed or changed in their nature, this fact should be noted and the reasons should be stated. Accidents on or about the jobsite should be given particular attention in the diary, even when they do not appear to involve the company directly.

Key instructions and requests that were not stated in written form should be recorded. Formal inspections, and visits to the site by non-resident staff of the owner, architect/engineer, or contractor should be noted. The assignment and utilization of labor and equipment unless these are recorded elsewhere should also be recorded.

A contractor frequently keeps a good, separate record of labor utilization by task, but fails to do the same for equipment. The diary should be concise and objective, and must actually be kept daily; otherwise, much information will be forgotten or misplaced.

Meeting minutes and periodic reports prepared by others must be reviewed carefully. If there are errors or important omissions, they should be corrected in writing as soon as possible. Furthermore, when daily logs indicate that key verbal instructions or approvals are given, these should be discussed during meetings. In this way, the problem situation is discussed openly and the issue is recorded in the course of the meeting.

Photos should be taken at regular intervals of day-to-day activities and of any special or unforeseen events. The date of each photo should be recorded, provide a brief description should be provided where necessary. Photographs provide significant factual information which may not have seemed important at the time.

Engineering drawings, calculations, technical data from catalogs and manuals, test certificates, and other technical information can be voluminous. It should be ensured that any of these documents within control are properly dated and identified with revisions indicated. If received or sent with transmittal correspondence and stored separately from the correspondence, it should be ensured that the documents are adequately cross-referenced with other documents and correspondence.

A contractor should be able to readily access job records and easily follow the paperwork regarding any project-related transactions. For instance, it shouldn't be a time- consuming search to track shop drawings from one supplier, submit them to the contractor three times, get them routed by the contractor to the owner's engineer three times, return them twice for correction, and finally to approve them. The contractor should have no trouble in identifying the final version upon which the fabrication was done.

Cost records cannot be overemphasized. Accountants may be satisfied with auditable, verifiable, and accurate records of total job costs that do not indicate the costs of a particular item of work or extra work. To request extra payments, however, the contractor will be required to demonstrate that the costs claimed were actually incurred on the extra work.

Cost records maintained in the normal course of business will carry much more weight than an after-the-fact reconstruction or estimate. This cost accounting system does not need to be complex. Most firms utilize uncomplicated cost code breakdowns that are tailored to the particular needs of the specialties.

Contractors should not overlook equipment utilization costs. If equipment cost is not distributed to work items in the cost system, contractors should keep a separate record of equipment utilization in the same fashion that labor utilization is recorded by work item and on a daily or weekly time sheet.

When extra work is identified and separable, it should be recorded under cost codes which are set up specifically to cover extra work. If possible, **c**ontractors should have the owner's representative sign force account sheets covering the extra work on a current basis. These can be signed as "without prejudice" if entitlement is not yet agreed upon.

The above checklist items highlight the essential documentation that should be maintained for a project. The ability to retrieve the documentation is almost as important as the creation and retention of records. Documentation management is an essential component of overall project management.

2.6 Claim Settlement Methods

Interface Consulting International, Inc. which is a leading construction management consulting firm that provides a portfolio of professional support services to all industries involved in the engineering and construction process defines the construction settlement methods as follows: A primary goal in any claim situation is to maintain control. One aspect that is often controllable is the choice of a claim settlement method. Knowledge about settlement options and their respective advantages and disadvantages helps to maintain that control. Typically, claims are settled by one or more of the following methods:

- negotiation
- mediation
- arbitration
- litigation

In negotiation and mediation, the disputing parties decide for themselves the issues at stake, while in arbitration and litigation; third parties are placed in a position to decide the outcome of the disputes. Every claim situation must be evaluated before deciding on the most advantageous claim settlement method. The appropriateness of a particular method will depend on the issues to be decided, the requirements of the parties involved, and the contract. The following questions outline specific issues and concerns to be considered before a particular method can be selected.

1. Are the issues questions of law or questions of fact?

2. Would a fair settlement require a high degree of technical knowledge on the part of the decision makers?

3. Does the amount at stake merit the cost of the settlement method selected?

4. Is timeliness of resolution essential?

5. Is confidentiality important to the parties?

6. Does the opposite side have the ability and the means to settle?

Often a claim may progress through several different methods before final settlement is achieved. Each of the major settlement options is briefly described below.

2.6.1 Negotiation

Most claims begin with negotiation, even if this phase is only the presentation and rejection of a change order request. With few exceptions, the best interests of both parties are served by resolving the dispute through negotiation.

Negotiation is the least costly and the most flexible method of dispute resolution, allowing a high degree of control over issues and time factors. The matter in question can remain confidential, and the differing parties can focus on the specific technical issues while avoiding legal technicalities. Negotiation is also the method to be most likely to preserve the ongoing business relationship of the parties.

2.6.2 Mediation

Mediation is characterized by the presence of a neutral third party that assists in the negotiations and often proposes solutions, but does not render a binding decision. The mediator works with both sides to develop and facilitate a settlement.

This method of conflict resolution is becoming increasingly popular seeing that costs can be kept relatively low while producing a timely settlement. The parties maintain close control of the issues as in negotiation, but with the added benefit of an objective opinion.

2.6.3 Arbitration

Arbitration is usually a formal legal procedure, required by contract or mutually agreed by both parties. Typically, arbitration proceedings are conducted under the auspices of a designated authority like the Construction Panel of the American Arbitration Association. The parties are usually represented by attorneys, entitled to the use of interrogatories and depositions, may call witnesses, and may cross-examine the other party's witnesses.

Arbitrators are selected depending on their expertise in the area of the dispute, which minimizes the need for education on general construction practices and frequently on the specific construction involved in the dispute. However, in some complex cases, the arbitrators perform a detailed review of the documentation in order to become knowledgeable about the specific case.

Arbitration is usually less costly than going to court, and it allows greater control of both time and decision making than litigation. Arbitration is becoming increasingly popular because of such advantages over litigation.

2.6.4 Litigation

Litigation is usually the final recourse as a settlement method and is utilized only when a construction claim cannot be resolved by negotiation, mediation, or arbitration.

Lawsuits are normally expensive and time consuming. Delays in settlement can be prohibitively expensive for a contractor or an owner incurring burdensome costs on a daily basis. In addition, legal action can expose the parties to undesirable publicity. After a decision is rendered, the case is still subject to appeal or nonpayment that can result in extra time and cost.

2.7 Construction Claim Process

A construction claim arises when a party to a construction contract believes that in some way, by act or omission, the other party has not fulfilled its part of the bargain (Levin 1998;Kartam 1999). Therefore, a construction claim is an assertion of and a demand for compensation by way of evidence produced and arguments advanced by a party in support of its case. Based on a literature review, the researchers modeled and developed the construction claim process based on the following variables (Easton 1989;European 1996;Kartam 1999):

- Claim identification
- Claim notification
- Claim examination
- Claim documentation
- Claim presentation
- Claim negotiation

2.7.1 Construction Claim Identification

Construction claim identification involves “timely” and “accurate” detection of a construction claim. This is the first and critically important ingredient of the claim process. An awareness of job factors, which gives rise to construction claims, is a skill that generally has to be specially acquired. Such learning not only sensitizes construction managers to potential construction claims, but also exposes company-wide problems to contract management. (Kululanga, et.al., 2001)

2.7.2 Construction Claim Notification

Construction claim notification involves alerting the other party of a potential problem in a manner that is nonadversarial. Time limit requirements are very crucial and critical. An initial letter of a claim notice to the other party should be short, clear, simple, conciliatory and cooperative. It should indicate the problem and alert the other party of the potential increases in time or cost. It is very hard to argue with someone who appears polite, sincere, helpful, and cooperative. (Kululanga, et.al., 2001)

2.7.3 Construction Claim Examination

Claim examination involves establishing the legal and factual grounds on which the claim is to be based. This should also involve the estimate of the potential recovery. Such issues may have to be investigated by interviewing staff who worked on the project. The primary sources for claim examination could deal with project files, video footage, memos and so on that must be used to prove the time and cost elements of the claim. (Kululanga, et.al., 2001)

2.7.4 Construction Claim Documentation

Claim documentation is the collection of hard facts that give the actual history of a construction claim. A well-prepared defendant quickly demolishes evidence and claim costs that are not supported by accurate records. The documented facts are the glue that holds the legal framework together. If these are insufficient, the claim will not stick. (Kululanga, et.al., 2001)

2.7.5 Construction Claim Presentation

A claim presentation should be logically built up, well organized, and factually convincing. Thus, a claim should be written in a format emphasizing the fact that a contract requirement was breached. A contractor must then demonstrate the resulting harm was caused by the owner's acts. (Kululanga, et.al., 2001)

2.7.6 Construction Claim Negotiation

According to Easton (1989) a structured and proper negotiation preparation includes (1) ascertaining that all information is current and complete; (2) minimizing the scope of negotiation beforehand so that insignificant points can not precipitate a violent argument and disrupt progress; (3) knowing one's weaknesses and trying to utilize weak points by conceding them in return from the other party; (4) foreseeing problems; and (5) anticipating the opposers's next move. To benefit from this stage, a construction contractor needs experts with skills for negotiation. There is a saying that "it is more important to be prepared than it is to be right." (Kululanga, et.al., 2001)

This chapter is aimed at defining some of the terms widely used in delay analysis and claim management literature. The reasons and impacts of work changes are discussed as well as types of delays stemming from work changes. Delay analysis tools present in current literature are presented and benefits of TIA are clarified. The importance of effective documentation is emphasized and the usage of delay analysis during construction claim process is highlighted. In the forthcoming chapters, a breakdown structure that summarizes the potential sources of delay in steel projects will be presented and a delay analysis methodology based on TIA will be proposed. Application of this method will be demonstrated on a steel construction project.

CHAPTER 3

A DELAY ANALYSIS METHODOLOGY
FOR
STEEL CONSTRUCTION PROJECTS

3.1 Disruptions Affecting Cost&Time of a Steel Construction Project

Steel construction industry is very sensitive to dispute. Whenever a dispute arises, the project suffers and progress slows down. Dispute diverts resources from meeting project objectives, and thus, project cost increases, and finish date extends due to disruptions caused by disputes.

Disruptions in steel construction industry can arise from different factors. In this study they will be categorized in three sections. The risk breakdown structure proposed to be used in steel construction projects is depicted in Figure 3.1.

1. Owner related disruptions
2. Contractor related disruptions
3. External Factors

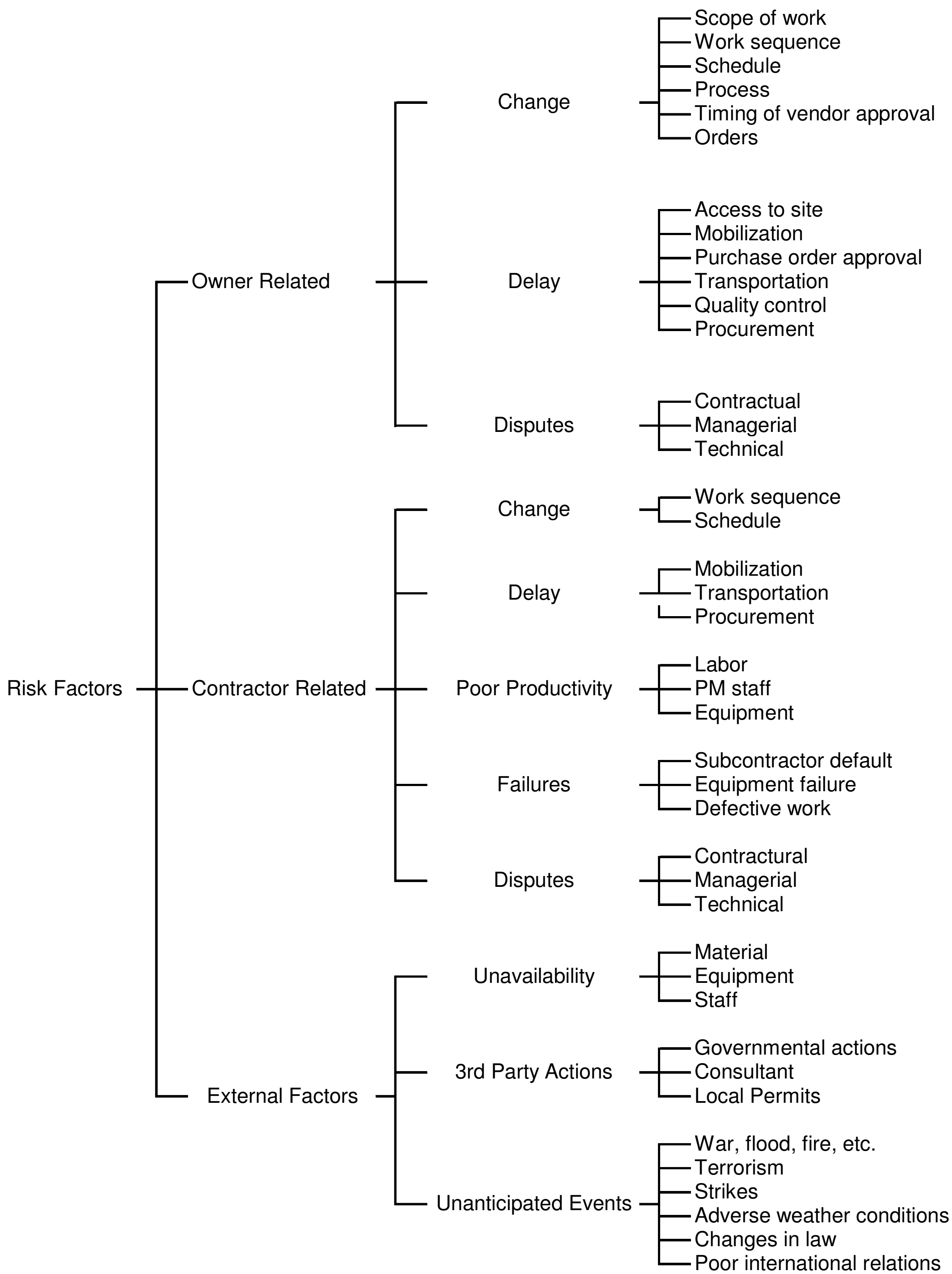

Figure 3.1 Risk Breakdown Structure for Steel Construction Projects

3.1.1 Owner Related Disruptions

Owner related disruptions result from the delays which are not contractually the responsibility of the contractor, but that of the owner. These are the ones for which the contractor could not be terminated for default for failing to perform within the original contract schedule or be subject to liquidated damages. Those delays are also called excusable/compensable delays. As a general rule, an excusable delay is the one arising from unforeseeable causes beyond the contractor's control and without contractor's fault or negligence. The delay is compensable if

- The contract language does not prohibit the recovery of compensation or financial damages for the delay;
- The contractor did not concurrently cause the delay; and
- The contractor can quantify its damages with reasonable certainty

The reasons for such delays, related with owner, in steel construction projects may result from several risk factors which are defined in Figure 3.1. This table is prepared with regard to the experience obtained from different projects. Some examples for such delays are as follows:

Delay in purchase order approval: Purchase order documentation is very important in steel construction projects. Every material that will be used throughout the project is specified in that documentation. The contractors can only use the approved materials present in the purchase order. To illustrate, in the steel construction project in Libya, the purchase order documentation was prepared and sent to the owner for approval. Although the purchase order documents fulfilled the requirements specified in the specifications, the owner couldn't decide the materials that would be used for the fabrication since some plates used in that project was with St44 quality and some were with St52 quality. According to the specifications, the origin of the materials with St44 quality may be Romania, China, England, or any equivalent country and all of them should be certified. The contactor offered to use materials produced in Turkish factories. The owner doubted about using the Turkish fabricated materials and decided to approve the purchase order documentation after some negotiations with the design firm. All the same, that period was out of the planned schedule, the project was delayed for that lateness and the total project cost increased due to increased overhead costs.

Delay in transportation: In steel construction projects, the transportation is usually in the scope of the owner if the work is carried out in a foreign country. To give an example, in the warehouse project in Iraq, the transportation was in the scope of the owner. The contractor submitted the fabricated columns and beams to the owner at their factory; however, the owner faced some problems due to some custom formalities and the transportation activity was delayed. As a consequence, the overall project was delayed and total project cost increased owing to increased overhead costs.

Technical disputes: Design errors are one of the most common faced problems in steel construction projects. The profiles used in the design may be tailor made or standard ones. If statically all the conditions are satisfied, the designer should select the profile with respect to the market availability, production duration and economy. As an example, in the steel bridge construction project in Sudan, I beams were selected as standard profiles at the beginning of the project but later on they were decided as tailor made. Even so, the change in the connecting members wasn't taken into account and the places of the holes were not suitable for the tailor made beams. That error in the design of the beams led to delay in the fabrication, the project completion date automatically extended and total project cost increased.

