Assessment and Evaluation of Detailed Schedules in Building Construction

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ABSTARCT

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Detailed schedules are essential in development of useful "project baselines"; needed for tracking and progress reporting as well as for the administration of construction disputes. Thus, it is necessary to insure the goodness of these schedules. Detailed construction schedules are frequently developed by contractors upon the award of contracts. Owners and engineers need to assess these schedules based on numerous considerations. However, many of these considerations are disregarded in the schedule review methods currently in practice.

This research provides a comprehensive study of criteria and methods used for evaluating the goodness of generated detailed schedules. As well, it presents a structured method to assist owners in performing an effective schedule assessment and evaluation based on a set of criteria extracted from literature. A composite index is proposed for assessment of the level of schedule goodness taking into account the relative level of importance of each criterion used in the developed index. A web-based questionnaire survey was conducted in order to collect feedback from industry professionals regarding the level of importance of each criterion. Furthermore, an empirical method for job logic assessment of institutional buildings is developed based on historical data and schedule analyses of successful projects. The developed method was automated in a developed software application. The software, called SAE (Schedule Assessment and Evaluation), was designed using object oriented modeling utilizing an application of Microsoft Visual Basic. The developed software encompasses three tiers of assessment: assessment against industry recommended practices and benchmarks; job logic review; and productivity assessment and crew size evaluation. The developed framework is flexible and can be used in different domains of construction. Nevertheless, the thresholds defined for the job logic review and evaluation of productivity and crew sizes are applicable to construction of buildings for educational institutions. Four case examples, including three of actual projects, were analysed to demonstrate the essential features of the developed method and to highlight its capabilities.

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CHAPTER ONE: INTRODUCTION

1.1 General

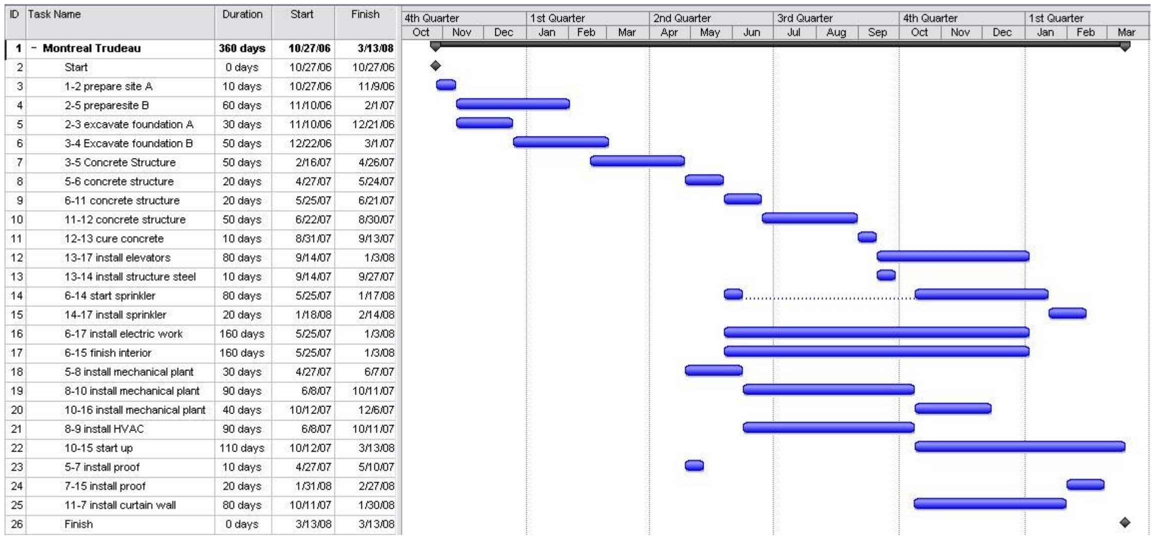
According to the North American Industry Classification System (NAICS), Canadian Chapter (Statistics Canada 2012), the construction sector consists of firms that are mainly engaged in construction, renovation and repair of engineering works and buildings, as well as land development. These firms may work independently, or they may work as contractors for other firms. Participating in joint ventures or subcontracting some or all parts of projects are common practices in this sector.

The construction industry accounts for more than 12% of Canada's gross domestic product (GDP) (B. C. Hydro, et al. 2010). The industry employs about 1.2 million workers, representing 6% of Canadian employment. Through numerous projects, the employees of the construction industry build, maintain and renovate infrastructures for a worth of more than $220 billion each year (B. C. Hydro, et al. 2010). The success of these projects largely depends on the quality of their schedules, which can be used to identify possible problems (United States Government Accountability Office (GAO) 2009). Research conducted in 2005 (Griffith 2006) demonstrated a clear correlation between schedule development and the final success of projects. That research revealed that projects which benefit from the early application of scheduling practices, and start the execution phase with well-developed schedules outperform other projects in terms of cost and time performance. Griffith concluded that the success of such projects is more predictable, as they consistently have less cost and time overruns. In addition, meeting an appropriate schedule is considered an important way of determining the success of projects (Sanvido et al, 1992). Thus, it is necessary to ensure a schedule's goodness (i.e. fitness for purpose).

1.2 Definition

The Project Management Institute (PMI) defines a schedule as a set of activities with start and finish dates. A schedule defines the work to be accomplished (what), the sequence of work (when), and the required resources (who). Therefore, the purpose of scheduling is to provide a road map for project execution, from inception to completion (PMI 2007).

The Association for the Advancement of Cost Engineering (AACE) defines a schedule as an "operating timetable" that specifies the start and finish time of each activity and the related occurrence time for each milestone. A bar chart is the simplest form of depicting a schedule, which contains the start and finish dates of activities, as well as their respective duration. More advanced schedules include job logic, the critical path and floats (AACE 2011-a). Consequently, the purpose of scheduling is outlined as defining activities, their duration, and the dependencies among them (Douglas 2006). A typical bar chart is demonstrated in Figure 1.1.



ID	Task Name	Duration	Start	Finish
1	− **Montreal Trudeau**	**360 days**	**10/27/06**	**3/13/08**
2	Start	0 days	10/27/06	10/27/06
3	1-2 prepare site A	10 days	10/27/06	11/9/06
4	2-5 preparesite B	60 days	11/10/06	2/1/07
5	2-3 excavate foundation A	30 days	11/10/06	12/21/06
6	3-4 Excavate foundation B	50 days	12/22/06	3/1/07
7	3-5 Concrete Structure	50 days	2/16/07	4/26/07
8	5-6 concrete structure	20 days	4/27/07	5/24/07
9	6-11 concrete structure	20 days	5/25/07	6/21/07
10	11-12 concrete structure	50 days	6/22/07	8/30/07
11	12-13 cure concrete	10 days	8/31/07	9/13/07
12	13-17 install elevators	80 days	9/14/07	1/3/08
13	13-14 install structure steel	10 days	9/14/07	9/27/07
14	6-14 start sprinkler	80 days	5/25/07	1/17/08
15	14-17 install sprinkler	20 days	1/18/08	2/14/08
16	6-17 install electric work	160 days	5/25/07	1/3/08
17	6-15 finish interior	160 days	5/25/07	1/3/08
18	5-8 install mechanical plant	30 days	4/27/07	6/7/07
19	8-10 install mechanical plant	90 days	6/8/07	10/11/07
20	10-16 install mechanical plant	40 days	10/12/07	12/6/07
21	8-9 install HVAC	90 days	6/8/07	10/11/07
22	10-15 start up	110 days	10/12/07	3/13/08
23	5-7 install proof	10 days	4/27/07	5/10/07
24	7-15 install proof	20 days	1/31/08	2/27/08
25	11-7 install curtain wall	80 days	10/11/07	1/30/08
26	Finish	0 days	3/13/08	3/13/08

Figure 1.1: A typical Bar Chart

There are various techniques for scheduling. These include, the critical path method (CPM), the program evaluation and review technique (PERT), the line of balance (LOB), and the linear scheduling method (LSM). Each of these techniques is recommended for particular circumstances. When there are uncertainties associated with the duration of activities, a probabilistic method such as PERT is recommended, while a deterministic method such as CPM is used for projects in which duration is estimated with reasonable confidence. LOB and LSM are used for projects that include a considerable number of repetitive tasks like highway and high-rise construction (Ranjbaran 2007). It is noteworthy to indicate that the CPM method is by far the most popular technique used for construction scheduling. According to a survey conducted by Kelleher (2004), the application of CPM has increased from 90% in 1973 to 98% in 2003 among the top 400 contractors ranked by Engineering News-Record.

1.3 Types of Schedule Reviews

Contractors are frequently required to develop and submit detailed schedules upon the award of contracts. Owners and/or their agents are to review and subsequently approve these schedules. Nonetheless, owners may reject schedules if they find them inappropriate. The approved schedules are then used to generate projects' baselines, necessary to manage the projects, including tracking and progress reporting as well as the administration of construction disputes and claims. In addition, a well-developed schedule is the most crucial element for the effective application of earned value technique. Schedules are also used to forecast activity and project completion dates. Considering the numerous applications of schedules, it is important to ensure their goodness.

Schedules are typically complex as they incorporate input from numerous stakeholders. They should thus be carefully reviewed to ensure that they are in line with stakeholders' milestones. Moreover, the scope of projects should be reflected in schedules as defined, and they should satisfy project control requirements. It is essential for parties to agree on the schedules, and to ensure that schedules are well understood in connection to contractual requirements (Dysert et al 2006).

Contractors should submit schedule updates during project execution as well. They should update schedules according to the latest status of the projects and the progress achieved, on a regular basis, in conformance with contractual provisions. Contractors collect the required data: actual dates, remaining duration, percent complete, and so forth. Afterwards, they input the collected data to project schedules, updating them, and submit them to owners. Owners are to review and approve these schedules as well. Although initial schedule review and schedule update review may seem similar, they differ greatly. While reviewing initial schedules, the focus is on the quality and completeness of proposed schedules. In the course of this process, the major review factors are job logic, timing, phasing and resource balance. Imposed constraints should be avoided in these schedules, and negative float is not permitted at all. On the other hand, when reviewing updated schedules, the focus is on the changes applied to schedules in comparison with the latest accepted update. The major review factors are project progress, changes in activities, job logic, and availability and usage of resources. Constraints may be added to update schedules if necessary. They should be well explained and documented in narratives. Updated schedules may contain negative float representing schedule delay (Winter 2008).

Considering the vast differences between initial schedule review and schedule update review, each of these processes requires a set of specific measures to be taken and attention should be paid to particular focal points. This dissertation focuses merely on the assessment and evaluation of detailed construction schedules, developed by contractors using CPM and submitted to owners for approval and review. It is noteworthy to indicate that schedule assessment and evaluation is also known as schedule review or schedule audit.

1.4 Motivation

Construction contracts frequently require owners to review detailed schedules of their projects. Usually a set of general clauses indicate that the schedule shall be in compliance with the scope of the project and shall be developed with an appropriate level of detail. Nevertheless, there are rarely adequate specifications indicating how the review should be conducted. There are several publications describing the process of a detailed analysis of a cost estimate. However, rarely can one find comparable resources for the review of detailed schedules (Douglas 2009-b). The results of a survey revealed the immediate need for standards and best practice guidelines in CPM scheduling (Galloway 2006). Furthermore, the contemporary schedule review process is based on individuals' knowledge and experience, and thus subjectivity is associated with current practices of schedule review. It is not uncommon to receive different review feedback from different schedule reviewers regarding a single schedule (Dzeng et al. 2005). A structured method for the assessment and evaluation of schedules could decrease the level of subjectivity inherent in the current process of schedule review.

In addition, the available methods of schedule assessment and evaluation approach different schedule assessment and evaluation criteria in the same manner. The different impacts that different criteria have on the goodness of schedules should be examined, as the importance of each schedule deficiency and its integrated impact have not been studied. Hence, with the available methods, it has not been clearly defined what to do after the assessment of the schedules. If a schedule satisfies most of the provisions but is unable to fulfill a limited number of requirements, the final decision of accepting or rejecting it, is not clear. These are the issues that this dissertation addresses.

1.5 Scope and Objectives

The primary objective of this dissertation is to study schedule development and the schedule review processes for construction projects in order to define a structured method for the effective assessment and evaluation of detailed construction schedules, usually developed by contractors and submitted to owners for review and approval. These schedules may involve owner participation in the schedule development process. It was deemed important to consider industry practices put in place to satisfy necessary requirements of effective schedule review. In this regard, a set of sub-objectives are defined in order to achieve the main objective:

1. To study current practices for schedule development and schedule review processes.
2. To conduct a comprehensive literature review.
3. To extract, organize and cluster the criteria to be considered in the schedule review process considering industry's recommended practices.
4. To assess the level of importance of each criterion for schedule goodness (i.e. fitness for purpose).
5. To develop a method that helps owners make decisions regarding detailed schedules.

6. To automate the developed method in a computer application.

1.6 Thesis Organization

A review of the available literature and current methods of schedule assessment and evaluation, developed by professional organizations or government bodies along with research works done in academia, with a focus on their limitations and advantages, is presented in chapter two. Solutions devised for similar problems are explained in that chapter as well. This dissertation's proposed method, its components and limitations are presented in detail in chapter three. Also, the results of an online survey conducted to discover the relative level of importance of each of the defined criterion are presented in this chapter. Chapter four presents the automated computer application of the proposed method; the coded software, its components and their interrelations are also described in detail. The validation process of the proposed method through the application of four case examples is described in chapter five. Finally, chapter six encompasses the summary of this study and concluding remarks. The contributions of the proposed method and recommendations for future research work are included in this chapter as well.

CHAPTER TWO: LITERATURE REVIEW

2.1 General

Schedules are the key elements in project management with significant impacts on projects' success. Therefore, it is important to deploy adequate effort in the process of developing schedules and their review in order to ensure their goodness. Owners or their agents usually prepare schedules up to level three, which are commonly CPM schedules with major milestones included (Bent and Humphreys 1996). Upon award of contracts, contractors are typically needed to expand those schedules up to level five, providing detailed schedules, which should have an adequate level of details for day-to-day applications, as they represent the planned sequence of work. These schedules are usually presented in bar chart format, which reveals subcontractors, suppliers and vendors' activities. (Douglas 2010).

In a construction environment, different bodies conduct schedule reviews for various purposes. In general, there are three different types of schedule reviews to be conducted in different stages of projects life cycle:

1) Detailed schedule review,

2) Schedule updates review,

3) Forensic schedule review.

Contractors frequently prepare detailed schedules and submit them to owners in between receiving notice to proceed with project execution. Next, owners and / or their agents conduct a detailed schedule review (also called baseline review) early in project life cycle. Owners undertake this process to assess and evaluate the submitted schedules. The main purpose of the detailed schedule review is to insure that they are in line with contractual documents and satisfy owners' expectations. Schedules are also reviewed as regards to technical accuracy, reasonableness and representativeness. After approval of owners, these schedules would be considered as baselines used for tracking, progress reporting, project control, and so forth. Baselines form the basis for the other types of schedule review as well.