3.1.2 Contractor Related Disruptions

Contractor related disruptions result from the delays that are completely under the control of the contractor. These types of delays are also called non-excusable delays. A non-excusable delay is a delay for which the contractor has assumed the risk under the contract.

The reasons for such delays, related with contractor, in steel construction projects may result from several risk factors which are defined in Table 3.1. Some examples for such delays are as follows:

Procurement: Before the fabrication stage, procurement is one of the most important activities affecting overall the project. In steel construction projects, there are different types of materials that can be used and the market conditions play a striking role for the procurement. Some materials such as some types of pipes, boxes, transmission bars, nonstandard plates, and, etc. are not easy to be found at any time and any place. Also, some St52 quality plates and profiles cannot be found from the local market in Turkey. Most of these materials are brought from abroad. For instance, a thick plate with St52 quality was needed by the contractor in airport steel construction in Turkey. That material couldn't be found in the local market and it was tried to be brought from Sweden. Before the contract was awarded, the difficulty in procurement of those type of materials had not been noticed by the contractor. For that reason, the procurement activity present in the as planned schedule, which was approved and attached to the contract, was delayed. Since that activity was on the critical path, the project completion date extended and the total project cost boosted due to increased overhead costs.

Poor Productivity: Productivity is one of the most important factors which affects the project time and cost in steel construction projects. In most of the international projects, especially the welders should be certificated on the fabrication and erection stage. For the quality of the work, this certification of welders is very important. Not only the certification is important but also the qualified labors, assemblers, painters, and, etc. play an important role for the quality of the job. For the fabrication, the contractors should have the staff that is familiar with the steel projects work. Otherwise, some parts of the work will be fabricated incorrectly and this will require extra time to make corrective actions for the fabricated products. To illustrate, in the dry storage warehouse steel construction project in Iraq, the contractor used assemblers with inadequate capacity for the erection activities. Because of this, the erection activities were completed ahead of the planned schedule. Since erection activities were on the critical path, the completion date of the project was affected, and total cost/time of the project increased.

Defective Work: At the beginning of the steel construction projects, the details of the project should be examined carefully and the vital points of interests should be noted. During the progress of the work, those points should be reviewed periodically. After the cutting, pre-assembly, welding, sand blasting and painting stages, the produced parts should be controlled. If any mistake is noticed during the quality control process, the corrective actions should be taken immediately. If the incorrect parts cannot be determined during the fabrication activity, the project completion date and cost may be affected due to time spent for the corrective actions taken after fabrication. To give an example, in the steel construction project in Afghanistan, the contractor produced some of the columns, not in accordance with the project. The plates connecting the beams and the columns were not at their right places. During the quality control inspection performed by the owner's 3rd party inspector, such a situation aroused and the contractor was forced to fabricate those columns again. Since those columns were the first priority members to be erected, the delayed fabrication activity, which was on the critical path, extended the project completion date, and the total project cost increased.

3.1.3 External Factors (Neither Contractor nor Owner Related)

External factors result from the delays, beyond the contractor's and owner's control. These types of delays are also called excusable/noncompensable delays.

The reasons for such delays, related with neither contractor nor owner, in steel construction projects may result from several risk factors which are defined in Figure 3.1. Some examples for such delays are as follows:

Unavailability: Some of the common risk factors faced in steel construction projects are the unavailability of the materials, required equipments and required skilled staff. At the bidding stages and at the time of contract award, those important factors are not taken into account by most of the contractors, so they cause disputes during the project, and thus the project completion date and total cost are affected. However, that situation is mostly not related with contractor or owner. The market conditions determine the availability of those materials, equipments or staffs. The available materials at the time of contract may not be found during project progress or the required staff easily available at the time of bidding may not be found easily when job is in progress. For instance, in the medical warehouse steel construction project in Iraq, there were 273x15mm pipes used in the upper part of the columns. Yet, since those dimensioned pipes were not standard products, that material couldn't be found in the markets present in Turkey or abroad. Hence, the owner was informed about his situation by letter. After negotiations between owner and the design firm, the type of the pipes was changed. That unavailability affected the procurement activity and that activity was delayed. Since the procurement activity was on the critical path, the project completion date was extended and the total project cost boosted due to increased overhead costs. That unavailability was related with neither owner nor contractor and the liquidated damages couldn't be charged into any of the parties.

Adverse Weather Conditions: The planned activities in steel construction projects may not progress as they are planned at the beginning of the project. One of the most important risk factors affecting the planned progresses is the weather condition feeling itself during the project. The adverse weather conditions affect almost every phase of the steel construction projects though mostly the erection activities are affected directly. As an example, in shopping center steel construction project in Russia, the weather was snowy when the erection activity was in progress. This adverse weather condition frequently halted the erection activity and that activity was delayed. Since erection was on the critical path, the project completion date was extended and total project cost increased.

3.2 Steps in the Methodology

For the methodology proposed in this study, some steps should be followed in an order. The steps can be summarized as follows;

1. Identify and quantify the delays
2. Allocate responsible parties
3. Apply a delay analysis

3.2.1 Identification and Quantification of Delays

In a steel construction project, to be able to make a delay analysis, a clear presentation of delays should be at hand. Before a powerful delay analysis can be developed, there must be basic documentation of the project progress. If no records are available, the project cannot be completely controlled and visualized, and so a successful analysis cannot be applied. Thus, project staff should be alerted when conditions on the project have changed, namely, they are different from the conditions anticipated in the plans, or from the expectations in the progress of work.

Besides, other documents, daily logs, diaries, and daily/weekly/monthly reports should be kept in a discipline. Keeping diaries should start just after the contract has been signed and finished after the acceptance is made. In the daily logs, important issues affecting project progress should also be noted. Any problems faced throughout the project should be written in letters. If planned operations are prevented, delayed or changed in their nature, this fact should be noted and the reasons should also be stated. The assignment and utilization of labor and equipment should be recorded if they are not recorded anywhere. The diary should be concise and objective, and must be kept daily during the fabrication and erection stages. Between the period of contract award and fabrication, the problems should be sent to the owner in a written form.

For the period of fabrication and erection, various formats can be used to indicate the progress of the work. An example for a daily report is given in Table 3.2.1.1. In addition to the normal diary entries, keeping a daily equipment list is recommended for the documentation of the contractor's equipment and manpower.

Important items in the documentation of the contractor's equipment are:

- An accurate record of working hours
- The item of work performed during those hours by each piece of equipment
- The location of the work performed
- Any down time hours for idle equipment
- Detailed information on the equipment to include type, year, make, and model

Table 3.2.1.1 Daily report format

Date :

Weather :

No	Description of the Activity	Planned Progress Qty.	Unit	Actual Progress Qty.	Unit	Remarks

NOTES :

Table 3.2.1.2 Contractor Daily Equipment and Labor

Project Name :
Contractor Name :

Date	Equipment							Labor				Remarks
	Type	Hours		Total Hours	Item of work	Location	Standby Hours	Name	Hours		Total Hours	
		Begin	End						Begin	End		

Table 3.2.1.2 is a "Contractor Daily Equipment and Labor" worksheet. This worksheet may be used by project staff to record the contractor's daily equipment usage and labor hours. For the analysis, the resources can be allocated in each activity and when the activity is delayed, the usage of these resources can also be delayed. In the case study, the impact of the changes on the activity duration and cost will be investigated.

After obtaining the necessary data from the diary logs and daily reports, the delayed activities should be put chronologically in a simple table like the one in Table 3.2.1.3.

Table 3.2.1.3 Delay Quantification Table

No	Date	Delay Description	Delayed Activity	Amount of Delay

3.2.2 Allocation of Responsible Parties

After the delays occurring throughout the project are identified and quantified, the responsible parties should be allocated. At the previous sections, it is learned that the delays may be related with three different parties which are owner related, contractor related and neither contractor nor owner related. By using table 3.2.1.3, a table should be prepared for the liable parties. Table 3.2.2 is an example for such a table.

Table 3.2.2 Allocation of Responsible Party

No	Date	Delayed Activity	Delay Category	Responsible Party

3.2.3 Delay Analysis

Accurately analyzing and apportioning delay is essential to the allocation of responsibility for time-related costs. The purpose is to calculate the project end delay, to calculate total change in project cost, and to try to identify how much of it is attributable to each party. Time Impact Analysis (TIA) represents a methodology to analyze the delays occurring in a project in order to determine and apportion, between the parties involved, the responsibility of such delays or disruptions that brought those delays out.

The methodology proposed in this study focuses on possible delays occurring during the progresses of project activities and delays stemming from disruption events. Time impact analysis represents an analytical approach aiming not only at identifying causes and consequences of possible delays occurring during the execution of a project, but also at assigning the corresponding responsibility of each party involved in the project.

The proposed methodology includes the application of TIA on steel construction projects. This analysis allows comparing a traditional “static”approach based on the comparison between the “as planned” schedule and the current as built schedule and the “dynamic” approach typical to TIA by considering the event chain which has determined the current status of the project step by step. The study also points out the different results achieved by the two different approaches and the effectiveness of the latter approach in order to rigorously apportion both responsibility and corresponding penalties for each party involved in project completion delay. It seems to be one of the best techniques for the steel construction projects where there are a very high number of activities, dependence links among them and where time represents a determinant constraint for the success of the project. The situation of this type leads to a high overlapping of the activities and to the presence of various potential critical paths. The TIA requires a dynamic analysis of the project that takes into account what actually has happened up to that date. The status of the project, in fact, evolves in time and it is possible that the critical path will change due to certain delayed activities which are not considered critical at the beginning of the project. The objectives of a TIA are first to determine the delayed activities that have affected the project execution and second to establish the ones which are critical. Thus, the slippage of the project completion date can be determined. It is then necessary to quantify the effect of each delay on the completion date and to apportion the responsibility to the parties involved.

Project scheduling can be achieved through different tools: the most common ones are networks and bar charts. The networks and CPM in particular, have the advantage of showing the precedence links among the various activities and identifying the critical path of the project. On the other hand, bar-charts are easy to be prepared and can be understood at a glance. Nowadays, there are soft wares like Primavera and Ms. Project that combine the advantages of the two methods, providing a diagram of the activities based on linked bar-charts.

Basic Steps for the analysis:

To start the analysis, originally prepared as-planned schedule for the execution of the project, mostly attached to the contract and approved by the owner, should be in hand. As an example, to see the basic steps, a simple project with 6 basic activities and the as planned schedule present at Table 3.2.3.1 will be examined. The project finish date and total cost can easily be calculated by using that as planned schedule. For the sake of simplicity, in these basic steps only the duration of the project is examined. It should be noted that in the case study in Chapter 4, a detailed analysis will be conducted to a real steel construction project.

Table 3.2.3.1 As-Planned Schedule

No	Name of the Activity	Duration (week)	1	2	3	4	5	6	7	8	9	10
1	Contract award	1										
2	Procurement of steel	2										
3	Fabrication of steel	3										
4	Painting	2										
5	Transportation	1										
6	Erection of steel	3										

- Original total project duration is 10 weeks

Then a table for the delayed activities should be created by using daily logs and reports. Table 3.2.3.2 shows the quantification of delayed activities.

Table 3.2.3.2 Delay Quantification Table

No	Date	Delay Description	Delayed Activity	Quantity of delay
1	week 2	procurement of steel is delayed	procurement of steel	1 week
2	week 6	painting of steel is delayed	painting	1 week
3	week 10	erection of steel is delayed	erection of steel	1 week

Then all of the delayed activities should be applied to the as-planned schedule to obtain as-built schedule present at Table 3.2.3.3. As-built schedule reflects the actual execution of the works and encompasses all the delays affecting the project and causing the project to deviate from the planned track. The actual project finish date and project actual total cost can also be calculated via that as-built schedule.

Table 3.2.3.3 As-Built Schedule

No	Name of the Activity	Duration (week)	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Contract award	1													
2	Procurement of steel	3													
3	Fabrication of steel	3													
4	Painting	3													
5	Transportation	1													
6	Erection of steel	4													

- Total project duration is 13 weeks

In order to allocate the impact of delays to the liable parties, it is not sufficient to compare the two mentioned representations, as-planned and as-built schedules, by simply superimposing one on the other, so it is necessary to develop a series of snapshots of the project showing the evolution from the "planned" situation to the "actual" one.

For this purpose, the concept of the "adjusted schedule" is employed through a series of subsequent representations of the project. The portion having already executed is shown by the "as built" schedule while the remaining part is described by the "as planned" schedule. To have adjusted schedules ;

- First actual progress of first delayed activity should be entered into as planned schedule.
- Next, schedule should be recalculated to determine whether a delay is occurred in the project completion date or not.

- If so, total project cost and new finish date of the project should be calculated, and responsible parties should be assigned.
- Then the new schedule should be copied as "baseline" for next delayed activity to be analyzed.
- These processes should be repeated as many times as necessary to complete schedule analysis till all the delayed activities are used to obtain as built schedule.

Table 3.2.3.4 Impact of first delay

No	Name of the Activity	Duration (week)	1	2	3	4	5	6	7	8	9	10	11
1	Contract award	1											
2	**Procurement of steel**	**3**											
3	Fabrication of steel	3											
4	Painting	2											
5	Transportation	1											
6	Erection of steel	3											

- procurement of steel activity is delayed for 1 week
- total project duration is 11 weeks

Table 3.2.3.5 Impact of second delay

No	Name of the Activity	Duration (week)	1	2	3	4	5	6	7	8	9	10	11	12
1	Contract award	1												
2	Procurement of steel	3												
3	Fabrication of steel	3												
4	**Painting**	**3**												
5	Transportation	1												
6	Erection of steel	3												

- painting activity is delayed for 1 week
- total project duration is 12 weeks

Table 3.2.3.6 Impact of third delay

No	Name of the Activity	Duration (week)	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Contract award	1													
2	Procurement of steel	3													
3	Fabrication of steel	3													
4	Painting	3													
5	Transportation	1													
6	**Erection of steel**	**4**													

- erection of steel activity is delayed for 1 week
- total project duration is 13 weeks

In steel construction projects, the main risk of a static analysis is often to charge the whole delay occurring without understanding how it actually develops in time to one of the actors of the project. In this methodology by using TIA, in contrast to the static analysis, we appraise the evolution of the network in time with particular reference to the critical path and to the dependencies among the activities.

CHAPTER 4

AN APPLICATION OF THE PROPOSED METHODOLOGY TO A STEEL CONSTRUCTION PROJECT

4.1 General Information About the Project

The project selected for the application of this methodology concerns the construction of an industrial facility in Libya which is considered fairly straightforward in design and construction. This project is a hypothetical project created referring to a real steel construction project. The names of the company and the trade marks will be not be presented due to confidentiality reasons. The real project which is still under construction is considered as an example and problems happened in previous projects are assumed to occur in this project. Thus, although the project is real, changes are hypothetical. A general description of the facility can be summarized as follows:

SIRT B (GAG) and SIRT END (AG) Buildings are the buildings of the pump house that will be constructed for the purpose of water supply for this country. The main frame of the buildings will be structural steelwork. The client is a

German Company (from now on it will be announced as “Main Client”) and the main contractor is a Turkish Company (from now on it will be announced as “Owner”. After the contract has been signed between the main client and the owner, the owner signs a contract with a Turkish Steel Construction Company , ABC Co. Ltd. (from now on it will be announced as “Contractor”). And a 3rd party inspector firm (from now on it will be announced as “inspector firm”) is controlling every phase of the job carried out by the contractor both in Turkey and Libya on behalf of the owner.

The scope of the contractor is the preparation of purchase order (PO) documents, procurement of the materials, fabrication and painting of the structural steelwork in Turkey at its factory and painting and erection of the structural steelwork in Libya on site. All of the transportation duties, commencing handling from contractor’s factory to the construction site in Libya, transportation and custom duties and costs are in the scope of the owner.

In this project GAG building has 260 tons and AG building has 240 tons steel construction tonnage. To be able to construct those buildings, the materials will be obtained from manufacturers both in and outside of Turkey. Those purchase orders that require out of-Turkey placement include the usual difficulties which are centered on the vendor drawings, vendor information meeting the design criteria and availability of the materials.

The contract between the owner and the contractor is based on some specifications about the steel structure. The standard technical specification for steel works covers the supply of all materials, fabrication, painting and erection of structural steel work. The contractor is fully and solely responsible for all materials and services provided under this specification and for the complete coordination of all the component parts. Besides, the contract signed between the owner and the contractor follows the FIDIC specifications.

Unless indicated otherwise in the specifications, there are several codes and standards which will be applied in this project. These standards are BS, EN and ASTM codes and regulations.

4.2 Steps in the Methodology

4.2.1 Identification and Quantification of Delays

From the daily reports and the diaries, it is observed that from the beginning of the contract award, several disruptions are faced between the owner and the contractor throughout this project. The total project completion time and the total project cost increased due to the effects of these disruptions. Obtained from daily reports, the most common 9 delay events which occurred in the progress of the project will be examined in this case study.