Schedule update review is a recurring process during the project life cycle carried out according to update periods, indicated in contracts. Therefore, contractors are required to submit progress reports along with updates of projects' baselines to the owners on a regular basis. Owners have the duty and right to review updated schedules. These schedules are important means of communication between contractors and owners as regards the project status, the progress achieved and the forecasted completion dates. The focus of this type of schedule review is on changes made to schedules in comparison with baselines or the last updated schedules (Winter 2008).

Forensic schedule review refers to the evaluation of schedules before conducting schedule delay analysis. Claim consultants are the bodies who undertake this type of schedule review. The main purpose of this process is to ensure the possibility of the project's construction, in the sequence reflected in the schedule (Hoshino 2011). Moreover, this type of schedule review attempts to make sure that the results of delay analysis, which is mainly based on the application of those schedules, yields accurate information as regards causation of delays (Winter 2008). This process is usually conducted at the end or late in the execution phase of projects. Forensic schedule review is usually followed and overlapped by rectification of schedules, correcting deficiencies recognised in forensic schedule review. It is necessary to indicate that the focus of this dissertation is on detailed schedule review, also known as schedule audit or detailed schedule assessment and evaluation.

A number of factors may lead to poor schedule development. These include, but are not limited to, failing to include all activities, the overuse of lags to manipulate the activities start dates (Nosbisch and Richey 2010), insufficient knowledge of the scheduler, inappropriate level of details, missing activity relationships, improper application of constraints, lack of necessary milestones (Lucas 2009), erroneous procedures in schedule development, (Glenwright and Mattos 2008), and so forth. It is important to assess and evaluate schedules precisely before acceptance or approval, as different applications of schedules such as tracking, progress reporting and claim resolution rely heavily on approved schedules. Generally, there are a number of benefits associated with the review of schedules. Firstly, schedule review process is a check up to ensure the schedule accuracy. Secondly, while conducting the schedule review, project stakeholders have the opportunity to verify if the schedule is in line with their expectations (Griffith 2006), which will be a binding document for engaged parties after approval.

O'Brien and Plotnick (2010) argued that owners have the right and duty to review, accept or reject the detailed schedules that are prepared and submitted by contractors. Nevertheless, any inappropriate decision at this stage could impose extra risks to owners. For instance, improper rejection of a well-developed schedule may release the contractor from the obligation of accomplishing the project on time. Consequently, Owners should deploy adequate effort to take the appropriate decision in this regard.

An effective method for assessment and evaluation of detailed schedules should address various challenges. Owners or their agents conduct schedule assessment and evaluation to determine if schedules are in line with contractual provisions. Disregarding other criteria, if schedules are not in conformance with the contract, they are not supposed to be accepted. Hence, owners should examine schedules as regards rationale of job logic and reasonability of activities duration (Avalon and Foster 2010; O'Brien and Plotnick 2010; Douglas 2009-b). Furthermore, they should walk through the critical path and near critical path to see if they are logical (O'Brien and Plotnick 2010). Moreover, schedules should be healthy and complete in covering all aspects of related projects in order to reveal change impacts accurately. Furthermore, it is of utmost importance to insure that schedules represent the way projects are going to be constructed on job sites (Douglas 2009-b), which is referred to as issue of representativeness in following parts. On top of that, there are numerous provisions in schedule assessment with different impacts on schedule goodness. The effective schedule review requires defining the related level of importance of each provision.

Different bodies have prepared various publications in the domain of scheduling in general, and schedule assessment and evaluation specifically. Professional organizations such as Project Management Institute (PMI) and Association for Advancement of Cost Engineers (AACE) have had some publications in this domain. Hence, there are guidelines developed by the government body in US besides other methods developed in academia. These publications mainly focus on the health assessment and disregard other necessary considerations such as completeness, reasonability of activities duration, representativeness and the process of schedule development, despite their significant impacts on the goodness of schedules. The recent methods incorporate two types of provisions including conceptual provisions and quantitative criteria, each with its specific advantages and disadvantages. While quantitative provisions result in an objective assessment, conceptual provisions could lead to a deeper evaluation. Moreover, issues such as representativeness cannot be assessed by application of quantitative provisions effectively.

A brief introduction to the project schedule review in general and a comprehensive review of recent literature on schedule development recommended practices are presented in this chapter. In addition, different methods of schedule assessment and evaluation along with their limitations are provided. A review of available literature as regards the solution applied for addressing similar issues in the domain of projects scope definition is also delivered. Finally, the identified gaps in recent literature on schedule assessment and evaluation, subjects of current research work, are highlighted to be addressed in following chapters.

2.2 Scope of Schedule Review Process

In the schedule assessment and evaluation process, schedules are reviewed from various perspectives, each of which requiring a specific area of knowledge. While assessing compliance of schedules with contractual requirements, adequate understanding of contractual provisions is required. In the course of evaluating the job logic and duration of project activities, the reviewer should be thoroughly familiar with the requirements of the respective project types (Douglas 2009-b). Representativeness could be insured by effective involvement of parties engaged in project execution in the schedule development process. Nonetheless, conducting schedule health evaluation requires knowledge about the schedule development practices. While conducting schedule health assessment process the reviewer is concerned to find out if the schedule is healthy and technically correct. Major focal points in this division would be conformance of the schedule with scheduling best practices and benchmarks. Health assessment is usually conducted by calculation of a set of selected quantitative health metrics, which address generally accepted principals. Focus of these metrics is on schedule mechanics in order to insure that the proposed schedule is a useful tool. It is worthwhile to indicate that schedule metrics highlight a potential issue, which should be mitigated or justified. These metrics include percentage of constraints, percentage of activities with lead and lag times, percentage of activities with high duration, total float, and so forth (National Defense Industrial Association (NDIA) 2011).

Besides reviewing the schedule as a product, it is recommended to have an eye on the schedule development process as well. Although there are a few recommended practices published as regards the scheduling process, they are frequently overlooked. Moreover, rarely there is any criterion included in available schedule review methods to assess the process of schedule development. Importance of scheduling process comes to mind particularly while examining the representativeness of schedules. Since a representative schedule could be achieved through a robust and accurate scheduling procedure by effective involvement of required parties. Furthermore, examining the issue of representativeness is more straightforward by reviewing the process of schedule development instead of assessment of the schedule as the product of this process. In summary, while conducting schedule assessment and evaluation the focus is on:

- Compliance with contractual provisions
- Reasonableness of job logic
- Rationale of duration
- Completeness
- Representativeness
- Health

Various bodies have prepared different publications in the domain of scheduling in general and schedule assessment and evaluation specifically. In this regard, four different categories could be considered:

1. Research works in academia.

   1.1 "CRITEX" (De La Garza and Ibbs 1990)

   A system for critiquing initial and in-progress schedules of medium-height commercial buildings. This system is among the first and most impressive works done in this domain.

   1.2 "ScheduleCoach" (Dzeng and Lee 2004)

   A computer system developed based on integration of case-based and rule-based reasoning for critiquing schedules of mid-rise construction.

2. Guides and standards developed by professional organizations.

   2.1 Practice Standard for Scheduling (PMI 2007)

   This standard explains schedule components as well as best practices recommended for scheduling with partial contribution to schedule review.

   2.2 Professional Practice Guide for Planning and Scheduling (AACE 2011-b)

   This guide encompasses several recommended practices under the general topic of planning and scheduling.

3. Guides prepared by government body.

3.1 DCMA 14-point assessment (Berg et Al 2009)

This method was introduced by the US Defence Contract Management Agency (DCMA) containing fourteen quantitative provisions for assessment of schedules' health.

3.2 GAO-9 (GAO 2009)

This guide was developed by GAO. Nine scheduling best practices have been included in a guide originally devised for cost estimating.

3.3 Planning And Scheduling Excellence Guide (PASEG) (NDIA 2011)

Encompassing generally accepted scheduling principles (GASP), the PASEG has recently been released by NDIA, Industrial Committee for program Management (ICPM). This guide resulted from joint effort of government body and industry experienced professionals. The main purpose of this guide is providing practical methods for developing and maintaining integrated master schedules.

4. Published recommendations based on professionals' individual experiences.

There are a set of conference or journal publications related to schedule review. These publications often encompass some suggestions to be considered while reviewing schedules. Two of the most recent publications are presented here

4.1 Schedule Quality Assurance Procedures (Avalon and Foster 2010)

4.2 Downstream Schedule Analysis for Non-Schedulers (Madl 2010)

Rarely one can find publications originally developed for schedule review. Current publications are primarily schedule development guides with partial contribution to schedule assessment and evaluation. Although these guidelines could be used for schedule assessment, they need to be organized in a way to ease this application. In other words, provisions originally devised for schedule development, should be transformed to criteria suitable for effective assessment and evaluation of schedules. There are also other types of guidelines with limited contribution to schedule assessment and evaluation. Forensic schedule analysis guidelines, and recommended practices (RPs) developed to protect schedules from claims are among this group of publications. In following sections, a review of available literature in this domain is presented.

2.3 Schedule Development Methods

A crying need of the construction industry was for standards in construction scheduling. Results of a survey conducted in 2006, by participation of construction industry stakeholders (owners, contractors, construction managers and government agencies) revealed that the construction industry was in an immediate need for standards as regards CPM scheduling. In addition to that, more than 92% of participants indicated that best practices guidelines in the CPM scheduling domain could be a useful tool for both owners and contractors (Galloway 2006). In response to those needs, PMI as one of the leading professional organizations in the domain of project management developed the guide "Practice Standard for Scheduling" (PMI 2007). This publication explains schedule components as well as best practices recommended for schedule development process. The guide aims to transform the sixth chapter of the Project Management Body of Knowledge (PMBOK), Project Time Management, into a standard to result in development of more valuable schedules. This guide defines a number of generic best practices, including but not limited to, adequate definition of project scope, thorough inclusion of project scope in the schedule model, clear definition of project calendars as well as working periods, devising effective coding structure for activities, and so forth. Furthermore, a set of schedule components necessary to meet the minimum schedule requirements were incorporated in this guide. This guide included a conformance Index to evaluate the degree of conformance of each schedule to the proposed standard (PMI 2007).

This guide and similar publications encompassing generic and conceptual scheduling best practices are originally devised with the intention of explaining the schedule development practices. Although these guidelines could be used for schedule assessment, provisions originally devised for schedule development should be transformed to criteria suitable for effective assessment and evaluation of schedules. Moreover, the desired provisions should be defined in a way to lead to a schedule review process that is as objective as possible. One of the disadvantages of generic and high level best practices in comparison with more detailed provisions, particularly quantitative criteria, is the issue of subjectivity. Since assessing schedules by applying merely generic and conceptual provisions could always be accused of subjectivity. Furthermore, those high-level best practices could be evaluated neither readily nor precisely.

The Government Accountability Office (GAO) of the US incorporated a set of best practices for managing capital program costs in its publication: "GAO Cost Estimating and Assessment Guide" (GAO 2009). The GAO considers an integrated schedule as the key for managing project performance and calculating the remaining work, and the expected cost to complete. Therefore, nine scheduling best practices were incorporated in this guide, with the intention of defining the characteristics of the desirable integrated schedules, including but not limited to:

- Schedule should reflect all activities in WBS
- Schedule should be integrated, both vertically and horizontally
- Activities to be loaded with labor, material and overhead
- Activities duration to be estimated realistically
- Activities float to be calculated
- Schedule to be updated on regular basis

In addition to the above best practices, eleven fundamental questions were included in this guide (GAO 2009). A reliable schedule in line with the recommended best practices is necessary for answering those questions (Nosbisch and Richey 2010).

The developed best practices are too generic, without adequate level of scrutiny. For instance, a criterion requires the critical path to be identified. However, a more in depth assessment and evaluation on critical path and even near critical activities is necessary. Merely identifying the critical path, although important, is not sufficient. Furthermore, this guide only concerns schedule health. Consequently, issues related to Contractual compliance, Job logic and representativeness are disregarded. In addition, the process of schedule development has been overlooked in this guide despite its significant impact on schedules' goodness. The GAO has received recommendations from AACE and other organizations to review this guide (Winter 2011).

The AACE collected a series of their published transactions under the topic of planning and scheduling and added thirteen related recommended practices in a collection called "AACE international's Professional Practice Guide to planning and scheduling" (AACE 2011-b). This guide encompasses publications covering different aspects of scheduling from the required skills for scheduling professionals to the methods required for protecting schedules from claims. The guide "Schedule Constructability Review" (Douglas 2009-b) is one of the recommended practices (RP) with contribution to schedule review. This RP provides a set of planning recommendations to be considered while developing a construction project schedule for the execution phase. A recommended schedule review process is included as well. The focus of the guide is on the concept of constructability. This RP has been developed with the intention of disclosing probable issues in the following areas:

- Reasonableness of Job logic
- Comprehensiveness of construction plan
- Coordination among trades and engineering work
- Adequacy of procurement leads time
- Job site accessibility and physical limitations

However, this guide does not address schedule health and contractual compliance issues. In addition, this guide does not address effective assessment of activities duration.

The "Planning and Scheduling Excellence Guide" (PASEG) is the most recent publication released in this domain. The PASEG was developed by the Industrial Committee for program Management (ICPM) of the United States National Defense Industrial Association (NDIA). The working draft of this guide was publicly released in April 2011 (NDIA 2011). The NDIA (2011) developed PASEG with the intention of providing program management teams with "practical approaches" for developing and maintaining Integrated Master Schedules. Furthermore, this guide attempts to define a "standardized approach to project planning, scheduling and analysis." This guide is the outcome of the joint effort of experienced professionals in both the construction industry and the government body. The PASEG provides program teams with common scheduling practices leading to sound and realistic schedules. Although this guide delivers generic practices applicable for any industry, the focus is mainly on large programs with significant risks in technique, schedule and cost. PASEG includes eight high-level and concise Generally Accepted Scheduling Principles (GASP) divided into two different sections. First section incorporates five GASP describing necessary requirements of a valid schedule; schedule should be 1) Complete, 2) Traceable, 3) Transparent, 4) Statused and finally 5) Predictive. The second section contains the other three GASP that could lead to effective schedules; schedule should be 1) Usable, 2) Resourced and 3) Controlled. The PASEG defines three different purposes for the GASP; tenets for sound scheduling, a tool for validating schedule maturity and new scheduling approaches (NDIA 2011). The PASEG highlights similar critical areas to those depicted by GAO. Unlike the latter guide, PASEG provided the how issue, i.e. how one can develop a good schedule (Program Planning and Scheduling Subcommittee (PPSS) 2011).