4.2.1.1 Problems Faced During Transportation

In this project**,** the transportation from the factory of the contractor to Libya site was planned to be performed by shipment. At the time of contract, some specific dates for shipment were determined and these dates were inserted to the as planned schedule. However, the owner had some problems for the 1st delivery. The ship did not arrive on the predetermined time. It arrived 8 days later and the planned activity delayed for 8 days.

4.2.1.2 Delay in Approval of Purchase Order

According to the specifications present in the contract between the owner and the contractor, it was stated that unless the materials that would be used in the project was approved by the owner, the contractor couldn't use any unapproved materials. For that reason; before the procurement activity, the contractor prepared purchase order documents and submitted them to the owner. Due to some problems, the owner couldn't examine these documents and failed to approve them within the planned time period present in the as planned schedule. The owner delayed for 15 days and thus, the planned activity was delayed for 15 days.

4.2.1.3 Poor Quality in Fabrication of GAG P.H. Steel Construction

In the contract between the owner and the contractor, some specifications about the quality control of structural steelwork were stated to be fulfilled by the contractor. In addition to the contractor's quality control team, the inspector firm was also controlling the production before the delivery. However, before the first delivery of GAG P.H. steel construction, the inspector firm determined some faulty parts, not relevant with the specifications present in the contract. Some of the fabricated structures were rejected and the contractor was forced to revise the faulty parts. As a consequence, the duration of production activity increased and the planned activity was delayed.

4.2.1.4 Change in Painting System of GAG P.H. Steel Construction

According to the specifications attached to the contract, the coating of this project would be in 4 stages. The primer coat 20 Micron and 80 micron first intermediate coat would be applied at the factory of the contractor and 80 micron second intermediate coat and 50 micron final coat would be applied on site. As the project was proceeded, the owner changed his mind and decided to apply the second intermediate coat at the factory of the contractor. This undetermined application caused duration of the painting activity of GAG P.H. to increase for 5 days and this planned activity delayed for 5 days.

4.2.1.5 Equipment Failure During Erection of AG P.H. Steel Structure

The contractor delivered 8 welding machinery to the site for welding the parts during the erection activity. Since these were old machines, they were breaking down from time to time. Thus, the erection activity was halting due to such idle times. The improper working time of these machines caused the planned erection activity of AG P.H. steel construction to be delayed for 7 days.

4.2.1.6 Poor Quality in Painting of AG P.H. at Site

The applied 180 microns coating at factory were damaged during the transportation activity. The contractor tried to apply the final coat directly on site. However, the total 230 microns thickness couldn’t be achieved. The inspector firm warned the contractor to satisfy the total thickness specified in the specifications attached to the contract. Moreover, the contractor applied the second intermediate and the final coat at some points not satisfying the 230 microns. This repainting increased the duration of the painting activity and this activity was delayed for 6 days.

4.2.1.7 Error in the Design of AG.P.H. Steel Structure

After the contractor had started for the fabrication of AG P.H. steel construction, he noticed that some beams' holes had not been fitting the columns' holes. He informed the owner about the problem and the owner made revisions by negotiation with the design firm**.** Even so, this was not a planned case and the duration of fabrication of AG P.H. extended. Thus, that activity was delayed for 6 days.

4.2.1.8 Unavailability of Materials

In this project some of the materials were St44 and some of them were St52 quality. Since some profiles were not standard productions, at the time of contract award, the contractor investigated the local and foreign market conditions to find out whether the necessary materials were available or not. However, when the procurement activity for GAG P.H. started, some profiles which would be procured from foreign markets were not available in those foreign markets. Finally, the design firm changed the sections with alternative available profiles. This unavailability of some profiles caused the procurement activity to be delayed for 12 days.

4.2.1.9 Poor Quality in Painting of AG P.H. at Factory

In the technical specifications of the painting firm, the "dry to touch" times of the coats were determined clearly. However, due to speeding up the painting work, the contractor did not wait for enough time between not only the primer coat and the first intermediate coat but the first intermediate coat and second intermediate coat. Thus, the quality of the paintings was not as required in the specifications. At the stage of quality control by the inspector firm, this faulty painting was noticed and the contractor was forced to repaint some of the steel sections. This repainting work extended the duration and the painting of AG P.H. at factory activity was delayed for 5 days.

A chronological summary of the events that caused delays during the project is recorded systematically in the "Delay Quantification Table" in Table 4.2.1.

Table 4.2.1 Delay Quantification Table

No	Date	Delay Description	Delayed Activity	Quantity of Delay
1	13-27.02.2006	Delay in approval of purchase order	150-Approval of purchase order	15 days
2	09-20.04.2006	Unavailability of materials	160-Procurement of steel for GAG P.H.	12 days
3	03-10.05.2006	Poor quality in fabrication of GAG P.H. steel construction	200-Fabrication of GAG P.H.	8 days
4	04-10.06.2006	Error in design of AG P.H. steel structure	210-Fabrication of AG P.H.	6 days
5	10-14.06.2006	Change in coating of GAG P.H. steel construction	220-Painting of GAG P.H. at factory	5 days
6	20-30.06.2006	Problems faced during transportation	280-1st delivery	8 days
7	12-18.07.2006	Poor quality in painting of AG P.H. at factory	230-Painting of AG P.H. at factory	5 days
8	28.09-03.10.2006	Poor quality in painting of AG P.H. at site	310-Painting of AG P.H. at site	6 days
9	12-18.10.2006	Equipment failure during erection of AG P.H. steel structure	350-Erection of AG P.H.	7 days

4.2.2 Allocation of Responsible Parties

By using Figure 3.1, Table 4.2.1 and considering contract clauses, the responsible parties are allocated, and presented in Table 4.2.2.

Table 4.2.2 Allocation of Responsible Party

No	Date	Delayed Activity	Delay Category	Responsible Party
1	13-27.02.2006	150-Approval of purchase order	owner related-delay-purchase order approval	Owner
2	09-20.04.2006	160-Procurement of steel for GAG P.H.	external factor-Unavailability-material	External
3	03-10.05.2006	200-Fabrication of GAG P.H.	Contractor related-failure-defective work	Contractor
4	04-10.06.2006	210-Fabrication of AG P.H.	owner related-dispute-technical	Owner
5	10-14.06.2006	220-Painting of GAG P.H. at factory	owner related-change-scope of work	Owner
6	20-30.06.2006	280-1st delivery	owner related-delay-transportation	Owner
7	12-18.07.2006	230-Painting of AG P.H. at factory	contractor related-failure-defective work	Contractor
8	28.09-03.10.2006	310-Painting of AG P.H. at site	contractor related-failure-defective work	Contractor
9	12-18.10.2006	350-Erection of AG P.H.	contractor related-poor productivity-equipment	Contractor

4.2.3 Delay Analysis

To be able to start the delay analysis, as it is stated before, the originally prepared "as planned schedule" which is attached to the contract in this project should be in hand. This schedule is prepared in PRIMAVERA software and all of the costs and durations are calculated by using this programme. For the cost calculations**,** three different cost items are included. These are the material costs, factory and site workmanship costs and the overhead costs including the headquarter, factory, site, equipments and consumable materials costs. The material cost is $ 425.650,00 and the overhead cost is 2000,00 $/day. The overhead and the workmanship costs differ with respect to the durations which are tend to be changed as a result of the delayed activities.

According to the as planned schedule given in Appendix A, the budgeted cost and the duration are calculated. Total duration is 222 days and the budgeted cost is $ 1.110.343,00. Firstly, first delayed activity is entered into the as planned schedule**,** "Adjusted 1 Schedule" in Appendix A is obtained and the new duration of the project and new the total cost are calculated. Secondly, the "Adjusted 1 Schedule" is copied as baseline and the second delayed activity is entered to the "Adjusted Schedule 1"**.** In addition, "Adjusted Schedule 2" is obtained and the new duration of the project and new the total cost are calculated. Finally, these computations are continued until all nine delayed activities are entered to obtain the "As Built Schedule" which is equal to the "Adjusted Schedule 9. The results achieved from these 11 schedules are given in Table 4.2.3.1. The As Planned, As Built and the Adjusted Schedules are given in Appendix A.

Table 4.2.3.1 Outcomes of the TIA Analysis

Schedule Type	Project Finish Date	Duration	Total Cost
As Planned Schedule	23.09.2006	222	$1.110.343,00
Adjusted Schedule 1	11.10.2006	237	$1.140.343,00
Adjusted Schedule 2	25.10.2006	249	$1.164.343,00
Adjusted Schedule 3	03.11.2006	257	$1.194.583,00
Adjusted Schedule 4	10.11.2006	263	$1.217.263,00
Adjusted Schedule 5	10.11.2006	263	$1.218.733,00
Adjusted Schedule 6	10.11.2006	263	$1.218.733,00
Adjusted Schedule 7	16.11.2006	268	$1.230.203,00
Adjusted Schedule 8	23.11.2006	274	$1.244.309,00
Adjusted Schedule 9	01.12.2006	281	$1.273.436,00
As Built Schedule	01.12.2006	281	$1.273.436,00

As it can be seen from the outcomes of the analysis**,** there are 59 days delay in the total completion time of the project and $ 163.093,00 increase in the total project cost. To be able to see how much of this cost is resulted and from which party, the differences between the costs of the schedules should be calculated. The results of these calculations are present in table 4.2.3.2.

Table 4.2.3.2 Cost Difference Calculation Results

Type Of Schedule	Duration	Budgeted Cost	Difference	Liable Party
As Planned Schedule	222	$ 1.110.343,00		
Adjusted Schedule 1	237	$ 1.140.343,00	$30.000,00	owner
Adjusted Schedule 2	249	$ 1.164.343,00	$24.000,00	external
Adjusted Schedule 3	257	$ 1.194.583,00	$30.240,00	contractor
Adjusted Schedule 4	263	$ 1.217.263,00	$22.680,00	owner
Adjusted Schedule 5	263	$ 1.218.733,00	$ 1.470,00	owner
Adjusted Schedule 6	263	$ 1.218.733,00	-	owner
Adjusted Schedule 7	268	$ 1.230.203,00	$11.470,00	contractor
Adjusted Schedule 8	274	$ 1.244.309,00	$14.106,00	contractor
Adjusted Schedule 9	281	$ 1.273.436,00	$29.127,00	contractor
As Built Schedule	281	$ 1.273.436,00	-	

Table 4.2.3.3 indicates that out of the total increased cost of the project the owner is responsible for $ 54.150,00 and the contractor is responsible for $ 84.943,00. The remained $ 24.000,00 is neither in the responsibility of the owner nor the contractor, but since the contract is based on the FIDIC specifications; this amount is also in the responsibility of the owner.

Table 4.2.3.3 Apportioning of the Total Cost Difference

Liable Party	Total Cost
Owner	$ 78.150,00
Contractor	$ 84.943,00
Total	$ 163.093,00

4.3 Discussion of the Analysis Results

In this kind of projects, 2 alternative methods exist for delay analysis: analytical approach and dynamic approach, which is TIA. The analytical approach is based on the comparison of the as planned schedule with the as built schedule. According to this approach, the project is delayed for 59 days and the project cost is increased to $ 163.093,00. However, which party is responsible for that increase cannot be determined directly by this approach. In other words, the owner's and the contractor's liability cannot be specified. By the help of dynamic approach, typical to TIA, the current status of the project can be determined step by step. In each step, the liable party and the increased cost in the total project cost can easily be found. At the end of the application of that approach, the results show that the owner is responsible for $ 78.150,00 and the contractor is responsible for $ 84.943,00.

In the application of the proposed methodology, the duration of the project changes due to some delayed activities which are on the critical path. For example, the delay in fabrication of AG P.H. activity extended the project duration for 6 days since this activity is on the critical path, but the delay in painting GAG P.H. at factory activity and delay in the 1st delivery activity did not change the project completion date as they are not on the critical path. But, it should be noted that if the delayed activity is not on the critical path**,** this does not mean that it won't affect the project total cost. For instance, the delay in painting GAG P.H. at factory activity is not on the critical path and the duration of the project is not changed, but the total project cost is increased owing to increased workmanship costs. It should also be noted that if the delayed activity stems from external risk factor, the increased project cost and the extended project completion date are not in the responsibility of the owner or the contractor. According to "General Specifications for Public Works" **,** the increased cost stemmed from the external factors that do not happen due to default of neither of the party's, is retained by contractor, but a time extension i**s** being given. However**,** according to the FIDIC conditions of contract, the increased cost may be chargeable to the owner. In other words, whether the delays and increased costs resulted from external factors are payable to the contractor or owner changes with respect to the contract type signed between the two parties.

The methodology proposed in this study has some pluses and minuses. The analysis method used in this methodology is the best technique to determine the amount of extension of time and the increased cost due to delays. Because of its benefits, this method is recommended within the Society of Construction Law Delay and Disruption Protocol (Peter Barnes, 2003). Using CPM helps the decision-makers to see the interrelations and interdependencies between the activities. The used software programs help to reduce the time spent for the analysis calculations. Furthermore, this methodology presents a clear presentation of the progress of the project. The current situation of the project can be visualized at any stage of the project. If there exists a problem in making a decision for an activity that could be delayed after that decision, the effect of that delay to the duration and total cost of the project can be observed by simply entering that delayed activity into the current schedule. Finally, the owner and/or the contractor can make their decision in an easier way. For instance, if the decision that causes the activity to be delayed extends the duration and increases the total cost of the project seriously, maybe the person that makes the decision may alter his/her mind. On the other hand, this methodology also has some minuses. The less accurate the programme and progress information available is, the more likely the results obtained from analysis will be inaccurate. The daily logs and the diaries should be kept systemically and accurately. Otherwise**,** all of the analysis results will be wrong. It is sometimes difficult to put the delay events into chronological order. For that reason, the daily logs should be examined carefully. In case of concurrent delays, the overlapping nature of the events makes it difficult to discern what portion of the overall delay is which party's responsibility. In those cases, to determine the effects of delays on time and cost of the project, some assumptions like "first cause defines liability" should be made.

CHAPTER 5

CONCLUSION

5.1 Conclusion

At the stage of bidding just like in other types of construction projects, steel contractors plan tasks and assign resources for the execution of the project. However, plans can hardly be realized due to changes that occur during the project. These changes usually cause delays in the total project duration and lead to cost increase. If the net impacts of these changes cannot be determined reliably, these problems may result in disputes between the project participants.

In construction management literature, there is no single methodology that can be used to identify and quantify the net impacts of changes that are very likely to occur during project execution. The aim of this thesis is to propose a methodology based on time impact analysis which can be used to quantify and apportion the delays in steel construction projects. It's hypothesized that the proposed method may be used during claim management process if disputes arise due to these changes. Besides, it's believed that the proposed methodology may give realistic and clear results about how the impacts on time and cost should be shared between the parties, thus, its usage may even help elimination of disputes and the need for claims.

In this thesis, a breakdown of commonly observed changes in steel projects is presented to be used along with the proposed delay analysis methodology. Based on experience in a number of steel construction projects, potential sources of changes are categorized in order to help decision-makers to identify possible sources of delay in steel construction projects. Using this breakdown, an inexperienced planner may increase his/her awareness on potential problems and prepare more realistic time and cost plans. Secondly, this breakdown is used together with TIA to categorize the changes with respect to their ownership and helps apportioning the impacts.

The proposed methodology uses the logic of TIA. TIA represents a methodology for analyzing delays in order to investigate the responsibility of parties and disruptions that are brought out by different work changes. It requires a dynamic analysis rather than a static one. In the proposed methodology, first, delays are identified (may also be grouped using the breakdown structure), their amounts are determined, second, responsible parties are decided and lastly, TIA is used to quantify the overall impact on time and cost as well as to distribute the impact between project participants. It's stressed that major critical success factor for this procedure is "information". Some data collection sheets to be used during delay analysis are presented in chapter 3.

The application of this method was demonstrated on a steel project. Results demonstrate that using TIA and CPM has certain benefits. Other than reliability of delay quantification and apportioning process, it provides a strong ground for monitoring and visualization of what actually happened throughout the project in a step-by-step manner. It is also an effective platform for decision-making and negotiation between the parties as impact of changes can be monitored easily in any given scenario on risk allocation, utilized strategy or actions taken by different parties. Time and cost planning throughout the project is facilitated.

As it is stated in previous chapters, the proposed methodology is not without flaws. If the programme is not accurate and project information is not enough, the results obtained from the analysis will be incorrect. Since, the analysis is based on the daily logs and diaries, if the information obtained is not systematic and accurate, the results will be totally wrong. In the TIA approach, the delayed activities should be put into chronological order. This is not always easy since the activity delays may occur at the same period of time. For instance, in concurrent delays it not easy to determine the liable parties. In those cases, to determine the effects of delays on time and cost of the project, some assumptions like "first cause defines liability" should be made.

The case study is a rather simple example that shows how changes may impact time and cost. The major impact considered is "delay". However, sometimes, in order to eliminate delays, schedules are accelerated. Acceleration results in poor productivity and creates an additional cost item for the contractor. The proposed methodology may be used to monitor impact of "acceleration" on project cost as well. In the case study, the impact of changes on "productivity" is not considered as well as impacts on quality, health and safety etc. As a final remark, the acceptability of this procedure is questionable and the legal issues are excluded from the contents of this thesis.

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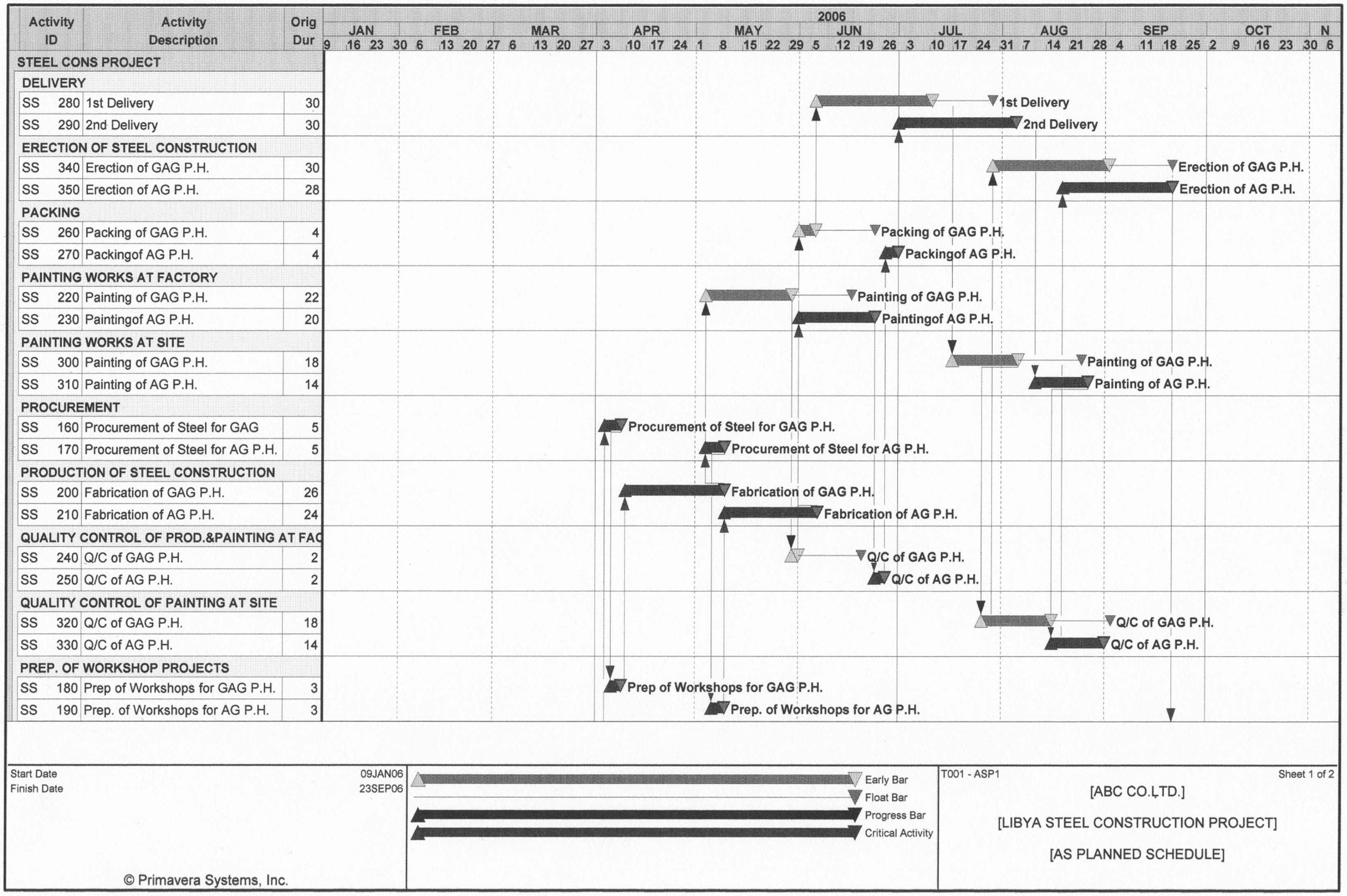
APPENDICES

A. TIA Schedules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DELIVERY
SS 280 1st Delivery 30
SS 290 2nd Delivery 30
ERECTION OF STEEL CONSTRUCTION
SS 340 Erection of GAG P.H. 30
SS 350 Erection of AG P.H. 28
PACKING
SS 260 Packing of GAG P.H. 4
SS 270 Packingof AG P.H. 4
PAINTING WORKS AT FACTORY
SS 220 Painting of GAG P.H. 22
SS 230 Paintingof AG P.H. 20
PAINTING WORKS AT SITE
SS 300 Painting of GAG P.H. 18
SS 310 Painting of AG P.H. 14
PROCUREMENT
SS 160 Procurement of Steel for GAG 5
SS 170 Procurement of Steel for AG P.H. 5
PRODUCTION OF STEEL CONSTRUCTION
SS 200 Fabrication of GAG P.H. 26
SS 210 Fabrication of AG P.H. 24
QUALITY CONTROL OF PROD.&PAINTING AT FAC
SS 240 Q/C of GAG P.H. 2
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QUALITY CONTROL OF PAINTING AT SITE
SS 320 Q/C of GAG P.H. 18
SS 330 Q/C of AG P.H. 14
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SS 190 Prep. of Workshops for AG P.H. 3
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2nd Delivery
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Erection of AG P.H.
Packing of GAG P.H.
Packingof AG P.H.
Painting of GAG P.H.
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Procurement of Steel for AG P.H.
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Fabrication of AG P.H.
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Q/C of AG P.H.
Q/C of GAG P.H.
Q/C of AG P.H.
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Finish Date 23SEP06
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Progress Bar
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[AS PLANNED SCHEDULE]
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SS	120	Design of the Project	20
SS	130	Approval of the Project	5
SS	140	Prep. of Purchase Order	15
SS	150	Approval of Purchase Order	30
SS	360	Handover	3
SS	370	End of the Project	0
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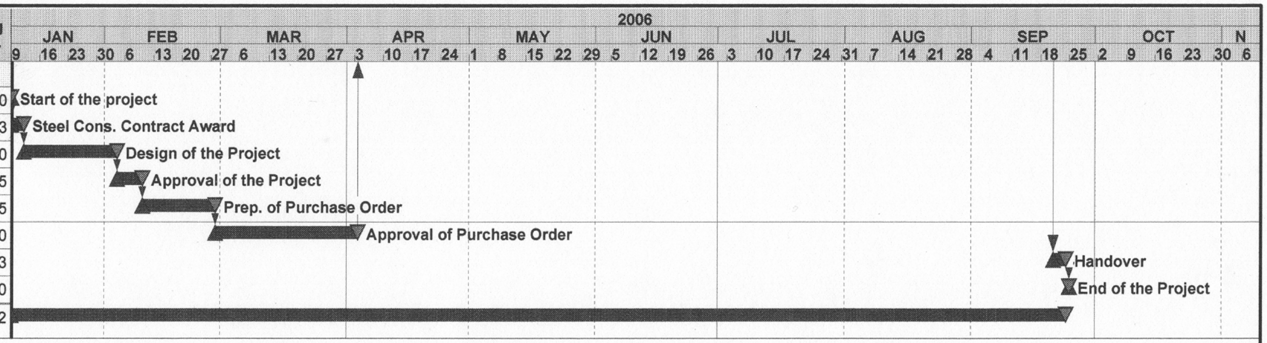

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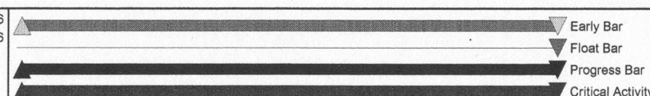

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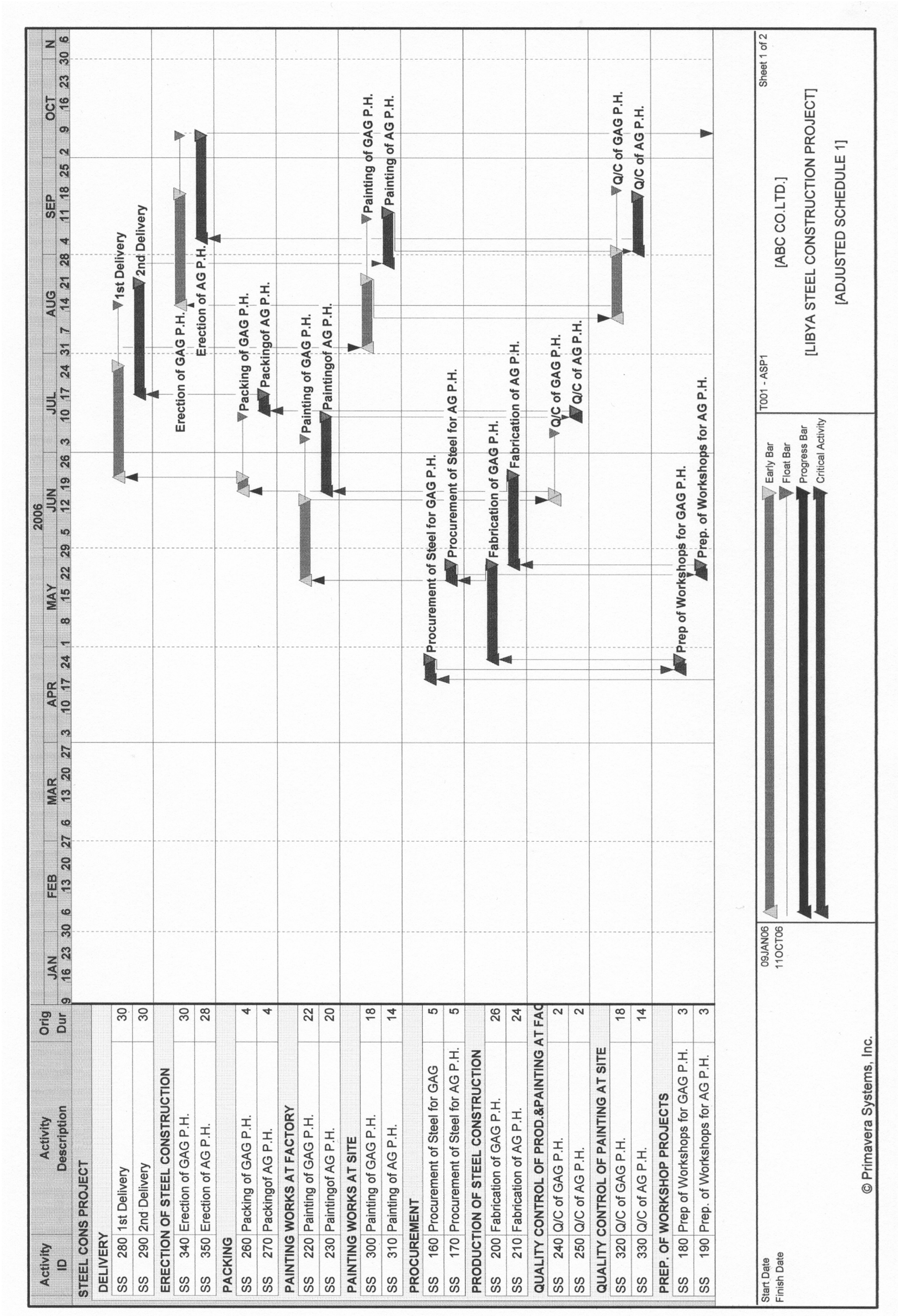
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Finish Date 11OCT06
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Float Bar
Progress Bar
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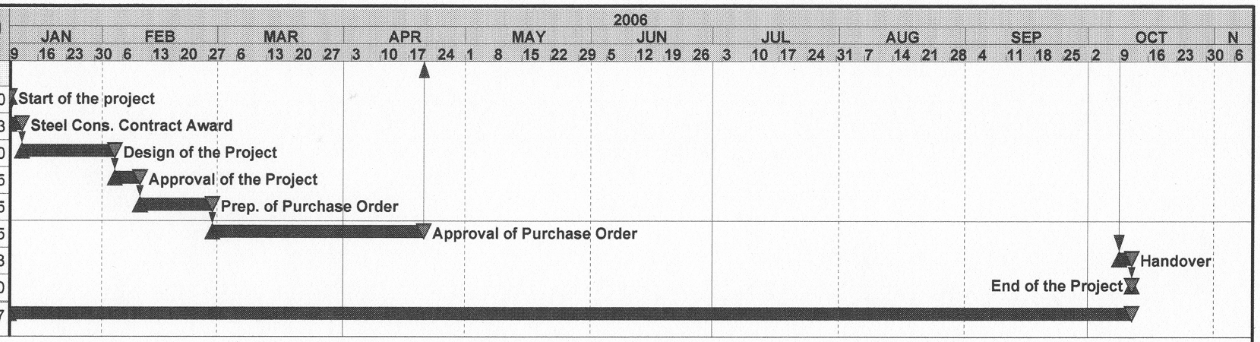

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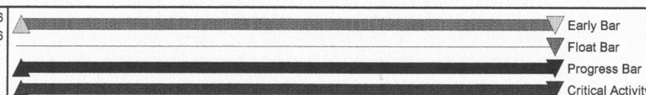

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SS	350	Erection of AG P.H.	28
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PAINTING WORKS AT FACTORY			
SS	220	Painting of GAG P.H.	22
SS	230	Paintingof AG P.H.	20
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SS	310	Painting of AG P.H.	14
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SS	210	Fabrication of AG P.H.	24
QUALITY CONTROL OF PROD.&PAINTING AT FAC			
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SS	250	Q/C of AG P.H.	2
QUALITY CONTROL OF PAINTING AT SITE			
SS	320	Q/C of GAG P.H.	18
SS	330	Q/C of AG P.H.	14
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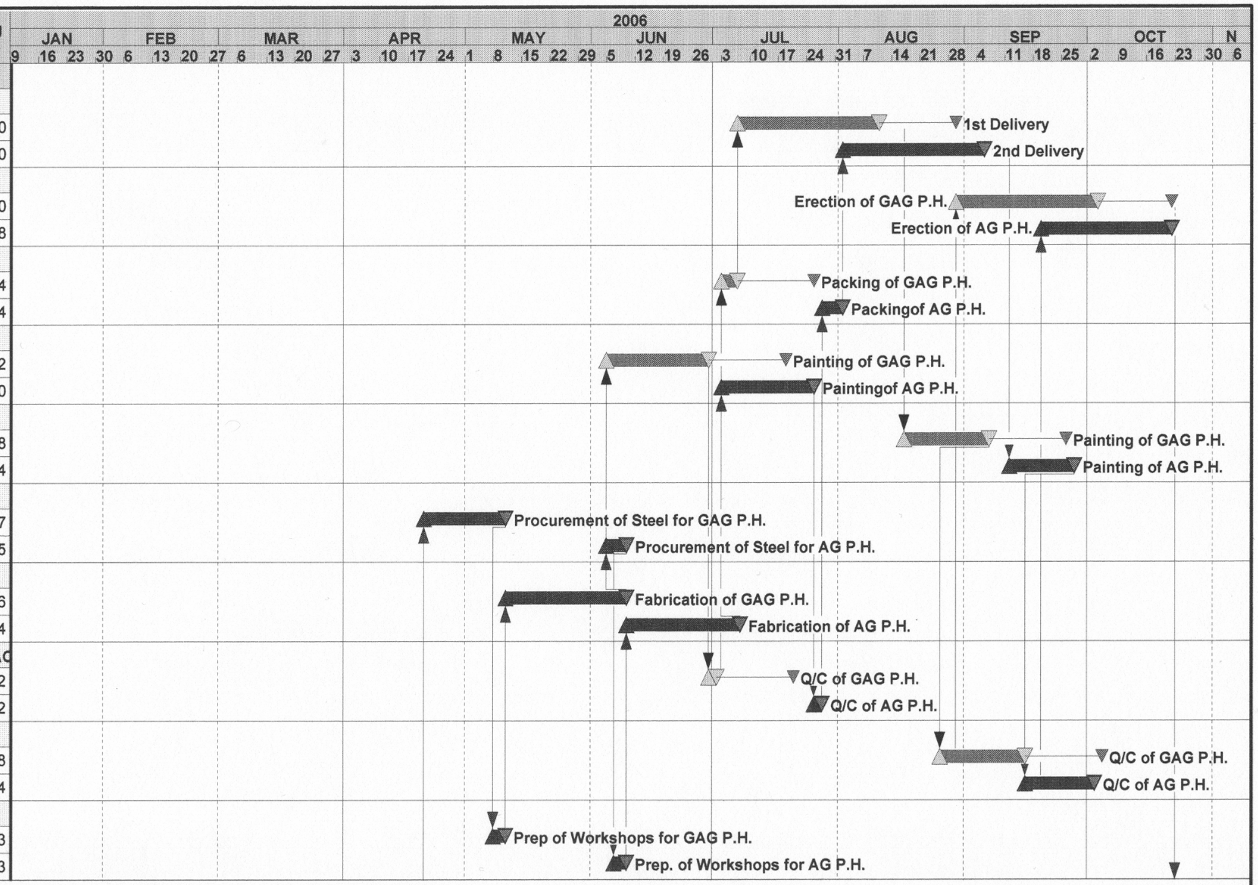
SS	190	Prep. of Workshops for AG P.H.	3