As regards schedule review, the PASEG encompasses a set of health assessment metrics without any specific recommended threshold value. Instead, the PASEG encourages the application of threshold guidelines as trigger points for further analysis (NDIA 2011). Considering on the one hand, the focus of this guide which is on large programs and on the other hand, the construction industry with its unique characteristics, particularly in medium and small size projects, applicability of this guide could be questioned. As the projects teams' ability to define the appropriate threshold guidelines is not of total certitude. In General, methods with more similarity to the concept of simplistic checklists, easy implementation but with enough details, could be more applicable. Moreover, PASEG recommends the application of other assessment methods such as DCMA for evaluating schedule health. Therefore, the PASEG suffers from similar deficiencies associated with DCMA. Despite the useful features of this guide, PASEG does not address issue of representativeness, contractual compliance, and reasonability of activities duration effectively.

2.4 Schedule Assessment and Evaluation Methods

De La Garza (1988) presented a knowledge based methodology to transform the captured scheduling knowledge into a specific structured format for future development of an operational Knowledge Based System. In that study, he defined thirty-four conceptual provisions for critiquing initial and in-progress schedules of mid-rise building construction. He used three different methods to capture the required knowledge, analyzing textbooks, experts' interviews and studying performance of experts. However, this work was not fully automated as a software system. In a later study, De La Garza and Ibbs (1990) introduced a computer system named "CRITEX". That system was developed for critiquing schedules of medium-height commercial building construction and is among the first efforts deployed in the domain of automated schedule review. "CRITEX" incorporated the same generic provisions defined in the former research to assess schedules from four perspectives: general requirements, time, cost and logic. Nonetheless, activities duration and job logic were not assessed effectively as the related provisions were too generic.

"ScheduleCoach" (Dzeng and Lee 2000) was another computer system devised for analyzing schedules of high-rise buildings construction. This system was developed based on integration of rule-based and case-based reasoning. "ScheduleCoach" was capable of providing advice based on related values of similar cases. In a later study, same authors used "ScheduleCoach" for critiquing schedules of mid-rise building construction (Dzeng and Lee 2004). That system incorporated forty six provisions divided to two sections; a) mandatory rules and logic, many of which are regulations specifically enforced in Taiwan, and b) provisions to improve scheduling practices. This guide includes a significant amount of provisions developed by De La Garza (1988). A similar system, "Network Review Assistant (NRA)", was developed to automatically review schedules of expressways construction as well (Dzeng et al. 2005). The latter three systems were able to examine activities duration by comparing proposed durations with those of similar cases. Nonetheless, the review of activities duration was inconclusive, as they did not consider resources usage (Dzeng et al. 2005). Moreover, those systems did not effectively address the schedules health issue. In addition, their application was restricted to schedules developed based on application of a single set of standard activities.

There were similar attempts leaded by the US Department of Defence (USDOD), which resulted in the guide “Integrated Master Plan and Integrated Master Schedule Preparation and Use Guide” (USDOD 2005). This publication provided guidance for “preparation and implementation of a program’s Integrated Master Plan (IMP) and Integrated Master Schedule (IMS)”. IMP and IMS are fundamental tools necessary for effective planning and execution of projects. That guide suggested evaluation of Integrated Master Schedules for source selection, as the submitted IMP and IMS demonstrate the level of offerors’ understanding of projects requirements. In addition, IMS could show soundness of their approach through project accomplishment (USDOD 2005). Nevertheless, that guide suffers from lack of adequate level of details particularly for provisions addressing schedule components such as activities duration, Floats, leads, lags, etc. For instance, that guide requires floats to be reasonable although it has not been described how long a reasonable float is.

In line with IMP and IMS preparation and use guide, the Defence Contract Management Agency (DCMA) of DOD released a 14-point schedule assessment method for evaluation of schedules. One of the rare resources explaining that method of schedule assessment is the related on-line training course: "IMP/IMS Basic Analysis" developed by the DCMA (Berg et al 2009). This method incorporates 14 measurement indices for assessing schedules health. The focus of DCMA assessment method is on quantitative schedule components. The defined provisions introduce thresholds on: 1) Logic, 2) Leads, 3) Lags, 4) Relationship Types, 5) Hard Constraints, 6) High Float, 7) Negative Float, 8) High Duration, 9) Invalid Dates, 10) Resources, 11) Missed Tasks, 12) Critical Path, 13) Critical Path Length Index and 14) Baseline Execution Index. This guide can be used for initial and in-progress schedule assessment although some provisions are applicable to in-progress schedules. This assessment method suggests a threshold of 5% for most of the defined measurement indices. Nonetheless, these thresholds have been in debate by professionals. For example, number of incomplete tasks with a high total float is required to remain below 5%. The guide does not clearly explain either why a threshold of 5% or what to do if the result of a test is over the defined threshold value. In previous versions of that guide, a test was stated as "Failed" if the related value was more than the defined threshold. However, rejecting a schedule merely because more than 5% of activities have total floats longer than 44 working days does not make sense (Winter 2011). Furthermore, as indicated in the documentation of the above training course, this method encompasses merely quantitative provisions to assess schedule health. Therefore numerous important issues are overlooked. For instance, issues such as Completeness, contractual conformance, reasonability of activity duration and above all, the issue of representativeness were ignored in this guideline. None of the 14 assessment criteria was defined to assess and evaluate the process of scheduling in spite of its significant impact on the schedule.

There are a few publications written based on experience of individual professionals in the domain of scheduling or schedule review. Frequently they contain a set of recommendations to augment current processes and to be used besides available methods. For instance, Madl (2010) defined some rules of thumb as a simple “sanity check” to evaluate schedules of chemical and refining facility projects. The defined rules were based on implementation of historical data of similar projects, and the defined relationship between projects’ total installed cost and phases’ duration. Occasionally, there are publications developed as a standalone method. Avalon and Foster (2010) introduced a set of procedures as well as metrics to evaluate the quality of schedules. The health metrics although quantitative, no threshold value were defined. Therefore, the user could be unclear about “excessively large float values” for instance. Moreover, similar to other publications the issues of representativeness, scheduling process and effective assessment of activities duration were disregarded.

There are other types of schedule review with strictly limited contribution to schedule assessment including methods developed as forensic schedule analysis. When validating a schedule for claims analysis in the course of forensic schedule review, the focus is on the possibility of building the project in the way reflected in the schedule, and contractual compliance. However, owners’ review of detailed schedules is conducted to assure reasonableness of information delivered by schedules (Hoshino 2011). Although there are vast differences, still there exist some provisions that could be used for detailed schedule review. Provisions incorporated to ensure full scope representation of projects, and to split activities to represent scope of work of merely one party (Hoshino 2009) are among these provisions.

Schedules claims protection methods have also limited contribution to detailed schedule review. These methods are devised mainly to explain procedures to be implemented while developing schedules, in order to mitigate potential of schedules claims (Douglas 2009-a). Therefore, these procedures could be among the considerations while developing schedules and respectively could be transformed to provisions to be applied while conducting schedule review.

2.5 Project Scope Assessment

On top of the limitations indicated during literature review, there is a major deficiency in common among available methods. Various provisions that have been defined for schedule assessment are not equally important with respect to their impact on the goodness of detailed schedules. For instance, importance of a realistic critical path is much higher than avoiding application of activities with a total float which is more than forty four working days (Berg et al 2009). Nonetheless, the available methods of schedule assessment and evaluation approach different schedule assessment and evaluation criteria in the same manner. The different impacts that different criteria have on the goodness of schedules should be examined, as the importance of each schedule deficiency and its integrated impact have not been studied. Hence, with the available methods, it has not been clearly defined what to do after the assessment of the schedules. If a schedule satisfies most of the provisions but is unable to fulfill a limited number of requirements, the final decision of accepting or rejecting is not clear. These are the issues that this study addresses.

It is necessary to indicate that a similar problem in the domain of projects scope definition was addressed by development of Project Definition Rating Index (PDRI) in an effort supported by Construction Industry Institute (CII). The PDRI is a tool to evaluate status of a project in pre-project planning phase, and to measure the level of project scope development based on best practices and benchmarks (Cho 2000). In essence, PDRI is a checklist encompassing numerous scope definition elements weighted according to their relative level of importance in comparison with others (CII 1999). CII has developed PDRI for different areas of construction industry through different research efforts. The work started by developing PDRI for Industrial projects (CII 1996). Considering success of this tool in industrial sector, similar means were developed for building (Cho 2000) and later for infrastructure projects (Bingham 2010).

The PDRI for building project encompasses sixty four scope definition elements divided to eleven categories and three sections. The output of this tool would be a total score representing quantitatively the level of project scope definition. This tool allows users to compare scope definition with project success as well (Cho 2000). A lower total score shows a more complete scope definition. After examination of numerous projects, it was proved that projects with a lower total score outperformed others as regards cost and schedule performance as well as change orders value. Therefore, a threshold was defined representing the minimum suggested level of project scope definition (Cho and Gibson 2001). Project participants have the opportunity to evaluate the level of projects' scope definition in different stages of project life cycle by means of this simplistic method. If the total calculated score is higher than the defined threshold, then project participants are recommended to go back and spend more effort in defining the scope of the project in required areas.

This thesis adopts a similar approach to devises a tool to assess and evaluate goodness of detailed schedules based on industry recommended practices and benchmarks. The proposed tool could be considered as a decision support system. Since the proposed tool could help owners in making decision as regards detailed schedules that are frequently prepared by contractors and may involve owners' participation.

2.6 Summary

During literature review, certain gaps were identified. Although available literature reviewed in this chapter delivers contributions to schedule review, there are still areas for improvement. In summary, available methods suffer from almost common deficiencies including in adequate level of details, and overlooking a set of necessary considerations in the course of schedule review process. In essence, available methods are almost merely tools for schedule health assessment. Therefore, other considerations such as contractual compliance, reasonability of activities duration, process of schedule development and issue of representativeness are usually overlooked. In addition, available publications are primarily developed by guideline mentality. Therefore, they could not be applied with the ease and practicality that a construction specific checklist could. Simplistic checklists that allow easy implementation with enough details could lead to more objective assessment and evaluation. Hence, a quantitative evaluation of schedule goodness has not been studied yet. Furthermore, systems developed originally for schedules review in specific domains of construction, "ScheduleCoach" (Dzeng and Lee 2000) and "NRA" (Dzeng et al. 2005), were capable to evaluate merely schedules developed based on application of a single set of standard activities. On top of that, an important limitation of available methods is their inability to take to account the related level of importance of each provision on goodness of schedules. They do not provide the required support for owners in the most crucial point of decision making as regards submitted schedules as well.

To address those issues, a structured method was developed for assessment and evaluation of detailed schedules based on integration of scattered knowledge. The developed method encompasses both conceptual criteria and quantitative provisions including necessary consideration for effective schedule assessment and evaluation. Adopting the methodology, which was developed for quantitative evaluation of the level of scope definition, PDRI, a composite index was defined to evaluate the level of schedule goodness. Moreover, considering schedules of large projects which may contain hundreds of activities if not thousands, the proposed method was automated for computer application. The developed method and the computer application are described in details in the following chapters.

CHAPTER THREE: PROPOSED METHODOLOGY

3.1 General

As presented in the previous chapters, an effective schedule assessment involves the review of schedules to examine their compliance with related contractual provisions, the reasonability of activities duration and job logic, representativeness, health, and completeness. However, current methods of schedule review consider merely a few of these considerations. The main purpose of this research is to develop an effective method of detailed schedule assessment and evaluation, in order to improve the current process of schedule review by integrating scattered knowledge and considering frequently disregarded best practices. This chapter outlines the methodology implemented in the Schedule Development Index (SDI) definition as a tool for the quantitative assessment and evaluation of schedules.

In addition, this research circumvents an important limitation of available methods, which is approaching different schedule review provisions in the same manner despite their varying levels of importance. This research aims to evaluate and consider the relative weight of each schedule review provision for schedule goodness. In this regard, this study adopts the methodology used by the Construction Industry Institute (CII) to develop a method for evaluating the level of project scope definition. More precisely, the methodology that was developed, implemented and proven in developing the Project Definition Rating Index (PDRI) for industrial projects (CII 1996), building projects (Cho 2000) and infrastructure projects (Bingham 2010) is adopted to be implemented in this study. However, this study deviates in some circumstances to suit the idiosyncrasies of its objectives and to overcome certain challenges. For instance, an online survey was conducted by participation of professionals to finalize the developed score sheet and to weigh the extracted elements, while CII administered numerous workshops in order to obtain construction experts' feedback for the same purpose.

The Schedule review provisions were extracted from three major sources, and were clustered and refined according to feedback received during several sessions of structured interviews. Moreover, it was decided to rely on a broad range of expertise in order to define the related level of importance of each provision for schedule goodness. Thus, an online survey was conducted to seek out expert opinions. Statistical analyses were used to examine the collected raw data. Consequently, a score sheet was created for the effective assessment and evaluation of detailed schedules, encompassing the extracted criteria and their related level of importance. The developed method was implemented in the Visual Basic environment with links to Microsoft Project and Microsoft Access to facilitate its application particularly for large and complicated schedules. Finally, the developed method was validated through a set of case examples and the results were compared with an available, objective method of schedule review. Figure 3.1 demonstrates the overview of the different stages of this research.

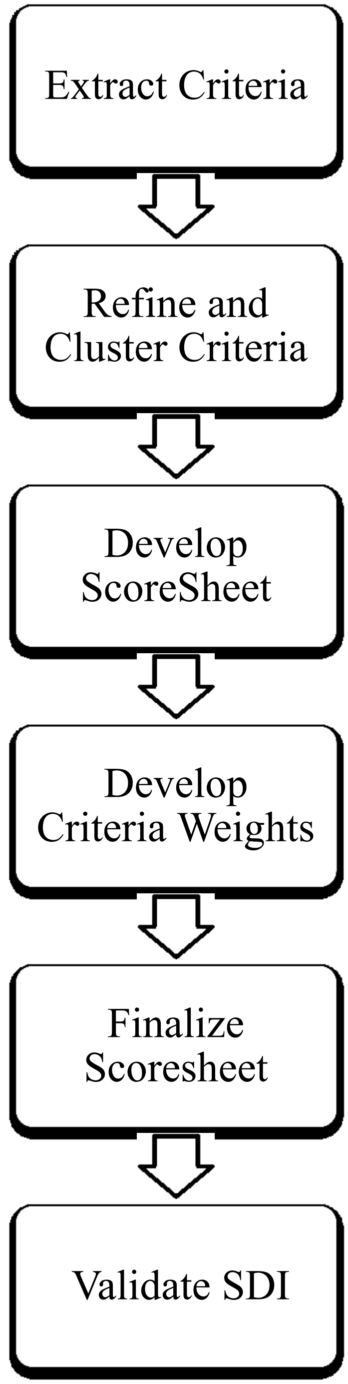


Figure 3.1: Overview of research methodology

3.2 Criteria Classification

The first step of this research was extracting the criteria, or provisions, for consideration in the process of schedule assessment and evaluation. In order to develop a structured and effective method, a comprehensive literature review was conducted. At this stage, it was planned to extract related provisions with the intention of having them refined and clustered later. Therefore, three major sources were examined closely:

1. Text books and dissertations
2. Recommended practices and guidelines
3. Journal articles and conference proceedings

For the second resource, recommended practices and guidelines, this study benefited from available publications from two main sources, government agencies and professional organizations.