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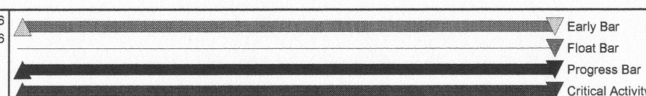

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[LIBYA STEEL CONSTRUCTION PROJECT]

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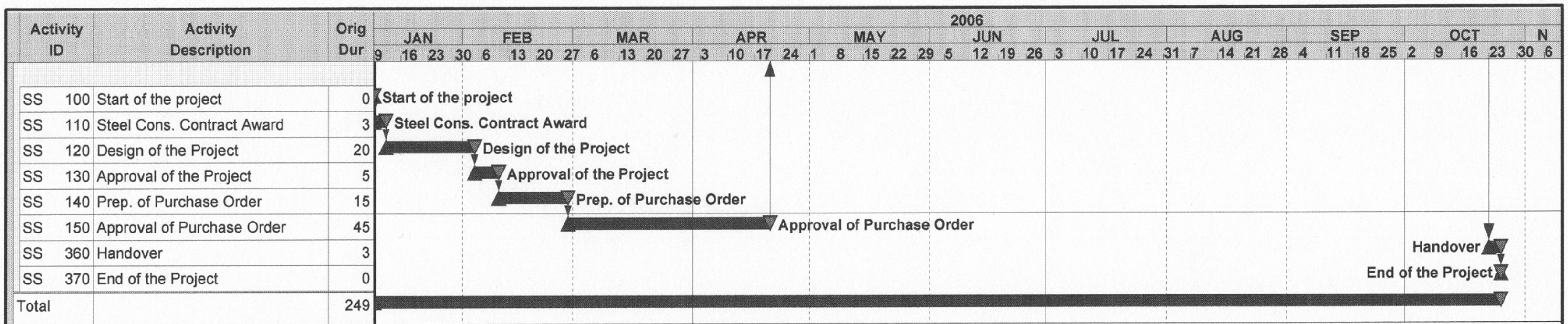

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SS	130	Approval of the Project	5
SS	140	Prep. of Purchase Order	15
SS	150	Approval of Purchase Order	45
SS	360	Handover	3
SS	370	End of the Project	0
Total			249

Start Date 09JAN06
Finish Date 25OCT06

T001 - ASP1 Sheet 2 of 2

[ABC CO.LTD.]

[LIBYA STEEL CONSTRUCTION PROJECT]

[ADJUSTED SCHEDULE 2]

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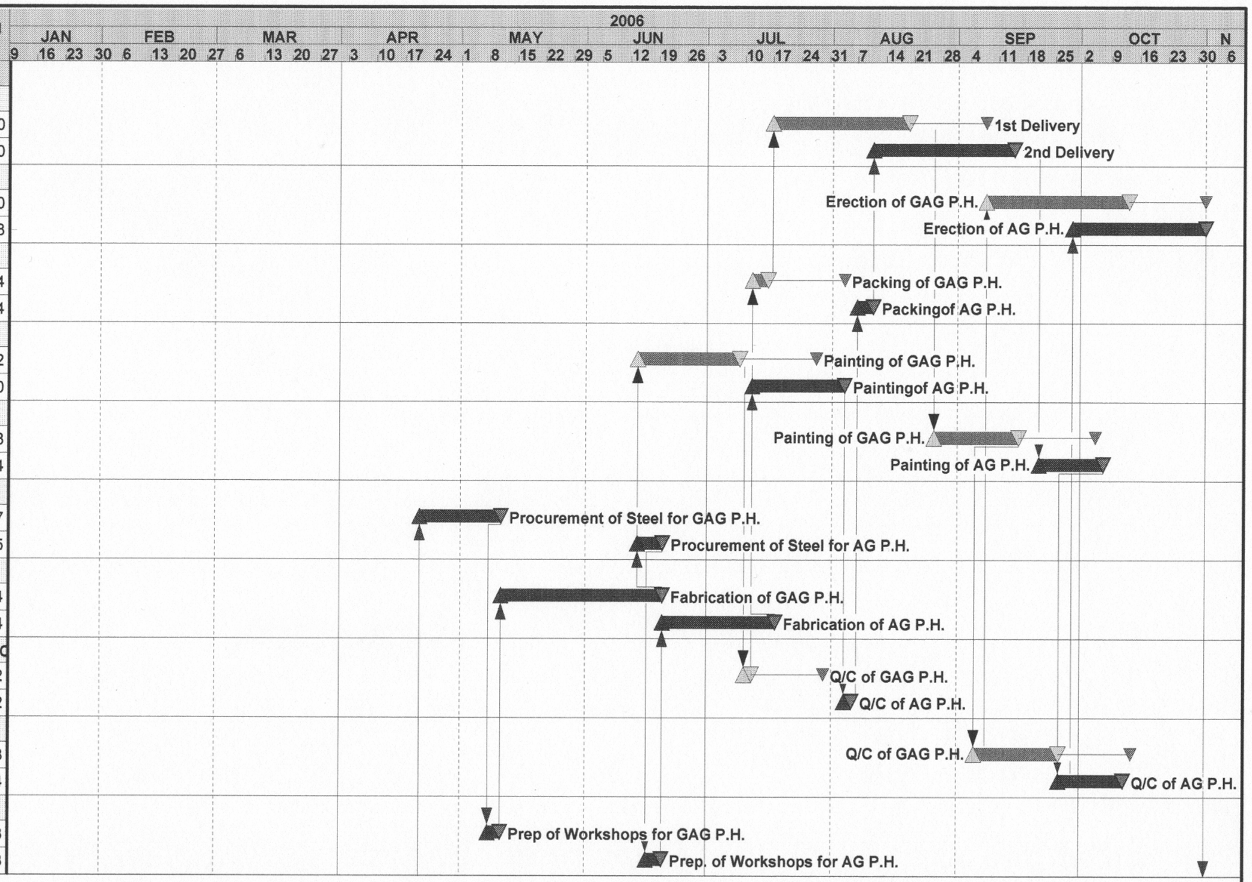
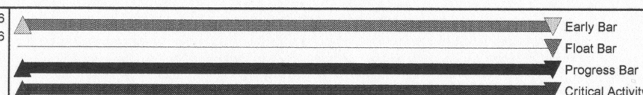
SS	290	2nd Delivery	30
ERECTION OF STEEL CONSTRUCTION			
SS	340	Erection of GAG P.H.	30
SS	350	Erection of AG P.H.	28
PACKING			
SS	260	Packing of GAG P.H.	4
SS	270	Packingof AG P.H.	4
PAINTING WORKS AT FACTORY			
SS	220	Painting of GAG P.H.	22
SS	230	Paintingof AG P.H.	20
PAINTING WORKS AT SITE			
SS	300	Painting of GAG P.H.	18
SS	310	Painting of AG P.H.	14
PROCUREMENT			
SS	160	Procurement of Steel for GAG	17
SS	170	Procurement of Steel for AG P.H.	5
PRODUCTION OF STEEL CONSTRUCTION			
SS	200	Fabrication of GAG P.H.	34
SS	210	Fabrication of AG P.H.	24
QUALITY CONTROL OF PROD.&PAINTING AT FAC			
SS	240	Q/C of GAG P.H.	2
SS	250	Q/C of AG P.H.	2
QUALITY CONTROL OF PAINTING AT SITE			
SS	320	Q/C of GAG P.H.	18
SS	330	Q/C of AG P.H.	14
PREP. OF WORKSHOP PROJECTS			
SS	180	Prep of Workshops for GAG P.H.	3
SS	190	Prep. of Workshops for AG P.H.	3



Start Date 09JAN06
Finish Date 03NOV06



T001 - ASP1

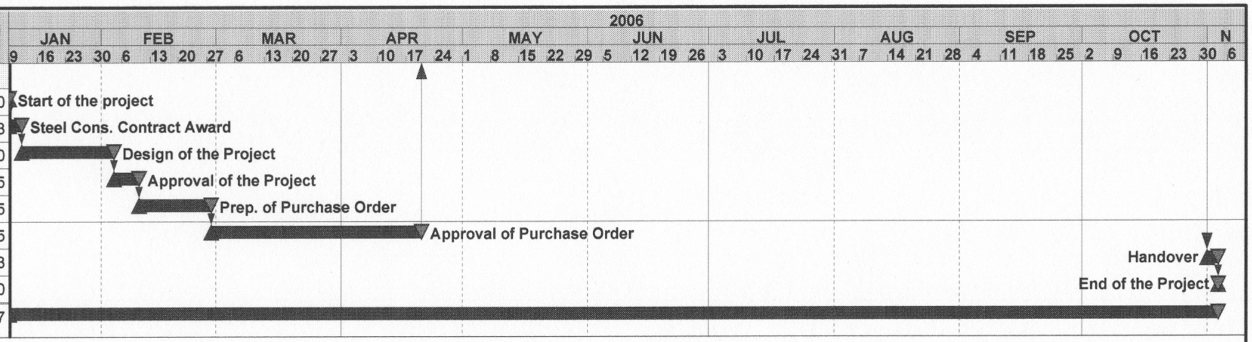
Sheet 1 of 2

[ABC CO.LTD.]

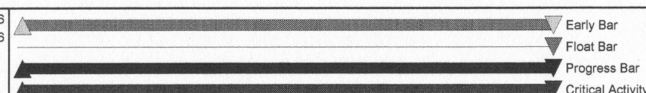
[LIBYA STEEL CONSTRUCTION PROJECT]

[ADJUSTED SCHEDULE 3]

Activity ID		Activity Description	Orig Dur
SS	100	Start of the project	0
SS	110	Steel Cons. Contract Award	3
SS	120	Design of the Project	20
SS	130	Approval of the Project	5
SS	140	Prep. of Purchase Order	15
SS	150	Approval of Purchase Order	45
SS	360	Handover	3
SS	370	End of the Project	0
Total			257



Start Date 09JAN06
Finish Date 03NOV06



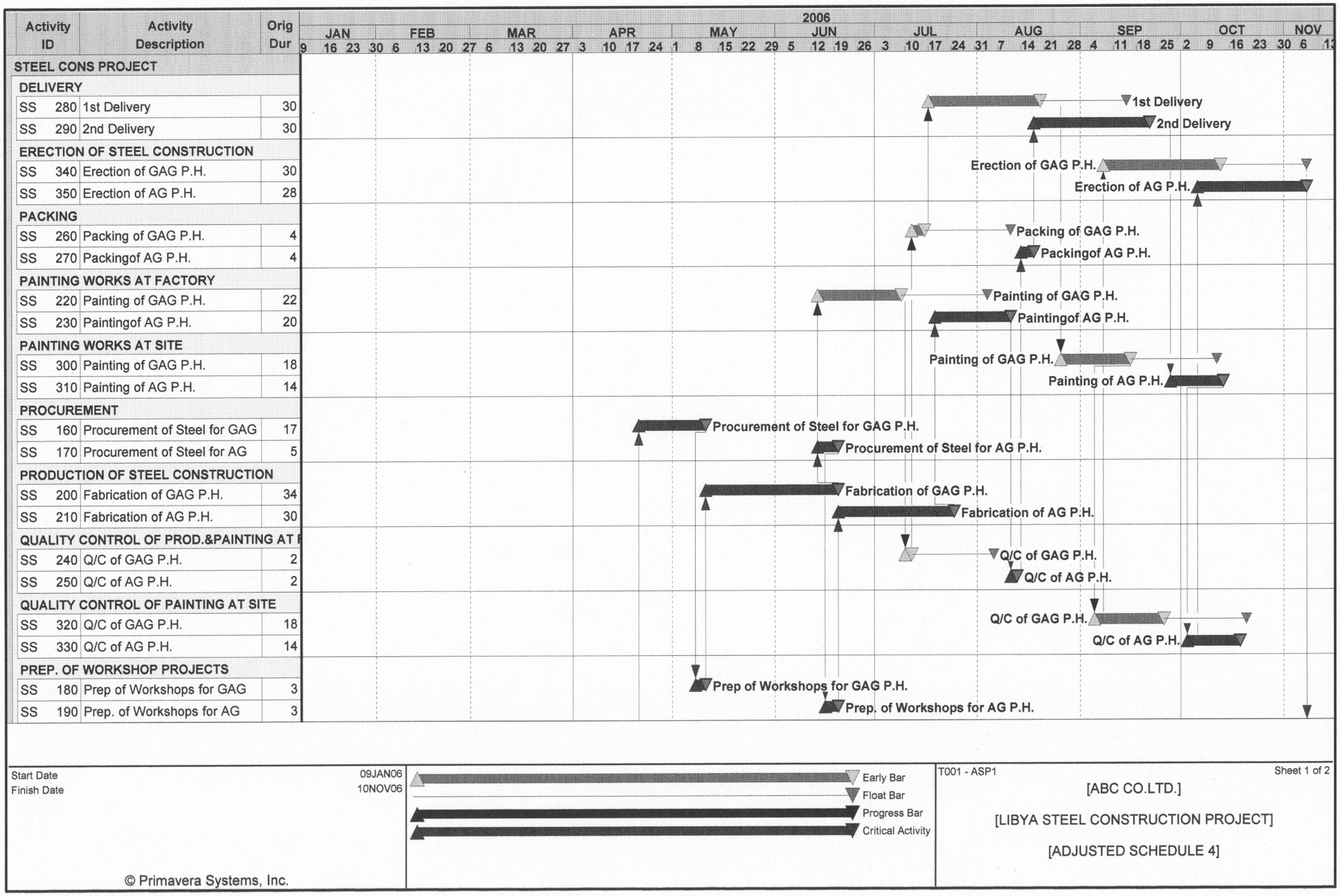
T001 - ASP1

Sheet 2 of 2

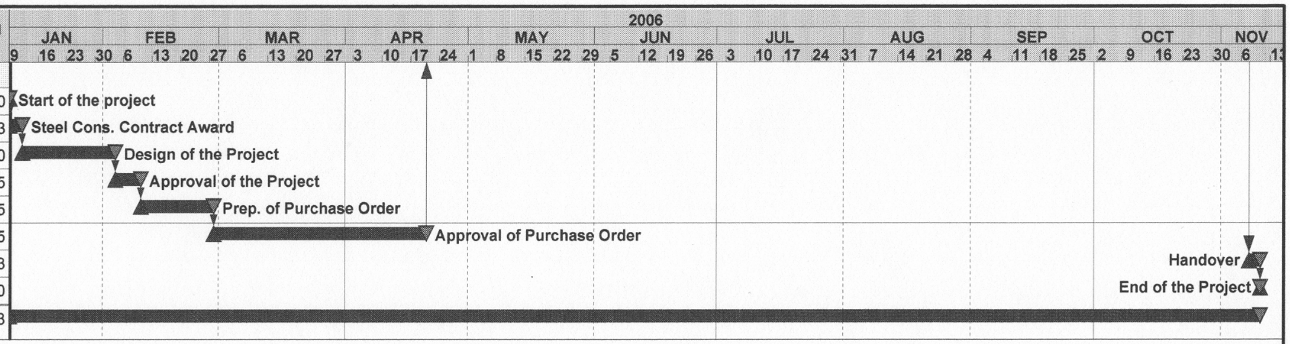
[ABC CO.LTD.]