In the course of the literature review for this research, more than one hundred publications from the above references were studied. Through the literature review, the recurring problem of no structured method was observed, as there are plenty of provisions pointing to a variety of important issues to be considered in schedule development and/or schedule review, many of which are typically disregarded. Thus, after a careful examination of available resources, an initial draft of about seventy provisions was prepared. In essence, the output of this phase was a checklist developed based on the integration of sporadic knowledge, encompassing a wide range of recommended schedule review provisions. The extracted criteria could be divided into two main categories: 1) conceptual and 2) quantitative provisions.

1) Conceptual criteria: these criteria reflect best practices, recommended for consideration while reviewing schedules, although they are usually generic and high level provisions without an adequate level of detail. Therefore, they are not sufficient for an effective method of schedule assessment, which requires more straightforward provisions. In order to remedy this deficiency, the generic best practices were replaced by more detailed provisions in order to overcome the above deficiency. For instance, in the GAO guideline (2009), a provision recommends the critical path to be identified. This recommended practice, although extremely important, is very generic, and was thus replaced by the following, more specific criteria.

    - All activities on the critical path should have a predecessor representing a physical dependency (O'brien and Plotnick 2010).
    - The criticality and near criticality rate should satisfy the defined thresholds (O'brien and Plotnick 2010, De La Garza 1988).
    - Critical activities, to be well manageable, should have a limited duration (De La Garza 1988).

There are other deficiencies associated with the application of conceptual provisions. These criteria cannot be readily assessed, and the assessment of schedules merely based on conceptual provisions would always be susceptible to subjectivity. It is not uncommon for different schedule reviewers to conclude with different, even contradictory, review results. One solution to overcome these limitations could be defining the proposed conceptual criteria in the clearest possible way to mitigate the possibility of misinterpretation. Furthermore, it would be recommended to include both conceptual provisions and quantitative criteria to decrease the level of subjectivity of the process of schedule evaluation. Both of these proposed solutions were implemented in this study.

2) Quantitative criteria: this category is comprised of empirical rules, or rules of thumb, introducing a set of thresholds on quantitative schedule components. The quantitative schedule components encompass total float (total slack), duration, criticality and near criticality rate, project cost and effort ratio, and so forth. These provisions are also known as "health metrics" (PASEG 2011) or "metrics" (Berg et al. 2009). The quantitative criteria are suitable for methods which include computer implementation, as these provisions can be the object of effective automation. The required time for assessing schedules based on these criteria is much shorter in comparison with conceptual provisions. In addition, the obtained results are objective. However, quantitative criteria are mostly applicable for health assessments. In fact, issues such as representativeness, completeness and job logic cannot be effectively assessed by the application of these criteria. Hence,

health metrics should be judicious; otherwise, they are merely meaningless numbers. Considering the advantages of quantitative criteria, a careful selection of widely accepted health metrics was included in the research method.

It is interesting to indicate that a considerable number of the selected provisions were repeated in different references. This matter could be considered as an indicator of consensus among experts in this domain. Nonetheless, keeping in mind one of the objectives of this research, developing a straightforward method, simple but with enough details to be effective, the extracted criteria were refined and augmented through several sessions of structured interviews. A copy of the questions asked in a set of the interviews is provided in Appendix A.1 of this thesis. A straightforward method necessitates avoiding trivial provisions and keeping those which are imperative but usually overlooked. In order to make sure that the selected provisions were appropriate and that they make sense for professionals in the industry, input from professionals seemed necessary. Therefore, several sessions of structured interviews were conducted.

In general, interviews could range from unstructured to structured. In unstructured ones, some themes should be prepared in advance, but questions can be modified to suit the particularity of each interview and interviewee. On the other hand, structured interviews are conducted in a rigorous manner like a postal survey with no opportunity for follow-up questions. Nonetheless, more explanations can be provided if required. Semi-structured interviews stand in the middle (Farrell 2011). As it was intended to merely refine the extracted criteria, omitting trivial provisions and keeping important ones, structured interviews were selected.

In each interview, the interviewer provided the interviewee with the extracted provisions one by one. A brief description was given along with the reason why each provision was included. Then, the interviewee was asked if he or she believes that the provision should be considered in an effective method of schedule assessment. The interviewer was required to give further clarification in some occasions during the interview sessions. The interviewer used this opportunity to make provisions more clear and practical for professionals in the industry. In other words, the interviewer translated the academic language of the extracted provisions into the current language of industry. After several interview sessions, a refined list of forty eight criteria emerged: in essence a check list of provisions to be considered while assessing and evaluating detailed schedules. Taking into account the various considerations associated with the process of detailed schedule review, those criteria were clustered into two main categories. Figure 3.2 demonstrates the criteria classification and each category is explained in detail below.

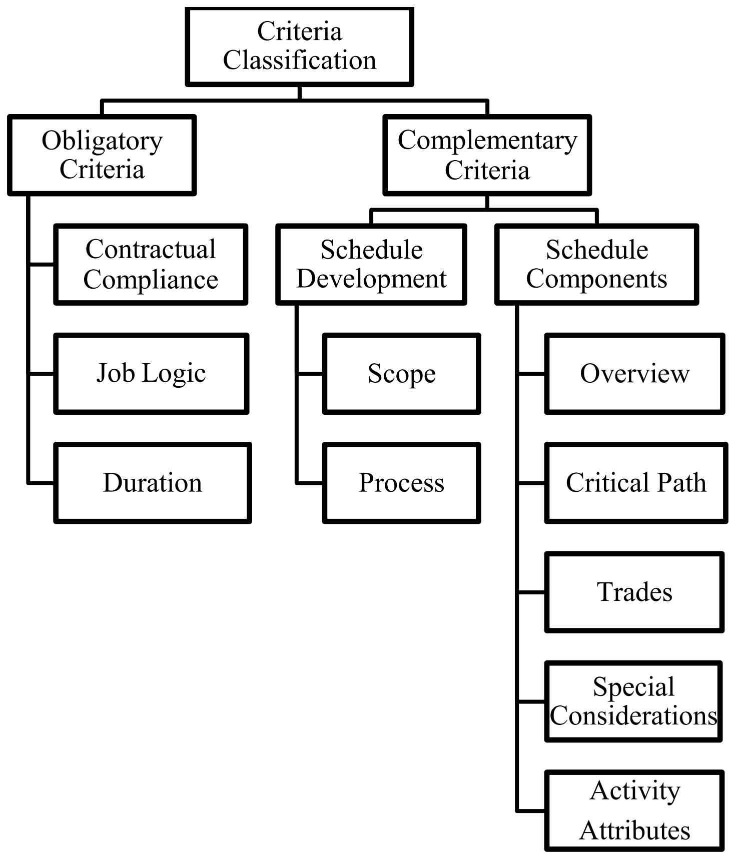


Figure 3.2: Criteria classification

3.2.1 Obligatory criteria

This category encompasses the necessary provisions of contractual compliance, rationale of job logic and reasonability of activity duration, which each schedule must satisfy. If any schedule is unable to fulfill any of these provisions, that schedule should be classified as unacceptable or “failed”. Each schedule must satisfy the contractual requirements, although it has been reported that only a limited number of schedules are entirely in conformance with contractual requirements in their first submittal (Li and Carter 2005, Zartab and Rasmussen 2001). Although the main concept is applicable to contracts in general, some of the extracted criteria in this group may not be applicable to all schedules, depending on the context of the related contract. In addition, schedules must be developed based on realistic and accurate job logic. The emphasis here is placed on hard logic, which respects the rigid sequence of construction operations. Faulty job logic results in impractical schedules; therefore, these schedules must be rejected. Moreover, the duration of activities must be in an acceptable range according to related typical productivity rates. An extremely high or low duration represents irrational activity duration and thus an unrealistic schedule. In conclusion, disregarding other criteria, schedules must satisfy the provisions included in this category. Otherwise, they should be marked as “failed” and there is no reason for evaluating these schedules with subsequent criteria. Eight criteria are included in this category, as shown in Table 3.1.

Table 3.1: First group: Obligatory Criteria

Obligatory Criteria		Source
1	Milestones and Project Duration	Spencer and Lewis 2006, De La Garza 1988
2	Phasing and Sequencing	Li and Carter 2005
3	Number of Activities	Li and Carter 2005
4	Activity Code	Li and Carter 2005
5	Schedule Submission Date	Zack 1991
6	Job Logic (rationale)	Avalon and Foster 2010, O’Brien and Plotnick 2010, Douglas 2009-b, GAO 2009
7	Activity Duration (reasonableness)	Avalon and Foster 2010, O’Brien and Plotnick 2010, Douglas 2009-b, GAO 2009
8	Scope Coverage	Douglas 2009-b; GAO 2009; PMI 2007; Li and Carter 2005

3.2.2 Complementary criteria

This category incorporates best practices, recommended for consideration while reviewing schedules. Forty provisions are clustered into two main categories and seven subcategories as shown in Figure 3.2 above. Compliance with this group of provisions is not obligatory. Nevertheless, being in line with these provisions could be an indicator of a robust schedule. Thus, if any schedule is able to satisfy the obligatory criteria, then it could be evaluated by applying complementary criteria to determine its level of goodness. This category is divided into two subcategories: schedule development and schedule components.

3.2.2.1 Schedule development

The importance of the process of schedule development cannot be overemphasized. A robust schedule will not be obtained unless the process of schedule development is conducted in an appropriate way. Five provisions are included in the proposed method, considering the significant impacts of the process of schedule development on the goodness of schedules, particularly the issues of representativeness. These provisions were divided into two subcategories: scope and process.

The schedule development category primarily attempts to address the issue of representativeness and completeness. One of the basic requirements of schedules is to correctly represent the way projects are going to be constructed (issue of representativeness). Otherwise, none of the forecasting functions of the schedule would be realistic. One of the best ways to insure the representativeness of schedules is through the involvement of appropriate parties in schedule development. Thus, effective schedule development necessitates the application of teamwork by the active involvement of required participants (Li and Carter 2005).

Furthermore, it is of outmost importance to involve the parties who build the projects. Thus, sub-contractors who are in charge of significant parts of projects should be involved in the scheduling process (Li and Carter 2005, Zack 1991, De La Garza 1988). Having sub-contractors involved in schedule development could insure to some degree the representativeness of schedules as sub-contractors are most aware of how projects are to be constructed. Moreover, involving sub-contractors in the scheduling process prevents general contractors from eliminating some activities and/or manipulating schedules as these acts are against sub-contractors as much as owners (Zack 1991). Therefore, some references recommend requiring sub-contractors to sign off on schedules as verification of their participation and commitment to scheduled dates (Li and Carter 2005, Zack 1991). In addition, schedules should reflect the start and completion dates of the prime contractors involved in each project (Douglas 2009-b, de La Garza 1988), demonstrating a better understanding of the scope of work of each contractor, which represents a more precise scheduling effort.

Moreover, it is extremely important for schedules to cover the project scope thoroughly (Douglas 2009-b, GAO 2009, PMI 2007, Li and Carter 2005). Otherwise, schedules would be neither complete nor representative. A well-developed scope of work and an approved Work Breakdown Structure (WBS) could provide a sound basis for a robust schedule. Consequently, it is recommended to ensure that the project scope is adequately defined and to start the schedule development process based on an approved WBS (PMI 2007). Considering the importance of the above recommended practices, related provisions were included in the developed method. The five provisions incorporated in this category are listed in Table 3.2.

Table 3.2: Second group: Schedule Development

2. Schedule Development		Source
2.1 Scope		
1	Project Scope Definition	PMI, 2007
2	WBS Verification	PMI, 2007
2.2 Process		
3	Scheduling Process	Li and Carter 2005
4	Subcontractor Participation	Li and Carter 2005, Zack 1991, De La Garza 1988
5	Verification of Subcontractors' Scope of Work	Douglas 2009-b, De La Garza 1988

3.2.2.2 Schedule components

Thirty-five provisions are included in this subcategory, mainly addressing the health issue of schedules based on the industry's recommended practices and benchmarks. This subcategory includes quantitative provisions that define a set of thresholds on numeric schedule components, assessing schedules from different perspectives including overview and general requirements, critical path, resources, activities attributes, and finally special considerations. It is necessary to indicate that, although the presented thresholds were retrieved from published material, each firm is encouraged to adjust these threshold values according to their particular needs (Moosavi and Moselhi 2012). The importance of quantitative criteria relies on their capability to be automated by means of computer application. A set of quantitative criteria are subject to automated computer application in the following chapter. The complete list of the provisions incorporated into the proposed method is presented in Table 3.3.

Table 3.3: Complete list of schedule assessment and evaluation criteria

Schedule Assessment And Evaluation Criteria Evaluating how good a schedule is			
No.	**Element**	**Explanation**	**Reference**
1. Obligatory criteria			
1.1 Contractual Compliance			
1	Milestones & Project Duration	Milestones & project duration must be in line with related contractual provisions.	Spencer and Lewis 2006, De La Garza 1988
2	Phasing and Sequencing	Phasing and sequencing must be in line with related contractual provisions (if applicable).	Li 2005
3	Number and Duration of Activities	Number and duration of activities must be in line with related contractual provisions (if applicable).	Li 2005
4	Activity Code	Activity code must be in line with related contractual provision (if applicable).	Li 2005
5	Schedule Submission Date	Schedule submission date should be in compliance with related contractual provision.	Zack 1991
6	Scope Coverage	Scope of the project should be covered by schedule	Douglas 2009-b, GAO 2009, PMI 2007, Li 2005

1.2 Job Logic			
7	Job Logic	Job logic must be rational.	O'brien and Plotnick 2010, Douglas 2009-b , GAO 2009, De La Garza 1988
1.3 Duration			
8	Activity Duration (reasonability)	Activity duration must be reasonable.	O'brien and Plotnick 2010, Douglas 2009-b, GAO 2009
2. Complementary Criteria			
2. 1 Schedule Development			
2.1.1 Scope			
9	Project Scope Definition	All aspects of project scope should be adequately defined before scheduling	PMI 2007
10	WBS Verification	Scheduling should be based on an approved WBS	PMI 2007
2.1.2 Process			
11	Scheduling Process	Schedule should be developed by participation of parties associated with the project	Li 2005
12	Subcontractors Participation	Subcontractors responsible for considerable parts of project should become involved in schedule development having their work integrated and coordinated.	Li 2005, Zack 1991, De La Garza 1988
13	Verification of Subcontractors' Scope of Work	The schedule should reflect the start and completion dates for prime contractors involved	Douglas 2009-b, De La Garza 1988
2.2 Schedule Components			
2.2.1 Overview			
14	Verification of Project Duration	Project duration should conform with parametric scheduling results	Moselhi 2010
15	Minimum Milestones	At least two milestones, start & end, should be included in each schedule	PMI 2007
16	Verification of Project Performance	Generated S-Curve should be in compliance with typical S-curves	De La garza 1988

17	Phase Duration	Each phase duration (Engineering, procurement, ...) should be in compliance with historical average data according to Total Installed Cost	Madl 2010
18	Phase Overlap	Engineering should not overlap construction by more than a percentage	Madl 2010
19	Calendar Verification	Non-working days should be indicated in the project calendar	Douglas 2009-b, Li 2005
20	Working Hours Schedule-Estimate Compliance	Basis of scheduling should be in compliance with basis of estimate as regards working hours	Madl 2010
21	Congestion Index (labor density)	Maximum number of workers per square meter should be limited to avoid congestion (25 to 30 sqm/man) (200sqf/person, Kerridge and Vervakin, Bent)	Russell and Udairpurwala 2000, Bent 1996, Kerridge and Vervakin 1986
2.2.2 Critical Path			
22	Critical Path	Each critical activity should have a predecessor reflecting a physical dependency	O'brien and Plotnick 2010
23.1	Schedule Criticality rate.1	Number of critical activities/ total number of activities should be limited	O'brien and Plotnick 2010, De La Garza 1988
23.2	Schedule Criticality rate.2	Duration of critical activities / total duration of activities should be limited	Spencer and Lewis 2006
24	Near criticality rate	Number of near critical activities/total number of activities should be limited (near critical activities: TF<5 to 10)	O'brien and Plotnick 2010
25	Project Effort Ratio	Project critical path effort(number of laborers)/ total project effort should be within a min/max range	Spencer and Lewis 2006
26	Project Cost Ratio	Project critical path cost/ total project cost should be within a min/max range	De la Garza 1988
27	Critical Activity Duration	Critical activities, to be well manageable, should have a limited duration	De la Garza 1988
2.2.3 Resources			
28	Resource Loading	Schedule should be loaded with resources	Madl 2010, Griffith 2005, Glenwright 2004, Zack 1991

29	Responsibility Assignment	A responsible party/person should be assigned to each activity	PMI 2007, De la Garza 1988
30	Schedule Leveling	Schedule should be leveled	GAO 2009, Douglas 2009-b
31	Trades' Peak Resource Loading	Compliance of peak resource loading of each trade with historical average data according to total installed cost and phase duration	Madl 2010
32	Trades' Peak Resource Loading relation	The relationship between various trades' peak resource loading should follow the historical average trend according to total installed cost and phase duration	Madl 2010
33	Trades' Rate of completion per week	Compliance of each trade's progress curve with historical (typical) average Data according to total installed cost and phase duration	Madl 2010
34	Peak to average labor ratio	Peak to average number of laborers for each trade should comply with the average historical data according to total installed cost and phase duration	Madl 2010
2.2.4 Special Considerations			
35	Permits & Environmental Remediation	Permits & environmental remediation should be included in the schedule (if applicable)	Nabros 1994, De La Garza 1988
36	Startup and Testing Activities	Start up and testing activities should be included in the schedule (if applicable)	Douglas 2009-b, Zack 1991
37	Submittal Activities	Material and/or methods requiring prior approval must have their submittal activities in the network	De la Garza 1988
38	Submittals Review Activities	Submittal reviews to be reflected in schedule as an activity	Fredlund and king 1992, Zack 1991, De La Garza 1988
39	Procurement Activities	Procurement activities should precede special installation tasks	De la Garza 1988

2.2.5 Activity Attributes			
40	Number of Constraints	Number of constraints on activities start and finish should be limited	GAO 2009, Spencer and Lewis 2006, Dzeng et al. 2005
41	Lag Duration	Should not be greater than the duration of Predecessor or Successor activity	Winter 2010
42	Relationship Ratio	Total number of relationships/Total number of activities, should be limited	O'brien and Plotnick 2010, Spencer and Lewis 2006
43	Activity without Affiliation	No open ended activity is allowed(activity without predecessor or successor)	Madl 2010, Li 2005, Winter 2010, Berg et al. 2009
44	Number of Activities	If number of activities has not been indicated in the contract, it has to be within a min/max range	O'brien and Plotnick 2010, De La Garza 1988
45	Activity Float	Activities with excessive Total Float should be avoided	Li 2005, Dzeng et al. 2005, Berg et al. 2009, De La Garza 1988
46	Negative Float	No activity with negative float is allowed	Madl 2010, GAO 2009, Berg et al. 2009, Winter 2008
47	Weather Sensitive Activities	Special measures should be taken for this type of activities (e.g., Adjusting productivity according to seasonal conditions)	Douglas 2007, Li 2005, Dzeng 2004, De La Garza 1988
48	Activity Duration (rules of thumb)	Activity duration should be limited to certain days	Berg et al. 2009, PMI 2007, De La Garza 1988

3.3 Criteria Structure and Weights

The best way to insure that the selected criteria are the appropriate ones was to rely on a broad range of professional expertise. In addition, the extracted provisions are not equally important considering their impacts on the goodness of schedules. Some provisions are more important in comparison to others, have higher weights, and should receive more attention in the course of schedule review process. Thus, it was necessary to ascertain the related level of importance of each criterion. This study adopts the methodology used for weighing PDRI elements (CII 1996, Cho 2000, Bingham 2010) to develop the weights of the extracted criteria. Therefore, a survey was carried out to collect experienced experts' feedback and define the weight of each criterion.

3.3.1 The survey

The proposed survey was in the form of an online questionnaire survey in the English language. Professionals were required to indicate 1) if each of the extracted criteria is important or not, 2) the related level of importance of each criterion, and finally 3) the recommended threshold value for quantitative provisions. Other methods of data acquisition, such as interviews or workshops, were less practical for this survey as it was difficult to gather all responders together. Furthermore, interviews are not as flexible as online surveys are; they have to be conducted at a particular time while an online survey allowed the participants to respond whenever they wanted. Thus, considering the number of questions and the time required, an online questionnaire was ideal for this survey.

In order to create a common understanding among the participants, a brief introduction was provided at the beginning of the survey, explaining the objectives of the questionnaire survey and giving short instructions for answering the questions. Also, an e-mail address was provided to make possible further inquiries and clarifications if necessary. The survey was also an opportunity to expose the extracted provisions to professionals and receive their feedback. Thus, different sections were devised in the survey for experts' comments.

The questionnaire started with some general questions about the relevant working experience of the participants and the fields of expertise in which they have gained professional experience. Afterwards, in the main part of the questionnaire, a scale of one to ten was provided for each provision. "One" represented "not important at all" and "ten" stood for an "extremely important" provision. Participants were required to indicate the related level of importance of each provision for schedule goodness. In addition, considering the quantitative criteria, a set of questions were included in the survey requiring participants to specify appropriate threshold values. Although some recommended values were provided for these thresholds, based on a set of published materials, the participants had the opportunity to indicate any threshold value. A copy of the survey is provided in Appendix A.2 of this thesis.

The survey was posted on the web for five months, and numerous invitations were sent to professionals including project managers, planners, schedulers and project control engineers mainly in North America. The survey was lengthy, and could take up to one hour to complete, resulting in a response rate of 49%. A total number of twenty eight individuals participated in the online survey. Considering the number of questions and the time required to answer, the response rate was acceptable. The participants' experience ranged from four to twenty eight years of experience with an average of more than fourteen years (see Figure 3.3).

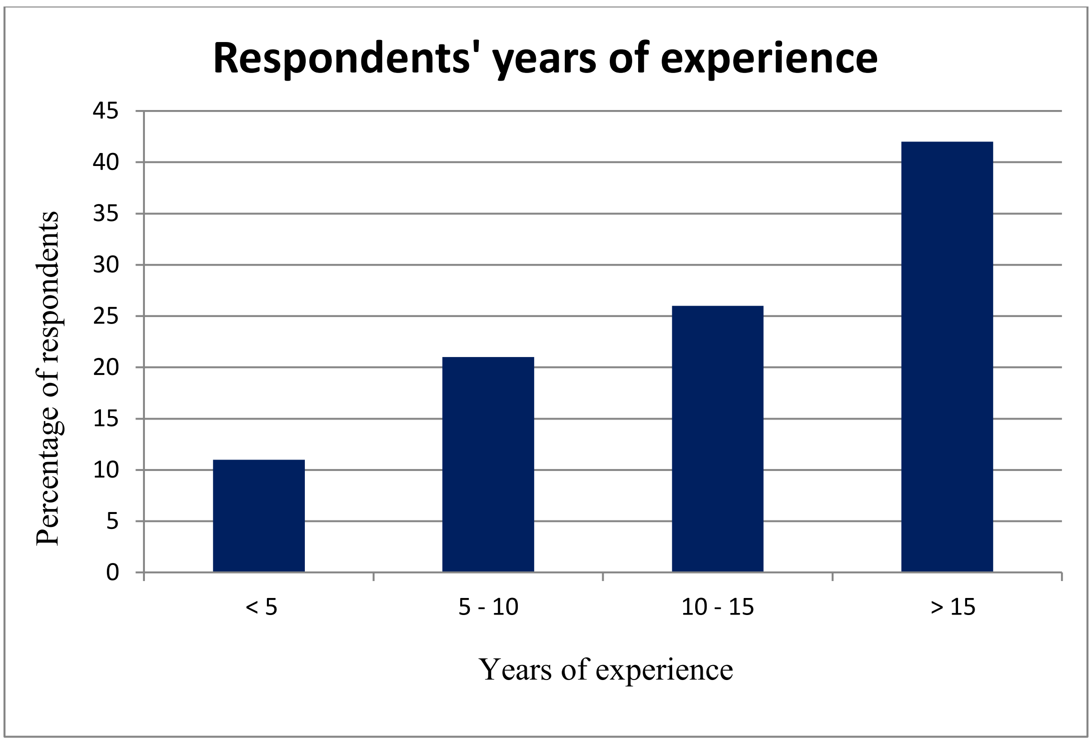


Figure 3.3: Participants' years of experience

Prior to analyzing the collected data, three of the responses were discarded. Two of these were incomplete with more than 30% of questions left unanswered. The third one was not reliable as the same importance level was indicated for all of the provisions. The remaining twenty five responses were analyzed. The survey revealed that professionals are in clear agreement as regards to the importance of the extracted criteria. It is interesting to indicate that for 27 provisions (56% of the provisions), respondents unanimously agreed that they are important, and schedules are recommended to be in line with those criteria. For the next ten provisions, the agreement rate was more than 95%, meaning that 95% of responders indicated that those provisions are important, and schedules should be in conformance with them. The lowest agreement rate was 85% for five provisions. Figure 3.4 indicates the level of agreement among the survey participants.

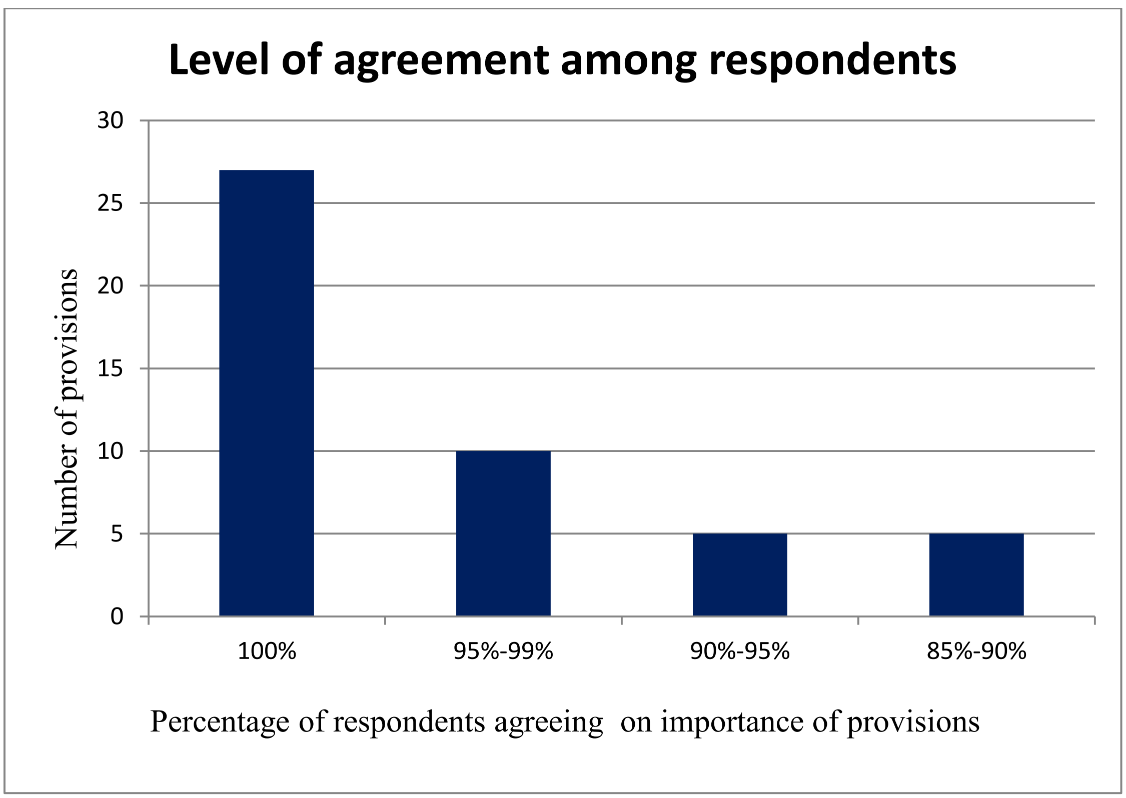


Figure 3.4: Level of agreement among survey participants

The results of this survey revealed that the extracted criteria are important and that detailed schedules should be in line with these criteria. In other words, the ability of satisfying the developed criteria could be considered as an indicator of a good schedule.

3.3.2 Relative weights

In order to define the related weight of the selected provisions, each response was coded and entered into a Microsoft Excel 2007 worksheet for further analysis. Only complementary criteria were weighed, since if a schedule is not in conformance with obligatory provisions, there is no need for it to be evaluated and ranked by complementary ones. It was intended to rely on a broad range of experienced professionals to ascertain the related level of importance of each provision. Thus, considering the obtained responses, the mean value for each provision's level of importance was calculated by the application of the SPSS software system. Nonetheless, one more participant was removed from the database, as the related responses were unreliable. A question was repeated in the survey to assess the consistency of each participant's responses. It was intended to eliminate the participants whose answers had significantly changed for the repeated question, and significantly different was defined as more than four units of difference on the importance scale.

Conducting descriptive statistical analysis, calculating the mean, variance and standard deviation for each provision, showed that a few responses were far from the others.