[LIBYA STEEL CONSTRUCTION PROJECT]

[ADJUSTED SCHEDULE 3]


Activity ID
Activity Description
Orig Dur
2006
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
STEEL CONS PROJECT
DELIVERY
SS 280 1st Delivery 30
SS 290 2nd Delivery 30
ERECTION OF STEEL CONSTRUCTION
SS 340 Erection of GAG P.H. 30
SS 350 Erection of AG P.H. 28
PACKING
SS 260 Packing of GAG P.H. 4
SS 270 Packingof AG P.H. 4
PAINTING WORKS AT FACTORY
SS 220 Painting of GAG P.H. 22
SS 230 Paintingof AG P.H. 20
PAINTING WORKS AT SITE
SS 300 Painting of GAG P.H. 18
SS 310 Painting of AG P.H. 14
PROCUREMENT
SS 160 Procurement of Steel for GAG 17
SS 170 Procurement of Steel for AG 5
PRODUCTION OF STEEL CONSTRUCTION
SS 200 Fabrication of GAG P.H. 34
SS 210 Fabrication of AG P.H. 30
QUALITY CONTROL OF PROD.&PAINTING AT F
SS 240 Q/C of GAG P.H. 2
SS 250 Q/C of AG P.H. 2
QUALITY CONTROL OF PAINTING AT SITE
SS 320 Q/C of GAG P.H. 18
SS 330 Q/C of AG P.H. 14
PREP. OF WORKSHOP PROJECTS
SS 180 Prep of Workshops for GAG 3
SS 190 Prep. of Workshops for AG 3
Procurement of Steel for GAG P.H.
Procurement of Steel for AG P.H.
Fabrication of GAG P.H.
Fabrication of AG P.H.
Prep of Workshops for GAG P.H.
Prep. of Workshops for AG P.H.
Start Date 09JAN06
Finish Date 10NOV06
Early Bar
Float Bar
Progress Bar
Critical Activity
© Primavera Systems, Inc.
T001 - ASP1
Sheet 1 of 2
[ABC CO.LTD.]
[LIBYA STEEL CONSTRUCTION PROJECT]
[ADJUSTED SCHEDULE 4]

Activity ID		Activity Description	Orig Dur
SS	100	Start of the project	0
SS	110	Steel Cons. Contract Award	3
SS	120	Design of the Project	20
SS	130	Approval of the Project	5
SS	140	Prep. of Purchase Order	15
SS	150	Approval of Purchase Order	45
SS	360	Handover	3
SS	370	End of the Project	0
Total			263



Start Date 09JAN06
Finish Date 10NOV06

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Early Bar
Float Bar
Progress Bar
Critical Activity

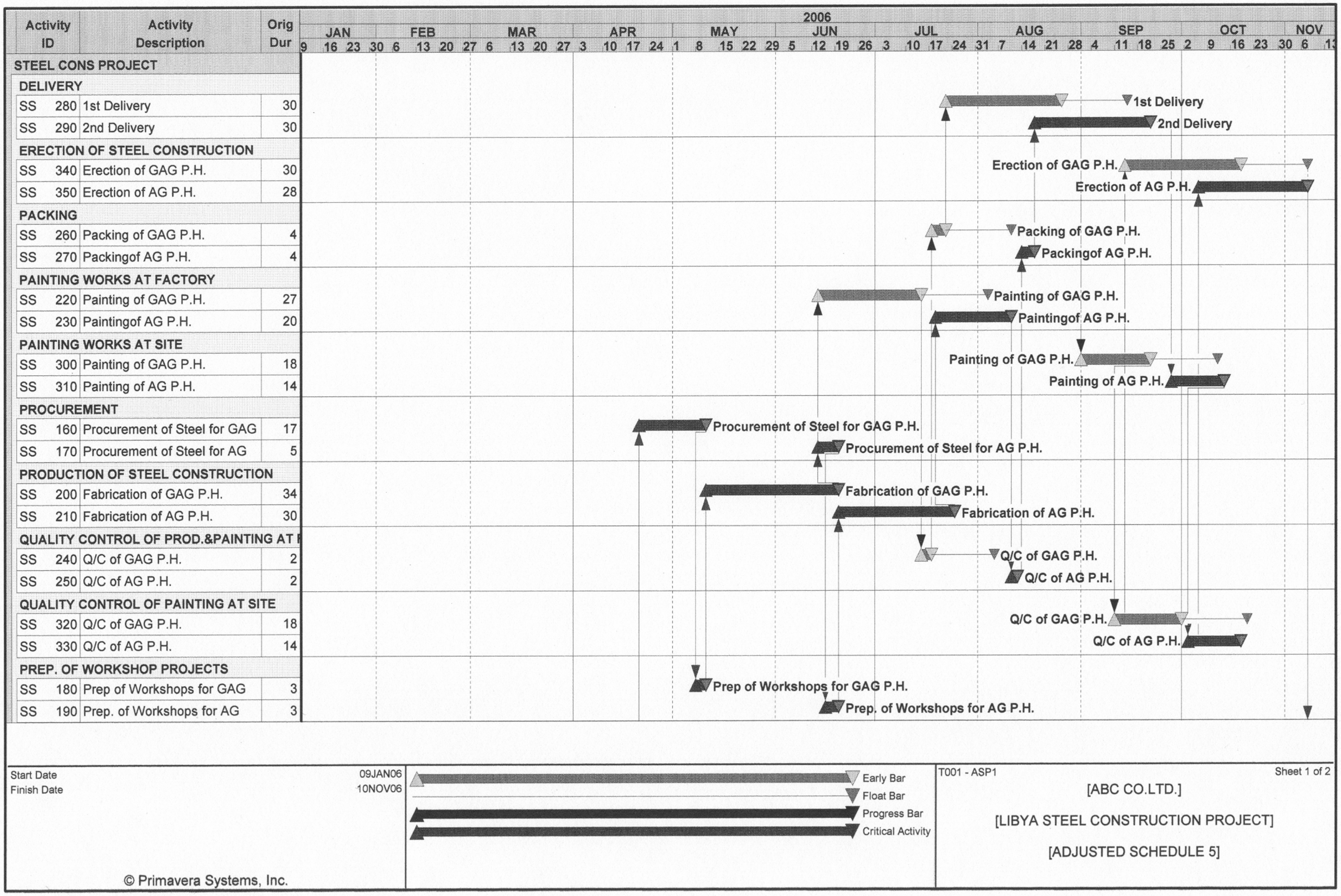
T001 - ASP1

Sheet 2 of 2

[ABC CO.LTD.]

[LIBYA STEEL CONSTRUCTION PROJECT]

[ADJUSTED SCHEDULE 4]


Activity ID
Activity Description
Orig Dur
2006
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
STEEL CONS PROJECT
DELIVERY
SS 280 1st Delivery 30
SS 290 2nd Delivery 30
ERECTION OF STEEL CONSTRUCTION
SS 340 Erection of GAG P.H. 30
SS 350 Erection of AG P.H. 28
PACKING
SS 260 Packing of GAG P.H. 4
SS 270 Packingof AG P.H. 4
PAINTING WORKS AT FACTORY
SS 220 Painting of GAG P.H. 27
SS 230 Paintingof AG P.H. 20
PAINTING WORKS AT SITE
SS 300 Painting of GAG P.H. 18
SS 310 Painting of AG P.H. 14
PROCUREMENT
SS 160 Procurement of Steel for GAG 17
SS 170 Procurement of Steel for AG 5
PRODUCTION OF STEEL CONSTRUCTION
SS 200 Fabrication of GAG P.H. 34
SS 210 Fabrication of AG P.H. 30
QUALITY CONTROL OF PROD.&PAINTING AT F
SS 240 Q/C of GAG P.H. 2
SS 250 Q/C of AG P.H. 2
QUALITY CONTROL OF PAINTING AT SITE
SS 320 Q/C of GAG P.H. 18
SS 330 Q/C of AG P.H. 14
PREP. OF WORKSHOP PROJECTS
SS 180 Prep of Workshops for GAG 3
SS 190 Prep. of Workshops for AG 3
1st Delivery
2nd Delivery
Erection of GAG P.H.
Erection of AG P.H.
Packing of GAG P.H.
Packingof AG P.H.
Painting of GAG P.H.
Paintingof AG P.H.
Painting of GAG P.H.
Painting of AG P.H.
Procurement of Steel for GAG P.H.
Procurement of Steel for AG P.H.
Fabrication of GAG P.H.
Fabrication of AG P.H.
Q/C of GAG P.H.
Q/C of AG P.H.
Q/C of GAG P.H.
Q/C of AG P.H.
Prep of Workshops for GAG P.H.
Prep. of Workshops for AG P.H.
Start Date 09JAN06
Finish Date 10NOV06
Early Bar
Float Bar
Progress Bar
Critical Activity
T001 - ASP1
Sheet 1 of 2
[ABC CO.LTD.]
[LIBYA STEEL CONSTRUCTION PROJECT]
[ADJUSTED SCHEDULE 5]
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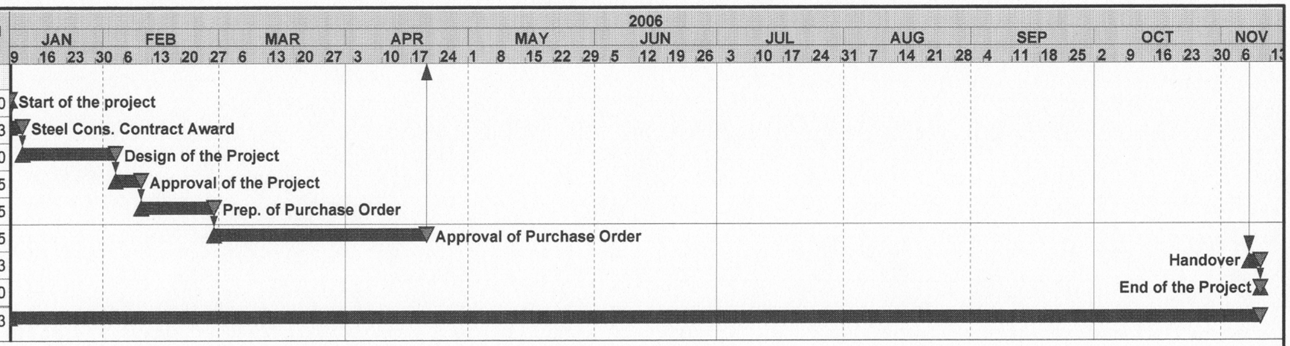
Activity ID		Activity Description	Orig Dur
SS	100	Start of the project	0
SS	110	Steel Cons. Contract Award	3
SS	120	Design of the Project	20
SS	130	Approval of the Project	5
SS	140	Prep. of Purchase Order	15
SS	150	Approval of Purchase Order	45
SS	360	Handover	3
SS	370	End of the Project	0
Total			263



Start Date	09JAN06
Finish Date	10NOV06

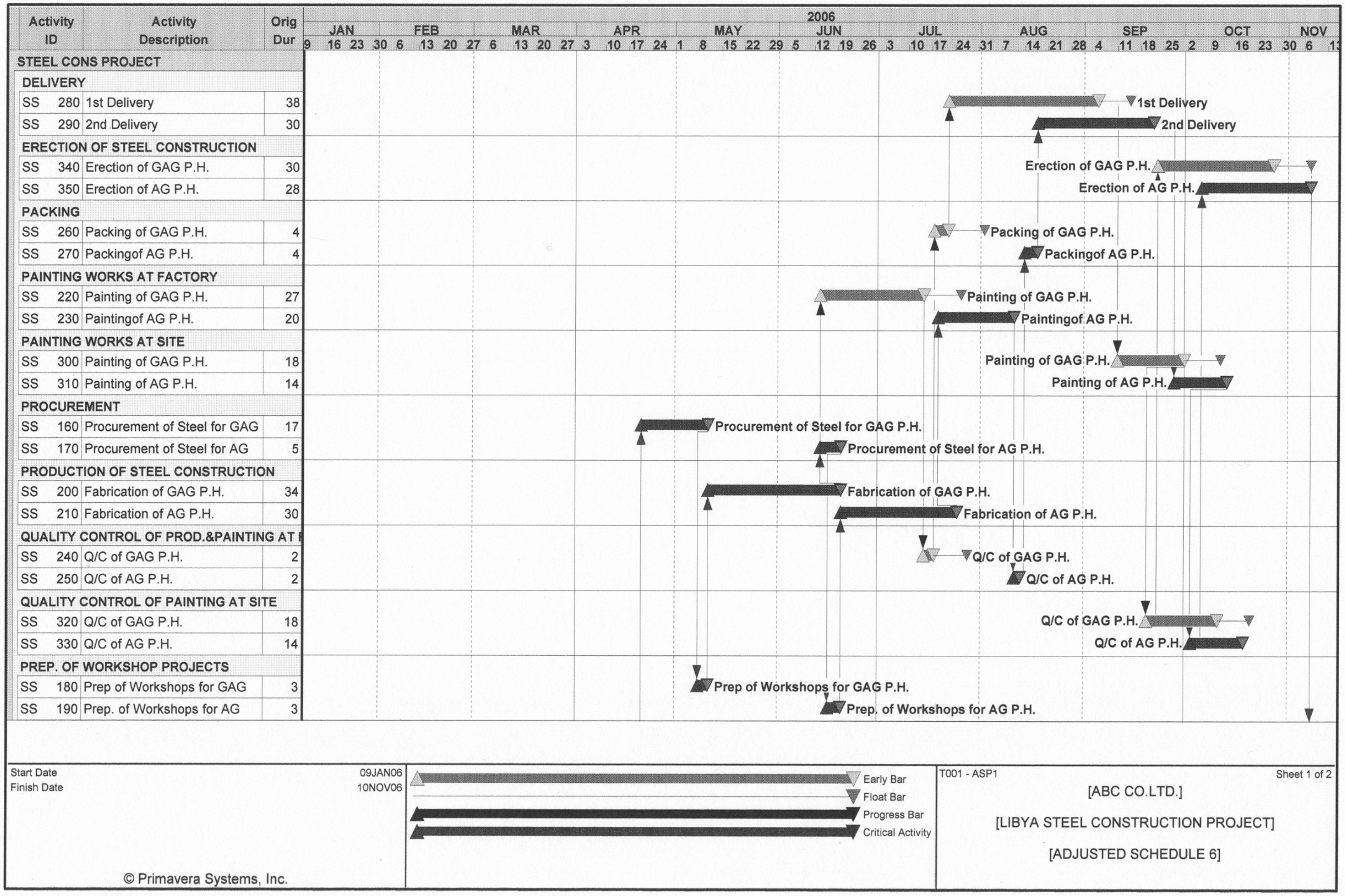
Early Bar
Float Bar
Progress Bar
Critical Activity

T001 - ASP1 Sheet 2 of 2

[ABC CO.LTD.]

[LIBYA STEEL CONSTRUCTION PROJECT]

[ADJUSTED SCHEDULE 5]


Activity ID
Activity Description
Orig Dur
2006
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
STEEL CONS PROJECT
DELIVERY
SS 280 1st Delivery 38
SS 290 2nd Delivery 30
ERECTION OF STEEL CONSTRUCTION
SS 340 Erection of GAG P.H. 30
SS 350 Erection of AG P.H. 28
PACKING
SS 260 Packing of GAG P.H. 4
SS 270 Packingof AG P.H. 4
PAINTING WORKS AT FACTORY
SS 220 Painting of GAG P.H. 27
SS 230 Paintingof AG P.H. 20
PAINTING WORKS AT SITE
SS 300 Painting of GAG P.H. 18
SS 310 Painting of AG P.H. 14
PROCUREMENT
SS 160 Procurement of Steel for GAG 17
SS 170 Procurement of Steel for AG 5
PRODUCTION OF STEEL CONSTRUCTION
SS 200 Fabrication of GAG P.H. 34
SS 210 Fabrication of AG P.H. 30
QUALITY CONTROL OF PROD.&PAINTING AT F
SS 240 Q/C of GAG P.H. 2
SS 250 Q/C of AG P.H. 2
QUALITY CONTROL OF PAINTING AT SITE
SS 320 Q/C of GAG P.H. 18
SS 330 Q/C of AG P.H. 14
PREP. OF WORKSHOP PROJECTS
SS 180 Prep of Workshops for GAG 3
SS 190 Prep. of Workshops for AG 3
Procurement of Steel for GAG P.H.
Procurement of Steel for AG P.H.
Fabrication of GAG P.H.
Fabrication of AG P.H.
Prep of Workshops for GAG P.H.
Prep. of Workshops for AG P.H.
Start Date 09JAN06
Finish Date 10NOV06
Early Bar
Float Bar
Progress Bar
Critical Activity
T001 - ASP1
Sheet 1 of 2
[ABC CO.LTD.]
[LIBYA STEEL CONSTRUCTION PROJECT]
[ADJUSTED SCHEDULE 6]
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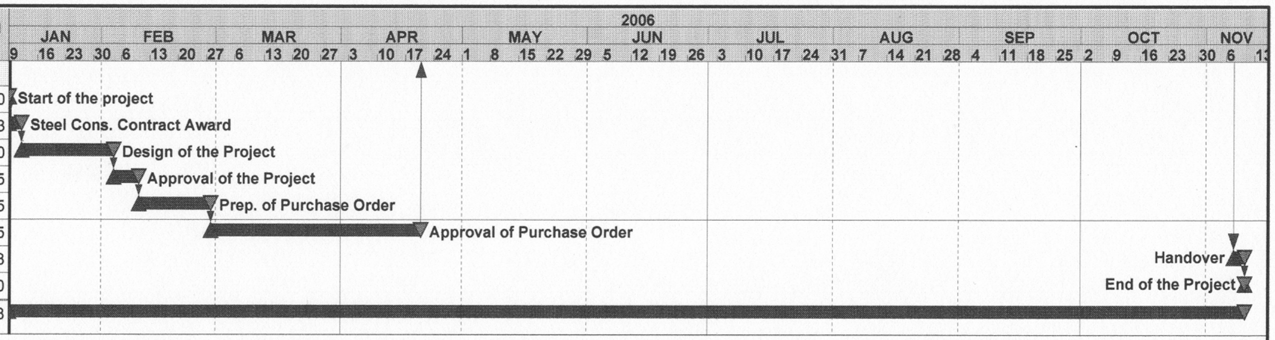
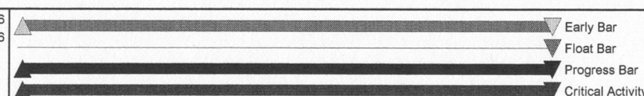
Activity ID		Activity Description	Orig Dur
SS	100	Start of the project	0
SS	110	Steel Cons. Contract Award	3
SS	120	Design of the Project	20
SS	130	Approval of the Project	5
SS	140	Prep. of Purchase Order	15
SS	150	Approval of Purchase Order	45
SS	360	Handover	3
SS	370	End of the Project	0
Total			263