Therefore, it was decided to conduct data screening by the application of Boxplot to find extreme and outlier responses, which frequently cause high variances. The Boxplot is a statistical tool that visualizes the data distribution with recommended formulas to distinguish outliers and extreme values objectively. The Boxplot graphically shows the median, minimum, maximum, first quartile and third quartile. Figure 3.5 shows a typical Boxplot sketch. Based on Tukey's hinges, which were used in the analysis, the extremes and outliers are defined as bellow (PASW Statistics 2009):

"The length of the box is the interquartile range (IQR) computed from Tukey's hinges. Values more than three IQR's from the end of a box are labeled as extreme and values more than 1.5 IQR's but less than 3 IQR's from the end of the box are labeled as outliers."

$IQR = Q_3 - Q_1$

Where Q_1 is the lower box end (25th percentile) and Q_3 is the higher box end (75th percentile)

X_i is outlier if

$Q_3 + 1.5\ IQR \leq X_i < Q_3 + 3\ IQR$ or $Q_1 - 3\ IQR < X_i \leq Q_1 - 1.5IQR$

X_i is extreme if

$X_i \geq Q_3 + 3\ IQR$ or $Xi \leq Q_1 - 3\ IQR$

SPSS version 18 was used for data analysis and to create Boxplots. In order to screen the collected data and ascertain the responders who are far from others more frequently, Boxplots were created for each provision. At this stage, three different scenarios were applicable for the unusual observations in the acquired data: 1) Discard the data sets (respondents) that more frequently have data points as extremes or outliers, 2) Eliminate only the data points, which are among the extremes or outliers on given provisions and keep the rest of the related datasets, and 3) Consider the extreme and outlier data points as valid data and proceed with all the responses (Bingham 2010). It was decided to opt for the first scenario and discard the datasets, which are far from others. Figure 3.6 demonstrates the Boxplots for a set of provisions.

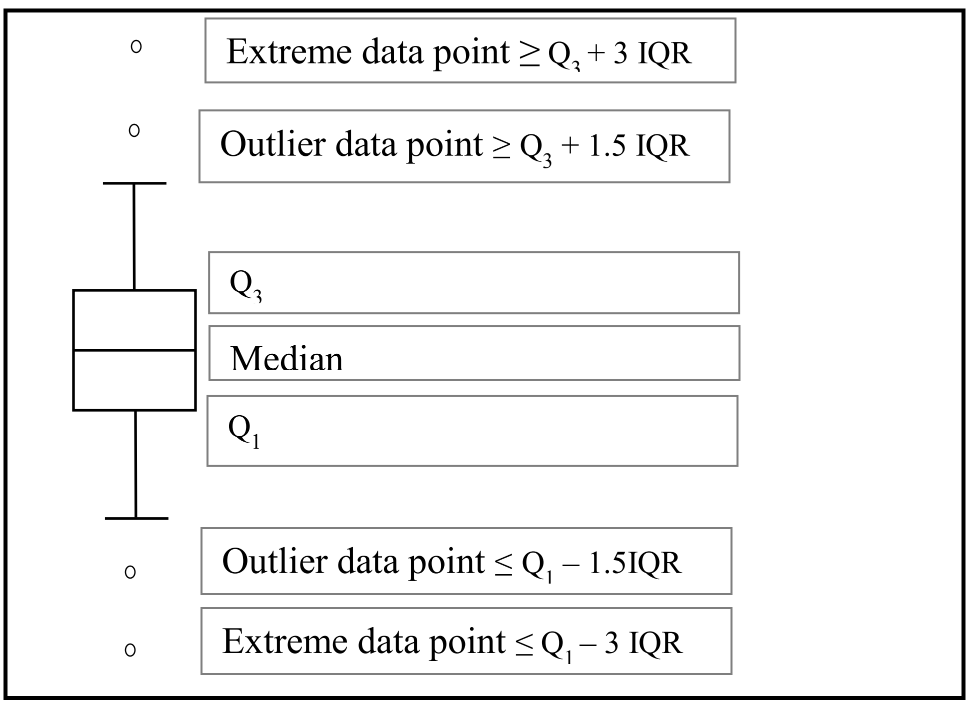


Figure 3.5: Typical Boxplot sketch

Further analysis of the results made clear that some datasets were more frequently associated to extremes and outliers. For instance, the data set number 10 was the only response that was far from other professionals' opinion and caused all the extreme data points. Thus, that dataset was discarded from the database developed for calculating the final weight of the defined provisions. In addition to the indicated extreme values, a set of outliers were identified and it was decided to remove datasets which caused outliers in more than five provisions. Therefore, two more datasets were removed from the database and the analysis proceeded with twenty one responses.

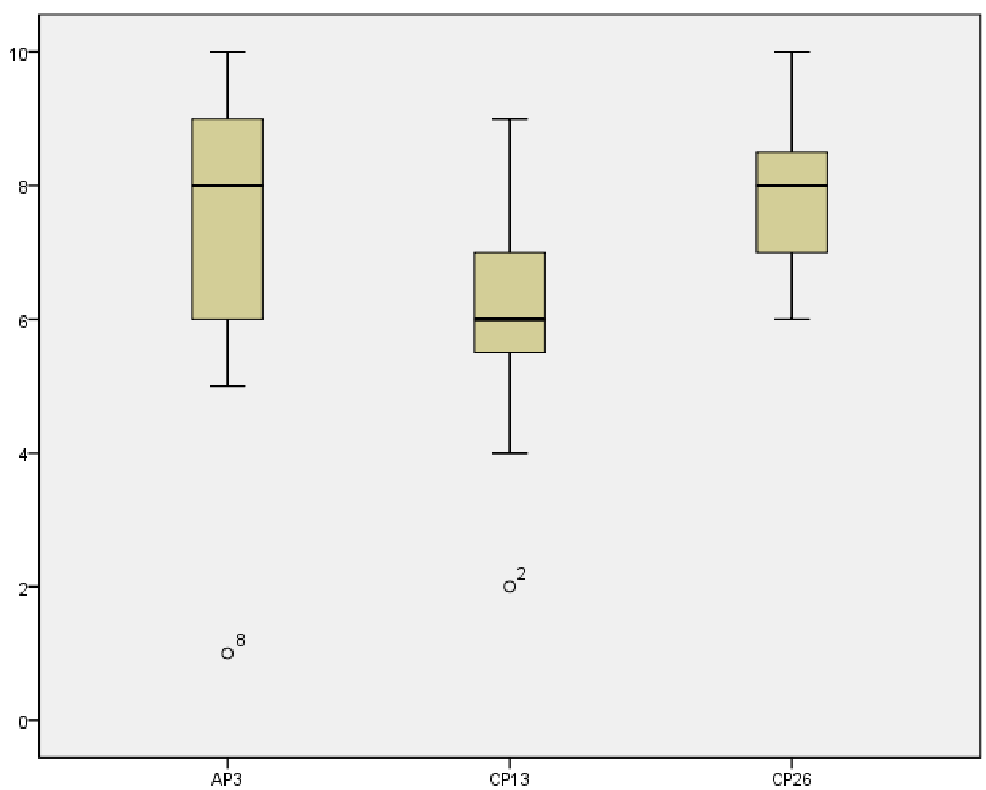


Figure 3.6: Identifying outliers from data sets

After the first round of data analysis, another round of data screening was conducted on the remaining datasets. The second round of data screening revealed that there still existed some outliers, which caused variances in mean scores. Nonetheless, no more responses were removed from the database since removing more datasets would not affect the accuracy of the developed method significantly.

After the completion of data screening, the mean weight for each provision was calculated. In order to obtain the mean value, all weights were added, and the results were divided by the number of responses. It was decided to normalize the calculated scores to a 1000-point scale to remove the decimal places and to make the target score of perfect schedules a whole number. In order to normalize the weights, 1000 was divided by the total sum of the weights, which was 305.71. The result was the normalizing multiplier: 3.27 in this case. Next, the mean weight of each provision was multiplied by the normalizing multiplier. The results of the calculations were rounded to the nearest whole number. Table 3.3 shows the weights before and after normalizing.

Thus, in this method, a schedule thoroughly in conformance with the defined provisions will be assigned a Schedule Development Index (SDI) of 1000, and in the contrary, a SDI of zero would be assigned to a schedule that cannot satisfy any of the complementary provisions. In order to conduct the assessment, the user should examine the schedule and find out if each provision is satisfied or not. Next, she/he should sum up the weights of the satisfied provisions. The result is the SDI representing the schedule goodness.

Table 3.4: Provisions' weights before and after normalizing

Provision	Initial Weight	Normalized Weight	Provision	Initial Weight	Normalized Weight
P 9	8.35	27	P 29	7.76	25
P10	8.48	28	P 30	7.7	25
P 11	9.10	30	P 31	7	23
P 12	8.25	27	P 32	6.6	22
P 13	8.70	28	P 33	6.4	21
P 14	6.33	21	P 34	6.1	20
P 15	9.00	29	P 35	8.25	27
P 16	7.05	23	P 36	8.55	28
P 17	6.52	21	P 37	8.65	28
P 18	6.60	22	P 38	8.25	27
P 19	8.33	27	P 39	8.8	29
P 20	8.67	28	P 40	7.57	25
P 21	6.65	22	P 41	6.1	20
P 22	8.48	28	P 42	5.28	17
P 23.1	7.43	24	P 43	7.81	26
P 23.2	6.95	23	P 44	6.06	20
P 24	6.2	20	P 45	6.76	22
P 25	6.42	21	P 46	8.24	28
P 26	6.47	21	P 47	8.16	27
P 27	7.65	25	P 48	6.56	21
P 28	7.48	24	**Total**	**305.71**	**1000**

The weights were recalculated for each criterion based on the lower and upper bounds of the mean values, taking to account the 95% confidence intervals as well. These weights were also used while assessing the case examples explained in chapter five.

Once the weights were calculated and the score sheet was finalized, the provisions were sorted in order of importance. The most important provision was "P11. Scheduling Process" which recommends that different participants (owner, engineers and contractors) be involved in the schedule development process. The next two important criteria were provisions 15 and 39. A list of the ten most important criteria is provided in Table 3.4.

Table 3.5: Ten most important provisions

No.	Provision
1	P11. Scheduling Process
2	P15. Minimum Milestones
3	P39. Procurement Activities
4	P10. WBS Verification
5	P13. Verification of Subcontractors' Scope of Work
6	P20. Working Hours Schedule-Estimate Compliance
7	P22. Critical Path
8	P36. Startup and Testing Activities
9	P37. Submittal Activities
10	P46. Negative Float

In addition to the questions of the importance of each criterion, a set of questions were encompassed into the questionnaire seeking the possibility of defining specific thresholds to the quantitative criteria. These included, but were not limited to, the number of constraints, schedule criticality rate, project cost and effort ratio, maximum acceptable total float, and maximum or minimum number of activities. The results of the survey revealed that the recommended values for quantitative criteria are not casted in stone. Experts indicated different values for each provision; therefore, no unique value could be suggested as a fixed threshold. For instance, a criterion required professionals to indicate the acceptable value for near criticality rate, the number of near critical activities divided by the total number of activities. While 25% of participants chose 0.1 as the recommended threshed for a healthy schedule, 19% of responders opted for 0.15, and 50% of experts indicated that no unique threshold value could be defined to suit all schedules.

A similar situation was observed for other criteria. The only exception was the provision concerning the maximum accepted number of activities with constrained dates for which 58% of participants chose 5% as the recommended threshold. Considering the number of participants and the acquired data, this study does not recommend any specific threshold value for quantitative criteria. Instead, various firms are encouraged to develop their own database of projects in order to define the appropriate thresholds to suit their specific needs (Moosavi and Moselhi 2012). Nonetheless, for a set of threshold values provided as initial suggested values, see Table 3.4.

Table 3.6: Recommended threshold values for quantitative criteria

Element	Explanation	Reference
Phases Overlaps	Engineering should not to overlap construction by more than 30%	Madl 2010
Congestion Index (labor density)	Maximum number of workers per square meter should be limited to 200 sqf/person	Bent 1996, Kerridge and Vervakin 1986
Schedule Criticality rate	Number of critical activities/ Total number of activities should be limited to 0.25	O'brien and Plotnick 2010
Critical Activity Duration	Critical activities, to be well manageable, should have a duration limited to one pay period	De la Garza 1988
Relationship Ratio	Total number of relationships/Total number of activities, should be limited to 1.6 per activity	O'brien and Plotnick 2010
Number of Activities	If the number of activities has not been indicated in the contract, it should be within a min/max range (at least one activity for each 10,000 $, O'brien and Plotnick) (40 to 250, De la Garza)	O'brien and Plotnick 2010, De La Garza 1988
Activity Float	Activities with total float bigger than 100 days (44 days GAO 2009, Berg et al. 2009) should be avoided	De La Garza 1988, Berg et al. 2009, GAO 2009
Activity Duration	Activity duration should be within a min/max range (not more than two times the update cycle, ideally never more than 3 times the update cycle, PMI)(44days Berg et al.) (5to 25 days, De La Garza)	PMI 2007, Berg et al. 2009, De La Garza 1988
Near criticality rate	Number of near critical activities/total number of activities should be limited to 0.1	Online Survey
Project Effort Ratio	Project critical path effort(number of laborers)/ total project effort should be within a min/max range (0.05 to 0.35)	Online Survey
Project Cost Ratio	Project critical path cost/ total project cost should be within a min/max range (0.1 to 0.3)	Online Survey
Number of Constraints	Number of constrains on activities start or finish should be limited to 5% of total activities	Online Survey

3.4 Ranking Categories

Considering the obligatory criteria, there are merely two possible scenarios. Schedules should be marked as “rejected” if they are unable to satisfy any of the obligatory criteria, and there is no need for further analysis. Nonetheless, if schedules are in conformance with the obligatory criteria, they satisfy the minimum requirements and could be subject of complementary review for a more detailed assessment and evaluation.

Three different levels of schedule goodness are defined for complementary assessment, according to the acquired final score. Schedules that obtain a score of 800 (out of 1000) or higher are marked as “Excellent”. “Good” represents schedules that are assigned a final score equal or higher than 500. Any schedule with a score below 500 is marked as “Acceptable” (see Table 3.5).

Table 3.7: Ranking categories

Level of Goodness	**Total Score (1000 scale)**
Excellent	Total Score ≥ 800
Good	800 > Total Score ≥ 500
Acceptable	Total Score < 500

3.5 Job Logic Assessment

As indicated in previous parts, schedules must be developed based on reasonable job logic. This issue is among the obligatory criteria in the developed method. Considering the importance of job logic assessment, an empirical method was devised in order to assist owners in the course of job logic review.

The devised method is based on the application of historical data acquired from similar successful projects. Successful projects are defined as projects that are completed on time or almost on time. Schedules of three educational buildings were examined closely in order to extract the relationship between major trades, in addition to the relationship between each trade and the project start date. In other words, the lag before the start date of each major trade was extracted as a percentage of the project and the predecessor trade's duration. Eight major trades were selected for this purpose: 1) Foundation, 2) Framing, 3) Curtain wall, 4) HVAC (plumbing, ventilation and control), 5) Fire fighting, 6) Elevator and escalator, 7) Electrical, and finally 8) Architectural finishing.

The three case examples were educational buildings recently constructed for Concordia University in Montreal, Canada. These included two high-rises and a five-story building. The high-rises were 17-story and 15-story towers with a net area of 68,000 m^2 and 33,000 m^2, project A and B respectively (Concordia University 2012). The other building has a net area of more than 6000 m^2 (project C). The three cases are reinforced concrete construction that benefit from similar technical specifications with only a few exceptions. Project B has a set of solar panels included in its curtain wall, which made the construction process more complicated. Moreover, that project has more complex framing structure since tension ducts are utilized as part of the framing system. Thus, it was expected to see some differences between the duration of those trades in this project in comparison to the other projects.

After extracting the required data, it was observed that there exist correlations between the three cases. A set of analysis was applied on the extracted data, as shown in Table 3.6. It is necessary to note that the finish times are not the sum of the start times and durations since there were gaps during the trades' execution. As expected, there were differences between project B and the other projects regarding the duration of the framing and curtain wall trade.

The duration of the framing trade in project B was a larger percentage in comparison to the other projects. This is justifiable as the framing in that case included the application of post tension ducts which made the process more complex. Another difference was observed in the curtain wall trade. This trade started sooner in project B while the related duration of that trade was longer as well. It was observed that in other projects, the curtain wall trade started when the framing was almost finished although in this case the contractor started the installation of the curtain wall when framing was at almost 50%. This difference is reasonable when we look at the particular specifications of this project's curtain wall, which included the installation of solar panels. The application of these types of panels made the process more complicated, and relatively longer in duration, so it is logical if the contractor scheduled the installation of the curtain wall sooner to catch up on the lost time.

Another difference was observed between the start times of HVAC trades. In project C, the HVAC trade started later in comparison to the other cases. This matter resulted in a similar difference between the start times of the fire fighting trade, since the fire fighting trade usually starts after the HVAC trade with a short lag in between. Careful scrutiny revealed that application of a constraint on the predecessor activity of HVAC trade in project C, postponed the start of HVAC activities. It was speculated that this constraint had been used to suit an idiosyncratic need; therefore, this difference was considered justifiable. In addition, a significant difference was between the duration of fire fighting trade in project B and other projects. This difference originated from definition of separate activities for the test of the fire fighting system of each floor in project B. However, such activities were not defined in other projects.

The last major difference was regarding the start time of electrical trade in project C. In this project electrical trade started sooner in comparison to other cases. There was a large gap between one specific activity, “Massive external electrical works”, which started first, and the rest of the electrical activities in that project. Therefore, the difference was justifiable. There was only one substantial difference without any specific reason identified. That was the significant difference between the duration of elevator and escalator trade in project B and the other projects.

Table 3.8: Analysis of schedules

No.	Trade	Activity	A	B	C	Average	Predecessor	Lag (average)	Delta (Lag range)
	Construction Duration		670	479	260				
1	Foundation	Start	79	59	48		Excavation	FS - 14%	-27%
			12%	12%	18%	14%			
		Duration	20	13	5				
			3%	3%	2%	3%			
		Finish	15%	15%	20%	17%			-15%
2	Framing	Start	97	66	52		Foundation	FS- 33%	-33%
			14%	14%	20%	16%			
		Duration	220	213	83				
			33%	44%	32%	36%			
		Finish	47%	58%	52%	52%			0%
3	Curtain wall	Start	317	181	131		Framing	FS - 19%	-45%
			47%	38%	50%	45%			-6%
		Duration	170	198	70				
			25%	41%	27%	31%	HVAC	SS + 14%	8%
		Finish	73%	79%	77%	76%			22%
4	HVAC (plumbing, ventilation & control)	Start	212	160	114		Framing	SS + 55%	43%
			32%	33%	44%	36%			69%
		Duration	455	312	142				
			68%	65%	55%	63%	Electrical	SS	-4%
		Finish	100%	99%	98%	99%			3%
5	Fire fighting	Start	251	166	141		HVAC	SS + 10%	3%
			37%	35%	54%	42%			18%
		Duration	170	177	68				
			25%	37%	26%	29%	Framing	FS - 28%	-52%
		Finish	89%	93%	86%	89%			6%

6	Elevator & Escalator	Start	359	257	137		Framing	FS + 3%	-9%
			54%	54%	53%	53%			
		Duration	130	200	64				
			19%	42%	25%	29%			21%
		Finish	92%	98%	79%	90%			
7	Electrical	Start	198	169	55		Framing	SS + 55%	47%
			30%	35%	21%	29%			
		Duration	317	307	150				72%
			47%	64%	57%	56%	HVAC	SS	-3%
		Finish	92%	99%	100%	97%			3%
8	Architectural Finishing	Start	373	245	148		Curtain wall	SS + 32%	26%
			56%	51%	57%	55%			36%
		Duration	260	234	96		HVAC	SS + 30%	24%
			39%	49%	37%	42%			35%
		Finish	94%	100%	94%	96%	Electrical	SS + 34%	24-55%

Finally, two general conclusions were speculated:

1) There is a tendency among project teams to start the longer than usual trades sooner in order to catch up on lost time.

2) There exist significant amount of float between trades that allow project teams to suit the idiosyncrasies of their specific needs in each project.

Based on the results of the analysis, a schedule that could be used for empirical analysis of the educational buildings' job logic was developed. Figure 3.7 demonstrates the generated schedule. Users could compare their specific schedules with this schedule. If there is any significant discrepancy (more than 30%) in duration and/or start dates of the major trades, then further investigation is recommended.

	Task Name	Duration	Start
1	**Typica Schedule for Construction of Building for Educational Institutions**		
2	Start of the Project		
3	Foundation	3%	14%
4	Framing	36%	16%
5	Electrical Works	56%	29%
6	HVAC	63%	36%
7	Fire Fithing	29%	42%
8	Curtain Wall	31%	45%
9	Elevator & Escalator	29%	53%
10	Architectural Finishing	42%	55%
11	End of the project		

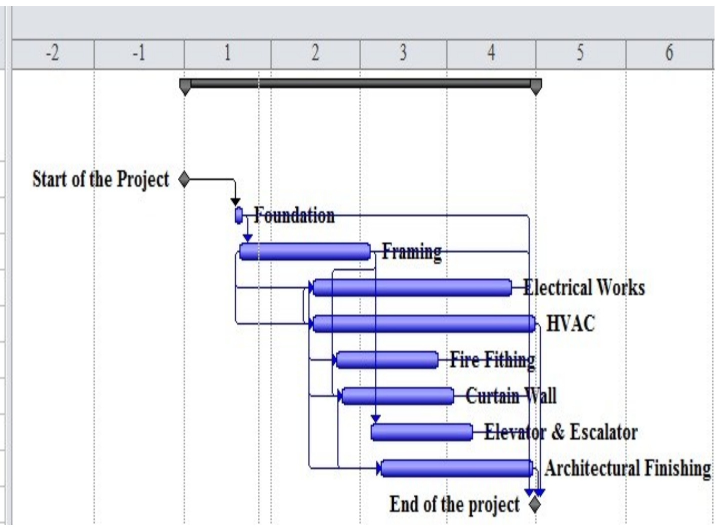


Figure 3.7: Typical schedule for construction of buildings for educational institutions

The results of the above analysis and the set of defined rules were presented to the Director in-charge of the three buildings projects considered in this study to elicit his feedback on the developed method and its results through a structured interview. A copy of the questions of the interview is presented in Appendix A.3. There was a general agreement for the most part with the results generated by the developed method, with few exceptions. In the meeting with the Director feedback was obtained on the percentage of overlap between foundation and framing trade; between framing and curtain wall trade; and between framing and HVAC trade, arguing that the successor trade could start sooner (larger overlaps). Minor modifications were made to the thresholds according to the feedback received. The result is a set of rules for empirical assessment of schedules of educational building construction (Table 3.9). It is necessary to indicate that this type of assessment is not supposed to replace the detailed review of job logic at this stage. The application of this method alongside the current method of job logic assessment is recommended in order to quickly gain an overview of the job logic of a schedule.

Table 3.9: Empirical rules of job logic assessment

No.	Rules
1	Duration of foundation activities is approximately 5% of framing activities duration
2	Typically once more than 30% of foundation is performed, framing activities can start
3	Duration of framing activities is approximately 35% of project duration
4	Typically once framing of three floors is performed, curtain wall activities could start
5	Duration of curtain wall activities is approximately 30% of project duration
6	Typically once 30% of curtain wall is performed, architectural activities start
7	Duration of architectural activities is approximately 40% of project duration
8	Typically HVAC and electrical activities could start at the same time, once 30% of framing is performed
9	Duration of electrical activities is approximately 60% of project duration
10	Duration of HVAC activities is approximately 65% of project duration
11	Once 10% of HVAC is performed, firefighting activities start
12	Duration of firefighting activities is approximately 30% of project duration
13	Typically once framing is done, elevator & escalator activities start
14	Duration of elevator & escalator activities is approximately 30% of project duration

3.6 Limitations

The presented method, in its current formulation, is not applicable to schedules developed based on other methods of scheduling, such as LOB. Nonetheless, a set of the defined provisions could be used for the review of those schedules. Furthermore, the empirical method of job logic review is only applicable to schedules of educational buildings. Moreover, the method of job logic review is developed based on analysis of three cases, all constructed for one client. In addition, the coded software (SAE), presented in chapter four, is coded to evaluate schedules generated by the application of MSP. Above that, the SAE evaluates the job logic, productivities, and crew sizes considered for selected trades in schedules developed with a certain level of detail.

CHAPTER FOUR: COMPUTER IMPLEMENTATION (SAE)

4.1 General

The developed method was automated in computer application in order to assist owners in review of schedules and facilitate its application and decrease the review time. Automation is extremely helpful while considering complexity and the number of activities associated with current schedules, particularly schedules of mega projects which encompass hundreds if not thousands of activities since manual assessment of those schedules is burdensome if not impractical. This chapter presents the developed software, Schedule Assessment and Evaluation (SAE), its components and interrelationships between them in detail.

The SAE is a Windows based software system coded in Visual Basic (VB) environment and could be run on different versions of the Windows operating system including XP and Seven. It was decided to code the proposed software in VB environment according to a set of consideration as regards the availability of the tool, the ability of the system to integrate and interact with on the shelf software systems and easy application of the final product as VB has the ability of providing user-friendly graphical user interfaces (GUI) in order to facilitate input and retrieval of the data. The coded software performs schedule review in three different tiers with the minimum input required from users. The three tiers of schedule assessment and evaluation are: 1) assessment of the schedules against industry recommended practices using rules of thumb and benchmarks, 2) job logic assessment and finally 3) assessment of activities duration based on relative productivities and crew sizes.

The coded software evaluates schedules developed based on application of Microsoft Project (MSP) and highlights problematic activities on the related schedules. Also the SAE provides comprehensive reports after each tier of schedule review reflecting the deficiencies identified. An advising module has been incorporated into this software in order to provide users with the common causes of the detected deficiencies and a set of recommendations as regards corrective actions. Figure 4.1 demonstrates the input and output of the SAE.

The SAE is flexible and could be used in default mode or in user-input mode. In the default mode, the SAE reviews schedules based on default thresholds. Thresholds are mainly a set of limitations introduced for a selection of quantitative schedule components. These include, but are not limited to, schedule criticality and near criticality rate, schedule cost and effort ratio, activities duration, total float, and so forth. Nonetheless, in the user-input mode the software lets the user to define the desired values for the above thresholds. Nonprofessional schedulers or even users with limited knowledge of schedule review are able to assess schedules by application of the SAE as minimum amount of input is required and the designed interfaces are user-friendly.

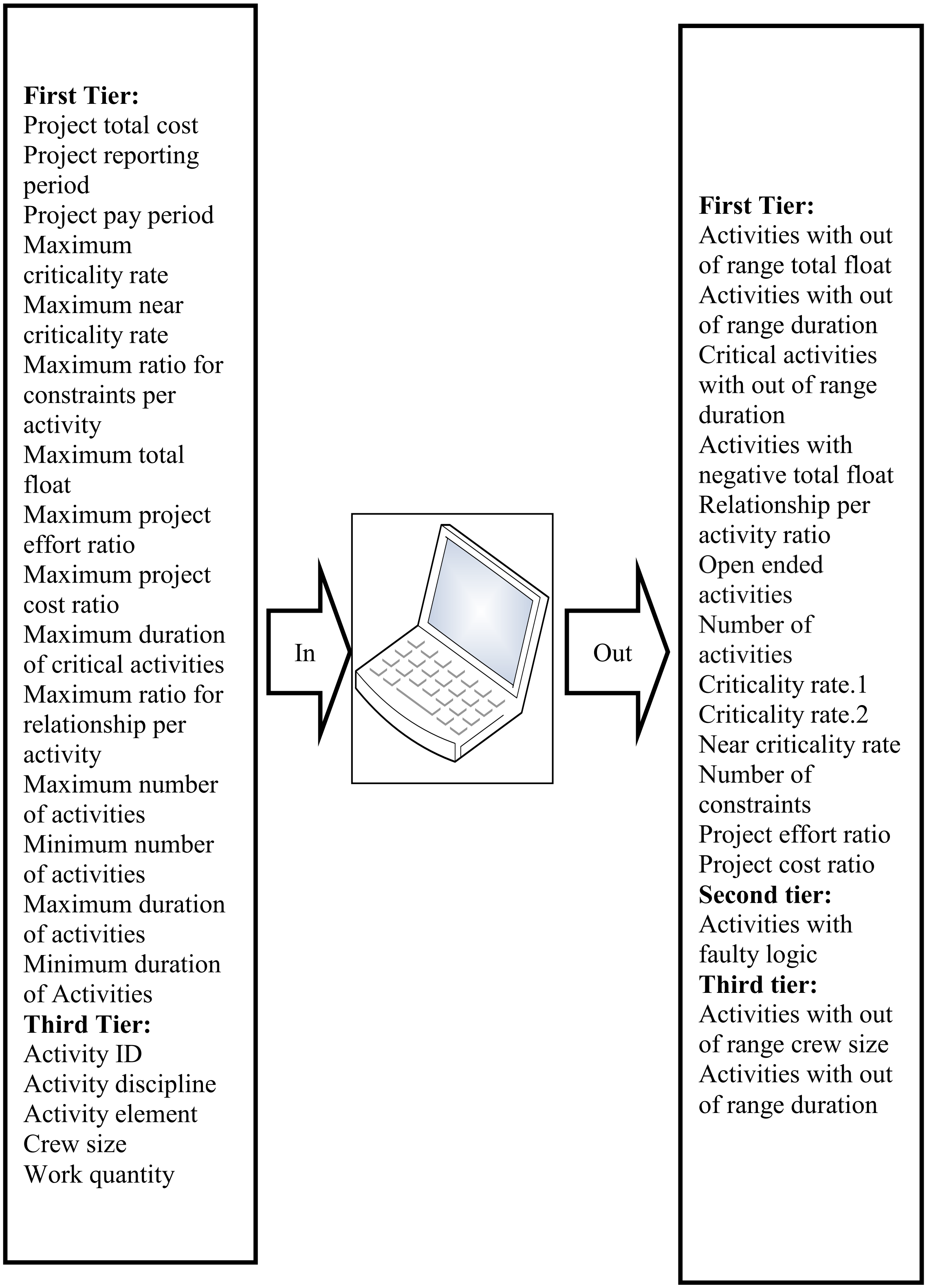


Figure 4.1: Major input and output of the SAE

4.2 System Components

The SAE consists of three main components; an interface, an assessment engine and finally a database. Figure4.2 displays the system architecture and the interrelationships among the different components. The interface is coded by application of visual Basic (VB) in Visual Studio 2008 environment, and incorporates menus, toolbars and dialog windows. The assessment engine is a module coded as a macro in MSP 2007 by implementation of Visual Basic for Application (VBA 6.5) for MSP. The coded macro is the component that conducts the assessment and evaluation on schedules.