Start Date 09JAN06
Finish Date 10NOV06



T001 - ASP1

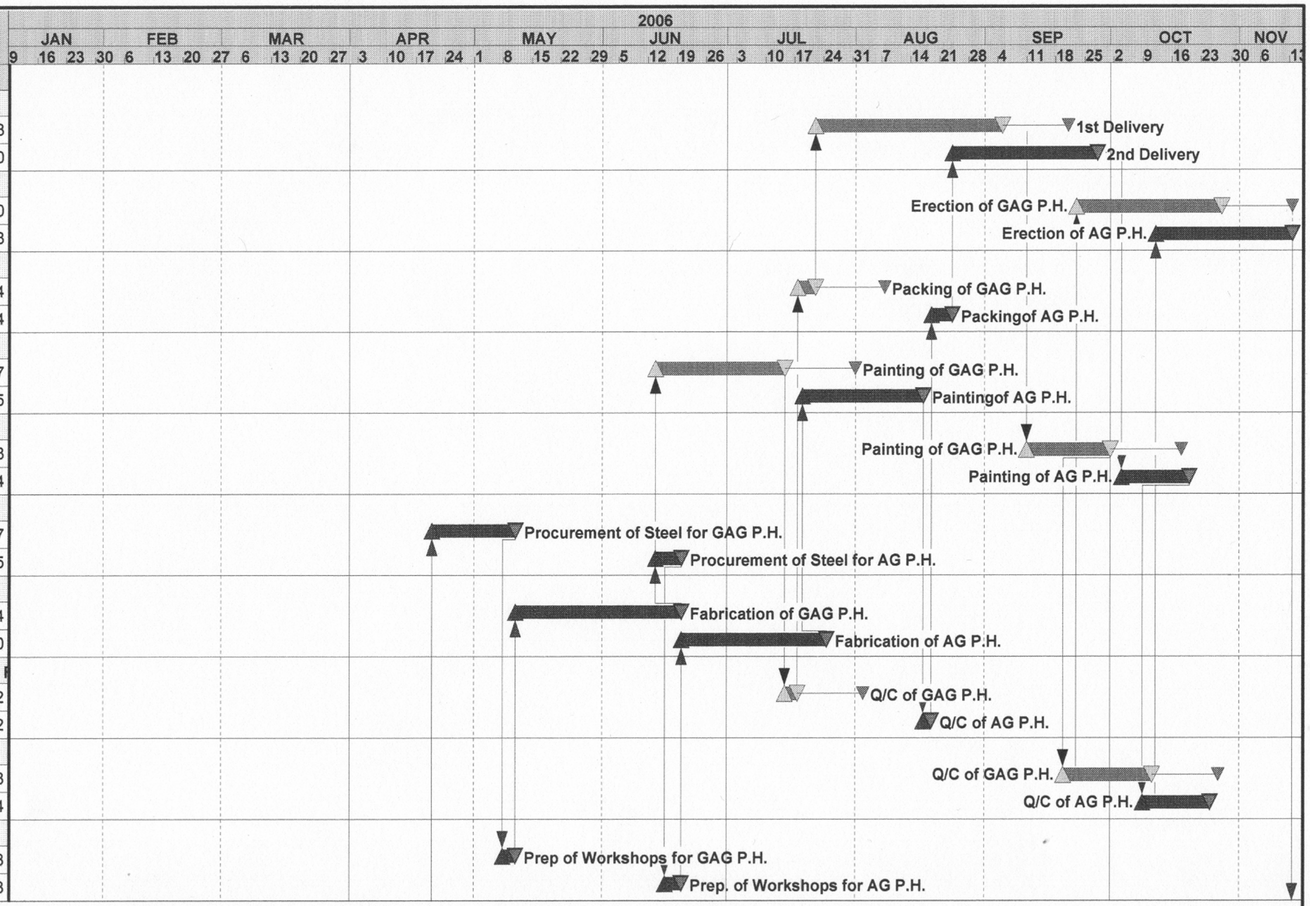
Sheet 2 of 2

[ABC CO.LTD.]

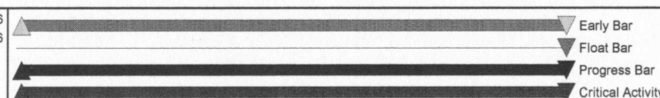
[LIBYA STEEL CONSTRUCTION PROJECT]

[ADJUSTED SCHEDULE 6]

Activity ID		Activity Description	Orig Dur
STEEL CONS PROJECT			
DELIVERY			
SS	280	1st Delivery	38
SS	290	2nd Delivery	30
ERECTION OF STEEL CONSTRUCTION			
SS	340	Erection of GAG P.H.	30
SS	350	Erection of AG P.H.	28
PACKING			
SS	260	Packing of GAG P.H.	4
SS	270	Packingof AG P.H.	4
PAINTING WORKS AT FACTORY			
SS	220	Painting of GAG P.H.	27
SS	230	Paintingof AG P.H.	25
PAINTING WORKS AT SITE			
SS	300	Painting of GAG P.H.	18
SS	310	Painting of AG P.H.	14
PROCUREMENT			
SS	160	Procurement of Steel for GAG	17
SS	170	Procurement of Steel for AG	5
PRODUCTION OF STEEL CONSTRUCTION			
SS	200	Fabrication of GAG P.H.	34
SS	210	Fabrication of AG P.H.	30
QUALITY CONTROL OF PROD.&PAINTING AT F			
SS	240	Q/C of GAG P.H.	2
SS	250	Q/C of AG P.H.	2
QUALITY CONTROL OF PAINTING AT SITE			
SS	320	Q/C of GAG P.H.	18
SS	330	Q/C of AG P.H.	14
PREP. OF WORKSHOP PROJECTS			
SS	180	Prep of Workshops for GAG	3
SS	190	Prep. of Workshops for AG	3



Start Date 09JAN06
Finish Date 16NOV06



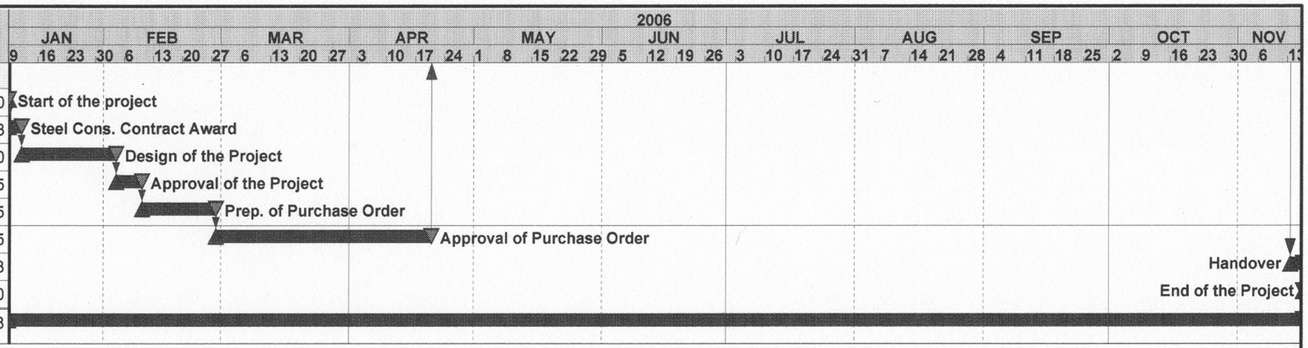
T001 - ASP1 Sheet 1 of 2

[ABC CO.LTD.]

[LIBYA STEEL CONSTRUCTION PROJECT]

[ADJUSTED SCHEDULE 7]

Activity ID		Activity Description	Orig Dur
SS	100	Start of the project	0
SS	110	Steel Cons. Contract Award	3
SS	120	Design of the Project	20
SS	130	Approval of the Project	5
SS	140	Prep. of Purchase Order	15
SS	150	Approval of Purchase Order	45
SS	360	Handover	3
SS	370	End of the Project	0
Total			268



Start Date 09JAN06
Finish Date 16NOV06

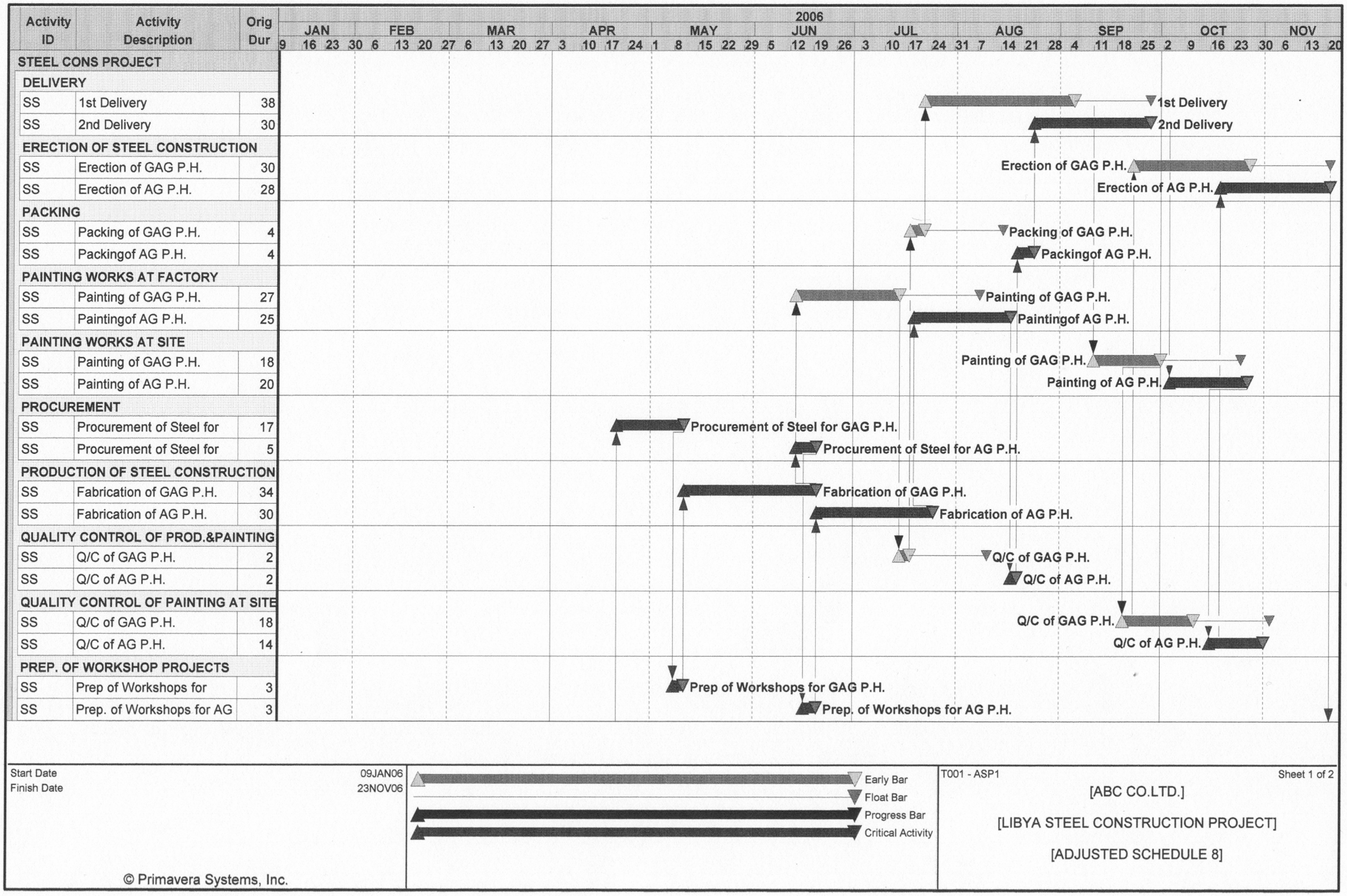
Early Bar
Float Bar
Progress Bar
Critical Activity

T001 - ASP1 Sheet 2 of 2

[ABC CO.LTD.]

[LIBYA STEEL CONSTRUCTION PROJECT]

[ADJUSTED SCHEDULE 7]



Activity ID
Activity Description
Orig Dur
2006
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
STEEL CONS PROJECT
DELIVERY
SS 1st Delivery 38
SS 2nd Delivery 30
ERECTION OF STEEL CONSTRUCTION
SS Erection of GAG P.H. 30
SS Erection of AG P.H. 28
PACKING
SS Packing of GAG P.H. 4
SS Packingof AG P.H. 4
PAINTING WORKS AT FACTORY
SS Painting of GAG P.H. 27
SS Paintingof AG P.H. 25
PAINTING WORKS AT SITE
SS Painting of GAG P.H. 18
SS Painting of AG P.H. 20
PROCUREMENT
SS Procurement of Steel for 17
SS Procurement of Steel for 5
PRODUCTION OF STEEL CONSTRUCTION
SS Fabrication of GAG P.H. 34
SS Fabrication of AG P.H. 30
QUALITY CONTROL OF PROD.&PAINTING
SS Q/C of GAG P.H. 2
SS Q/C of AG P.H. 2
QUALITY CONTROL OF PAINTING AT SITE
SS Q/C of GAG P.H. 18
SS Q/C of AG P.H. 14
PREP. OF WORKSHOP PROJECTS
SS Prep of Workshops for 3
SS Prep. of Workshops for AG 3
1st Delivery
2nd Delivery
Erection of GAG P.H.
Erection of AG P.H.
Packing of GAG P.H.
Packingof AG P.H.
Painting of GAG P.H.
Paintingof AG P.H.
Painting of GAG P.H.
Painting of AG P.H.
Procurement of Steel for GAG P.H.
Procurement of Steel for AG P.H.
Fabrication of GAG P.H.
Fabrication of AG P.H.
Q/C of GAG P.H.
Q/C of AG P.H.
Q/C of GAG P.H.
Q/C of AG P.H.
Prep of Workshops for GAG P.H.
Prep. of Workshops for AG P.H.
Start Date 09JAN06
Finish Date 23NOV06
Early Bar
Float Bar
Progress Bar
Critical Activity
T001 - ASP1
Sheet 1 of 2
[ABC CO.LTD.]
[LIBYA STEEL CONSTRUCTION PROJECT]
[ADJUSTED SCHEDULE 8]
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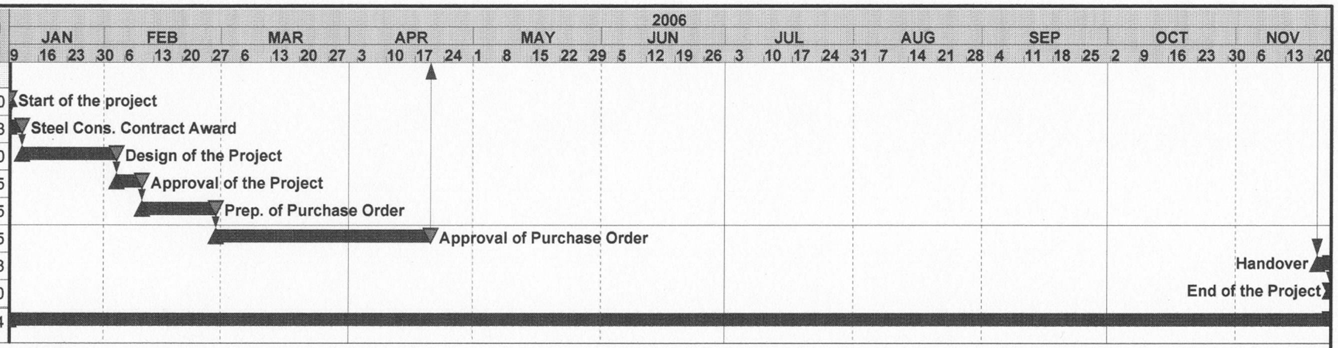
Activity ID	Activity Description	Orig Dur
SS	Start of the project	0
SS	Steel Cons. Contract Award	3
SS	Design of the Project	20
SS	Approval of the Project	5
SS	Prep. of Purchase Order	15
SS	Approval of Purchase	45
SS	Handover	3
SS	End of the Project	0
Total		274



Start Date 09JAN06
Finish Date 23NOV06

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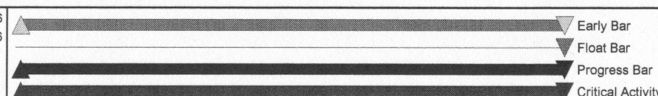


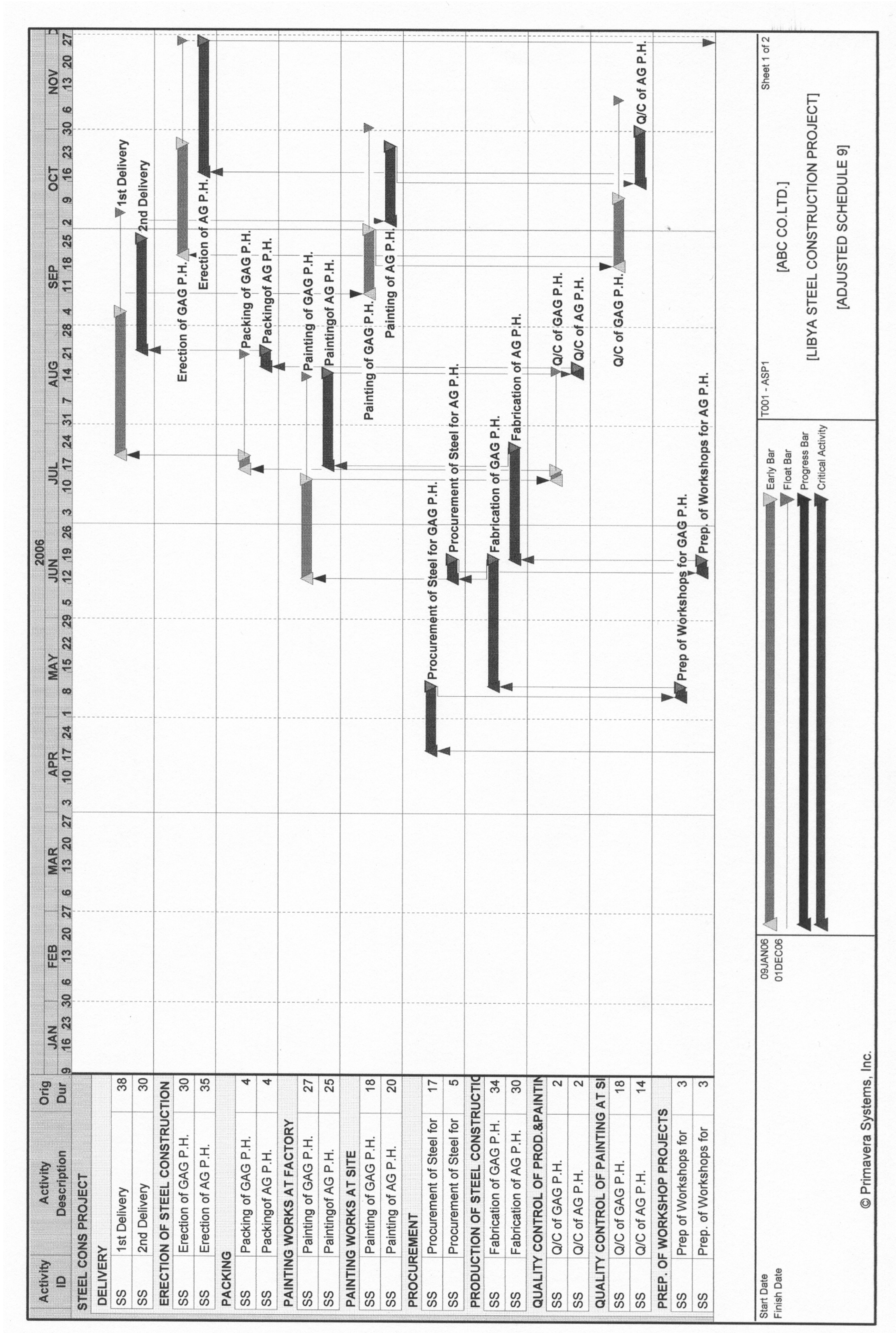
T001 - ASP1

Sheet 2 of 2

[ABC CO.LTD.]

[LIBYA STEEL CONSTRUCTION PROJECT]

[ADJUSTED SCHEDULE 8]



Activity ID
Activity Description
Orig Dur
2006
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
STEEL CONS PROJECT
DELIVERY
SS 1st Delivery 38
SS 2nd Delivery 30
ERECTION OF STEEL CONSTRUCTION
SS Erection of GAG P.H. 30
SS Erection of AG P.H. 35
PACKING
SS Packing of GAG P.H. 4
SS Packingof AG P.H. 4
PAINTING WORKS AT FACTORY
SS Painting of GAG P.H. 27
SS Paintingof AG P.H. 25
PAINTING WORKS AT SITE
SS Painting of GAG P.H. 18
SS Painting of AG P.H. 20
PROCUREMENT
SS Procurement of Steel for 17
SS Procurement of Steel for 5
PRODUCTION OF STEEL CONSTRUCTIO
SS Fabrication of GAG P.H. 34
SS Fabrication of AG P.H. 30
QUALITY CONTROL OF PROD.&PAINTIN
SS Q/C of GAG P.H. 2
SS Q/C of AG P.H. 2
QUALITY CONTROL OF PAINTING AT SI
SS Q/C of GAG P.H. 18
SS Q/C of AG P.H. 14
PREP. OF WORKSHOP PROJECTS
SS Prep of Workshops for 3
SS Prep. of Workshops for 3
Procurement of Steel for GAG P.H.
Procurement of Steel for AG P.H.
Prep of Workshops for GAG P.H.
Prep. of Workshops for AG P.H.
Fabrication of GAG P.H.
Fabrication of AG P.H.
Q/C of GAG P.H.
Q/C of AG P.H.
Painting of GAG P.H.
Paintingof AG P.H.
Packing of GAG P.H.
Packingof AG P.H.
Erection of GAG P.H.
Erection of AG P.H.
1st Delivery
2nd Delivery
Start Date 09JAN06
Finish Date 01DEC06
Early Bar
Float Bar
Progress Bar
Critical Activity
T001 - ASP1
Sheet 1 of 2
[ABC CO.LTD.]
[LIBYA STEEL CONSTRUCTION PROJECT]
[ADJUSTED SCHEDULE 9]
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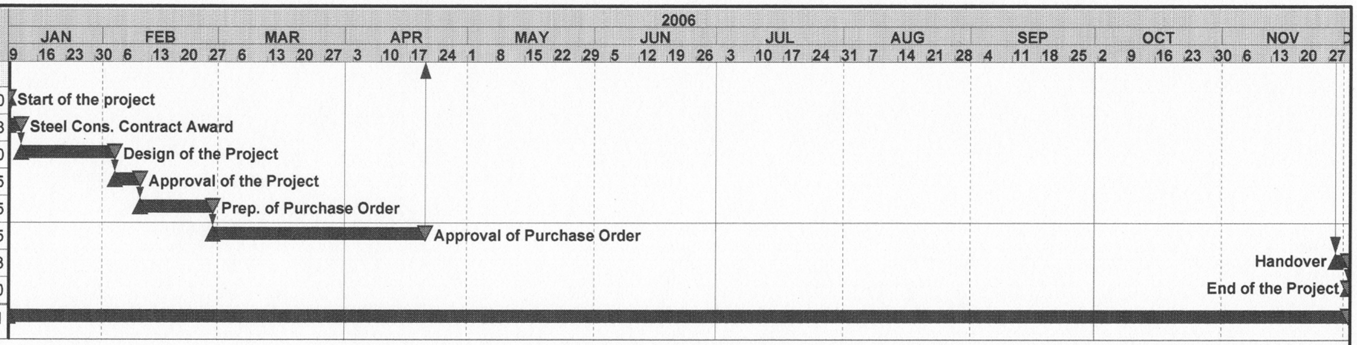
Activity ID	Activity Description	Orig Dur
SS	Start of the project	0
SS	Steel Cons. Contract	3
SS	Design of the Project	20
SS	Approval of the Project	5
SS	Prep. of Purchase Order	15
SS	Approval of Purchase	45
SS	Handover	3
SS	End of the Project	0
Total		281



Start Date 09JAN06
Finish Date 01DEC06

Early Bar
Float Bar
Progress Bar
Critical Activity

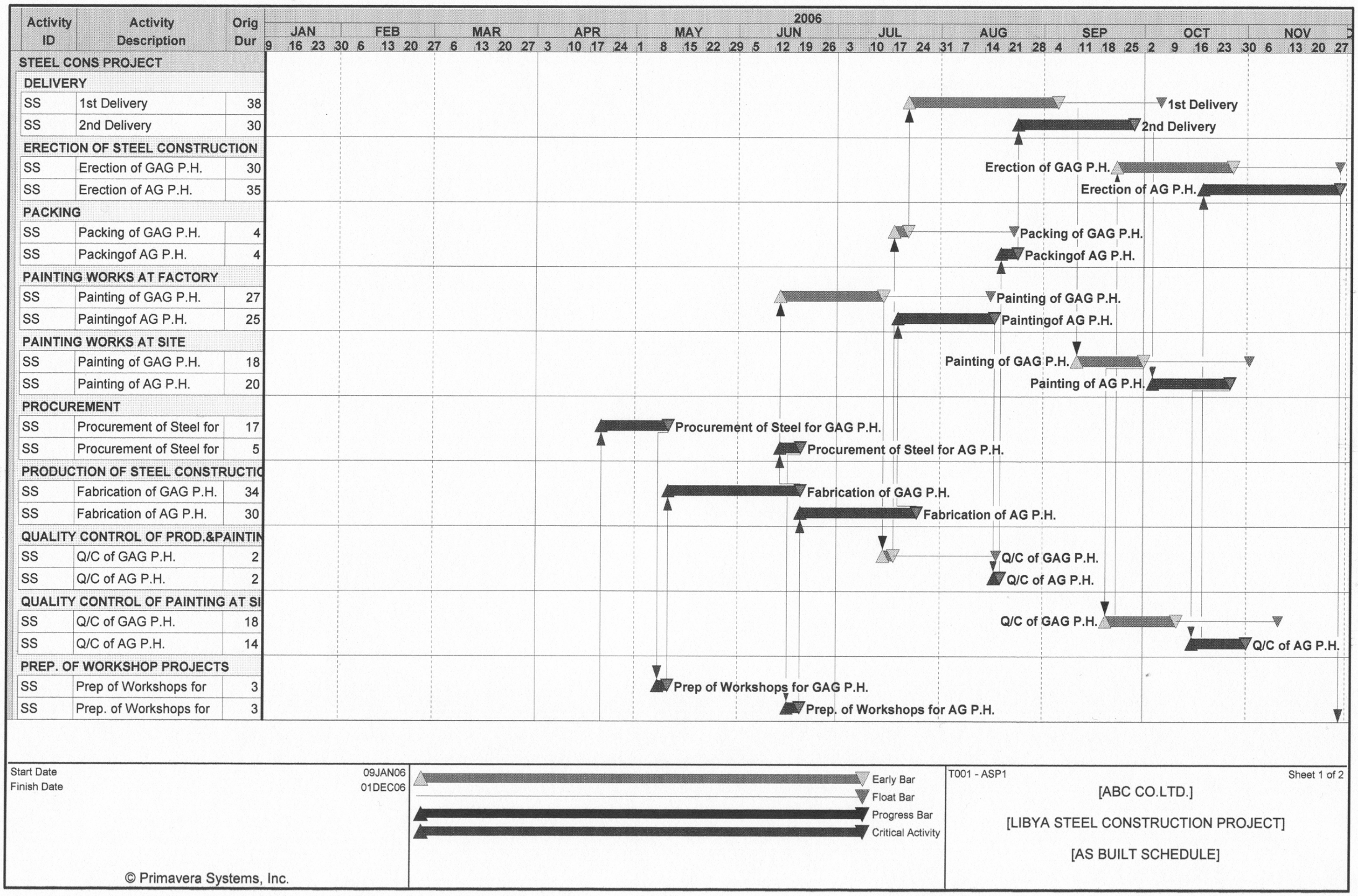
T001 - ASP1

Sheet 2 of 2

[ABC CO.LTD.]

[LIBYA STEEL CONSTRUCTION PROJECT]

[ADJUSTED SCHEDULE 9]


2006
Activity ID | Activity Description | Orig Dur
STEEL CONS PROJECT
DELIVERY
SS | 1st Delivery | 38
SS | 2nd Delivery | 30
ERECTION OF STEEL CONSTRUCTION
SS | Erection of GAG P.H. | 30
SS | Erection of AG P.H. | 35
PACKING
SS | Packing of GAG P.H. | 4
SS | Packingof AG P.H. | 4
PAINTING WORKS AT FACTORY
SS | Painting of GAG P.H. | 27
SS | Paintingof AG P.H. | 25
PAINTING WORKS AT SITE
SS | Painting of GAG P.H. | 18
SS | Painting of AG P.H. | 20
PROCUREMENT
SS | Procurement of Steel for | 17
SS | Procurement of Steel for | 5
PRODUCTION OF STEEL CONSTRUCTIO
SS | Fabrication of GAG P.H. | 34
SS | Fabrication of AG P.H. | 30
QUALITY CONTROL OF PROD.&PAINTIN
SS | Q/C of GAG P.H. | 2
SS | Q/C of AG P.H. | 2
QUALITY CONTROL OF PAINTING AT SI
SS | Q/C of GAG P.H. | 18
SS | Q/C of AG P.H. | 14
PREP. OF WORKSHOP PROJECTS
SS | Prep of Workshops for | 3
SS | Prep. of Workshops for | 3
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
9 16 23 30 6 13 20 27 6 13 20 27 3 10 17 24 1 8 15 22 29 5 12 19 26 3 10 17 24 31 7 14 21 28 4 11 18 25 2 9 16 23 30 6 13 20 27
1st Delivery
2nd Delivery
Erection of GAG P.H.
Erection of AG P.H.
Packing of GAG P.H.
Packingof AG P.H.
Painting of GAG P.H.
Paintingof AG P.H.
Painting of GAG P.H.
Painting of AG P.H.
Procurement of Steel for GAG P.H.
Procurement of Steel for AG P.H.
Fabrication of GAG P.H.
Fabrication of AG P.H.
Q/C of GAG P.H.
Q/C of AG P.H.
Q/C of GAG P.H.
Q/C of AG P.H.
Prep of Workshops for GAG P.H.
Prep. of Workshops for AG P.H.
Start Date 09JAN06
Finish Date 01DEC06
Early Bar
Float Bar
Progress Bar
Critical Activity
T001 - ASP1
Sheet 1 of 2
[ABC CO.LTD.]
[LIBYA STEEL CONSTRUCTION PROJECT]
[AS BUILT SCHEDULE]
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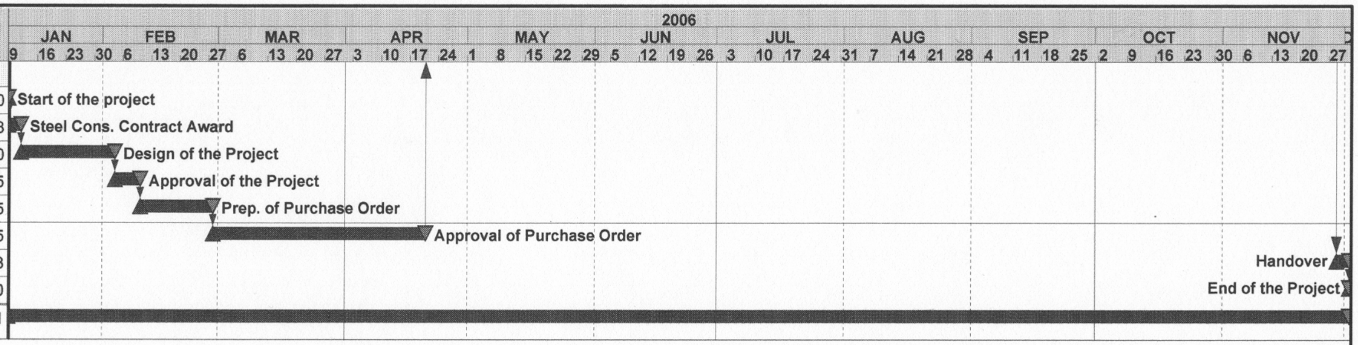
Activity ID	Activity Description	Orig Dur
SS	Start of the project	0
SS	Steel Cons. Contract	3
SS	Design of the Project	20
SS	Approval of the Project	5
SS	Prep. of Purchase Order	15
SS	Approval of Purchase	45
SS	Handover	3
SS	End of the Project	0
Total		281



Start Date 09JAN06
Finish Date 01DEC06

Early Bar
Float Bar
Progress Bar
Critical Activity

T001 - ASP1

Sheet 2 of 2

[ABC CO.LTD.]

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