The last part of the SAE is a database developed in order to store and retrieve required data regarding productivities and crew sizes associated with a set of construction activities. The database was developed in Microsoft Office Access 2007 environment. Each component of the coded software system is described next.

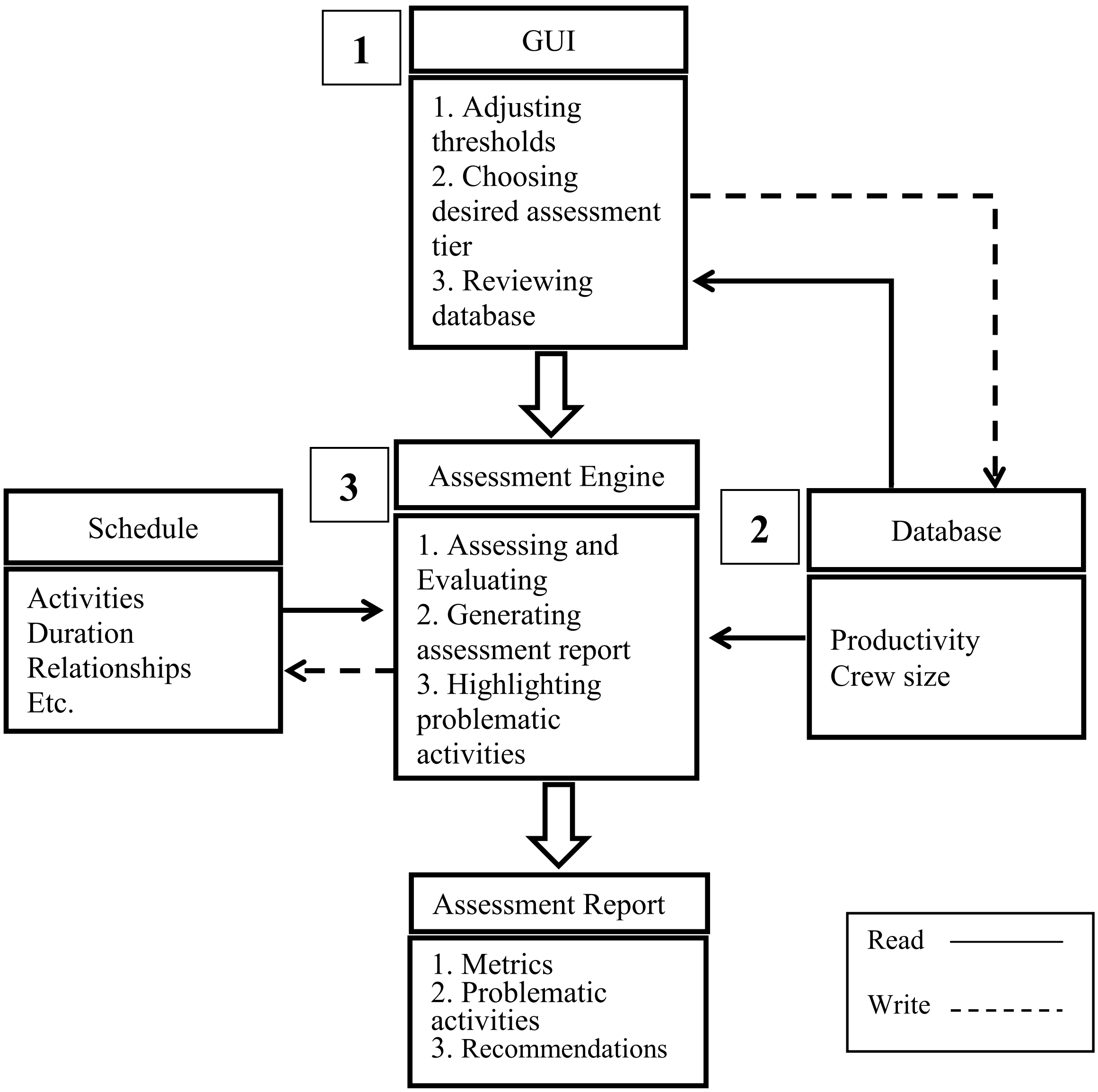


Figure 4.2: Flow of data and system architecture of SAE

4.2.1 GUI

A set of graphical user interfaces were designed to facilitate user interaction with the software by application of VB 2008. The main screen of the SAE has a menu on top and some shortcuts in order to ease access to some specific functions of the software (see Figure 4.3). The menu bar includes five functions, two of which (File and Help) perform typical Windows functions similar to other software.

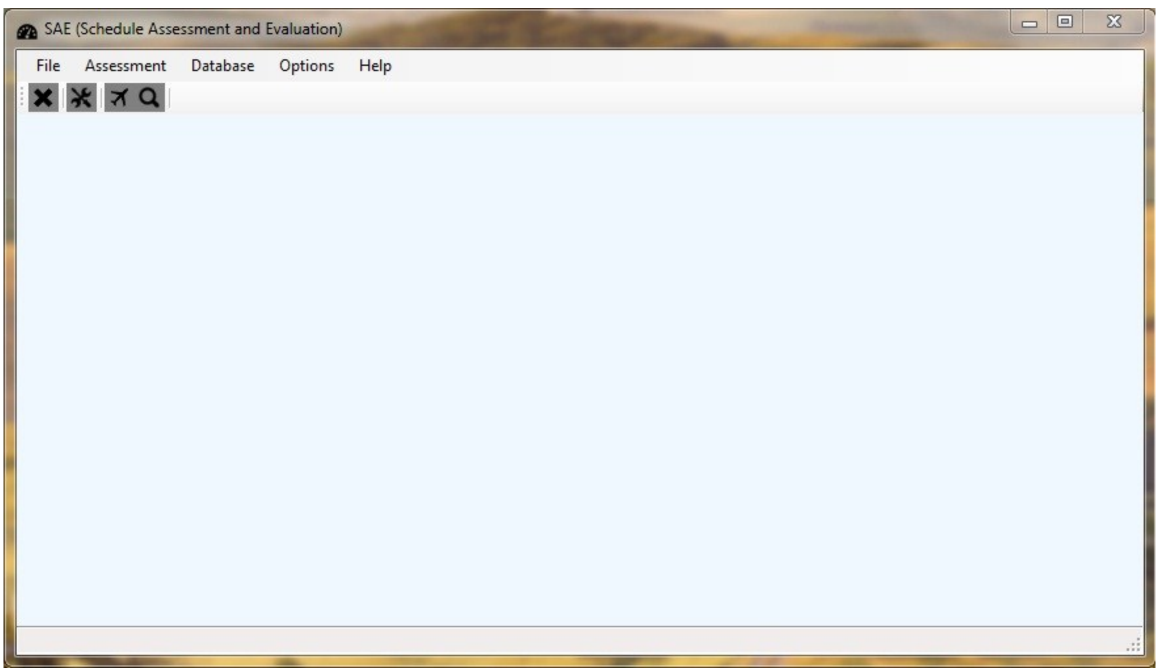


Figure 4.3: Main screen of SAE

The assessment menu contains five items representing different types of assessment (Figure 4.4). These include, 1) First Tier: assessment of schedules against recommended practices and benchmarks; Indeed, assessment of schedules against the quantitative provisions, 2) Second Tier: job logic assessment for selected construction trades, 3) Third

Tier: assessment of activities duration based on relative productivities and crew sizes considered for a number of commonly used trades in building construction, 4) Thorough Assessment, in essence the three levels of assessment together, and finally 5) Fast Assessment: the first tier of assessment but based on default thresholds (default mode).

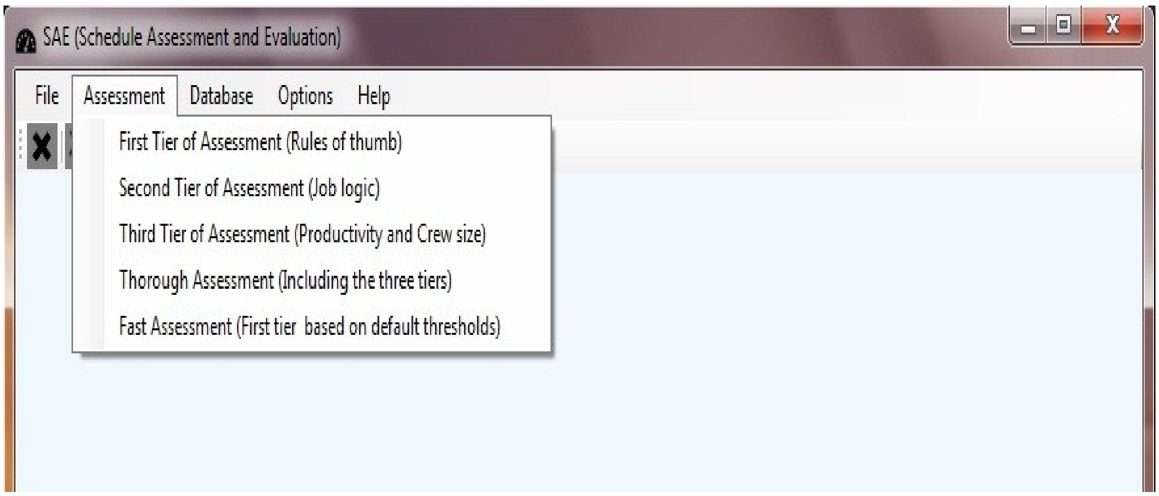


Figure 4.4: Assessment menu of SAE

The "Options" menu provides access to two options windows for first and third tier of assessment, which need input from users. The developed options windows are indeed dialog boxes designed to facilitate data entry (see Figure 4.5 and Figure 4.6).

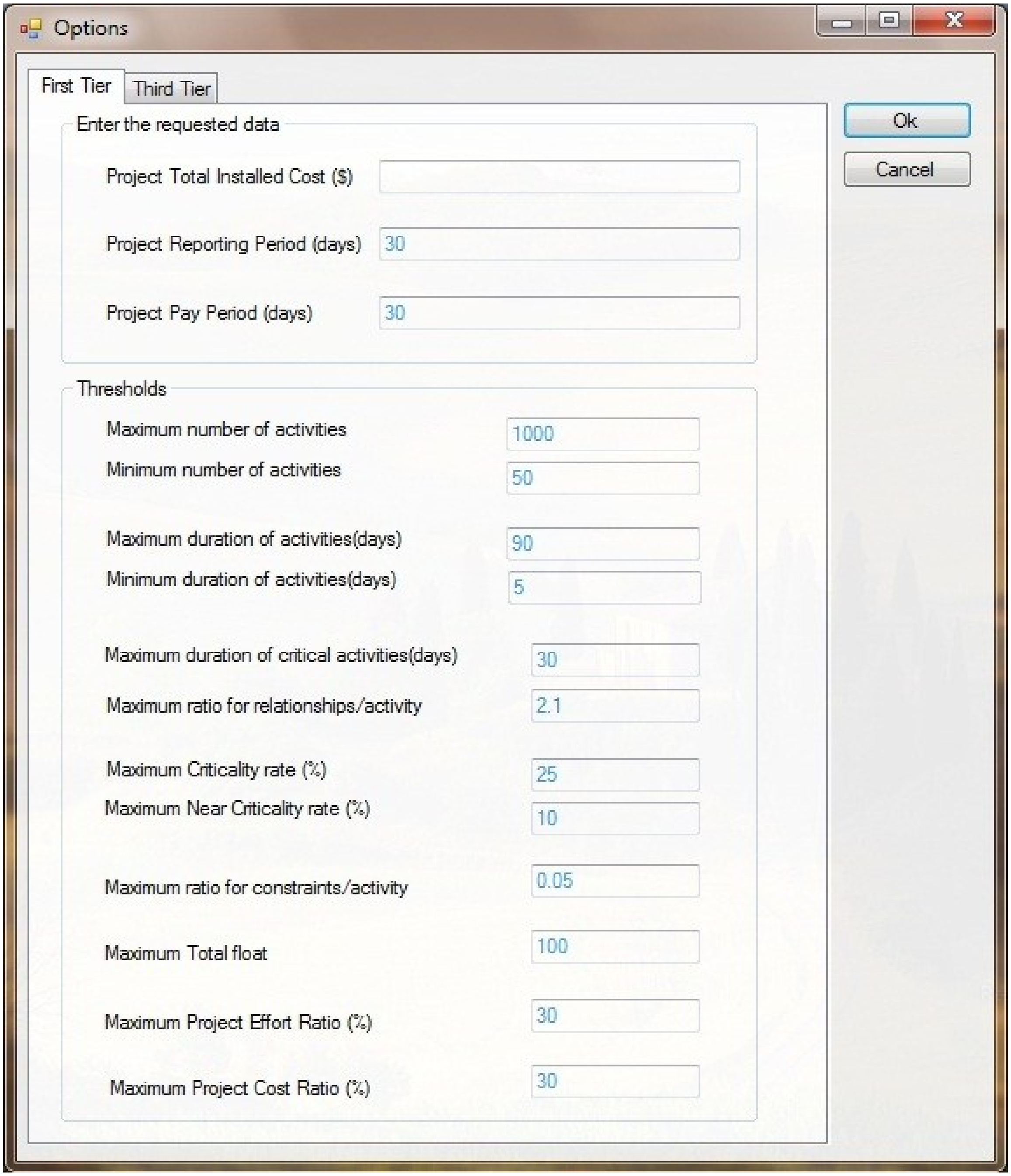


Figure 4.5: First tier options

The last menu item is “Database” menu that provides access to the developed database through a database window. This menu lets the user to review and modify the stored data in the database. Figure 4.7 demonstrates the related window.

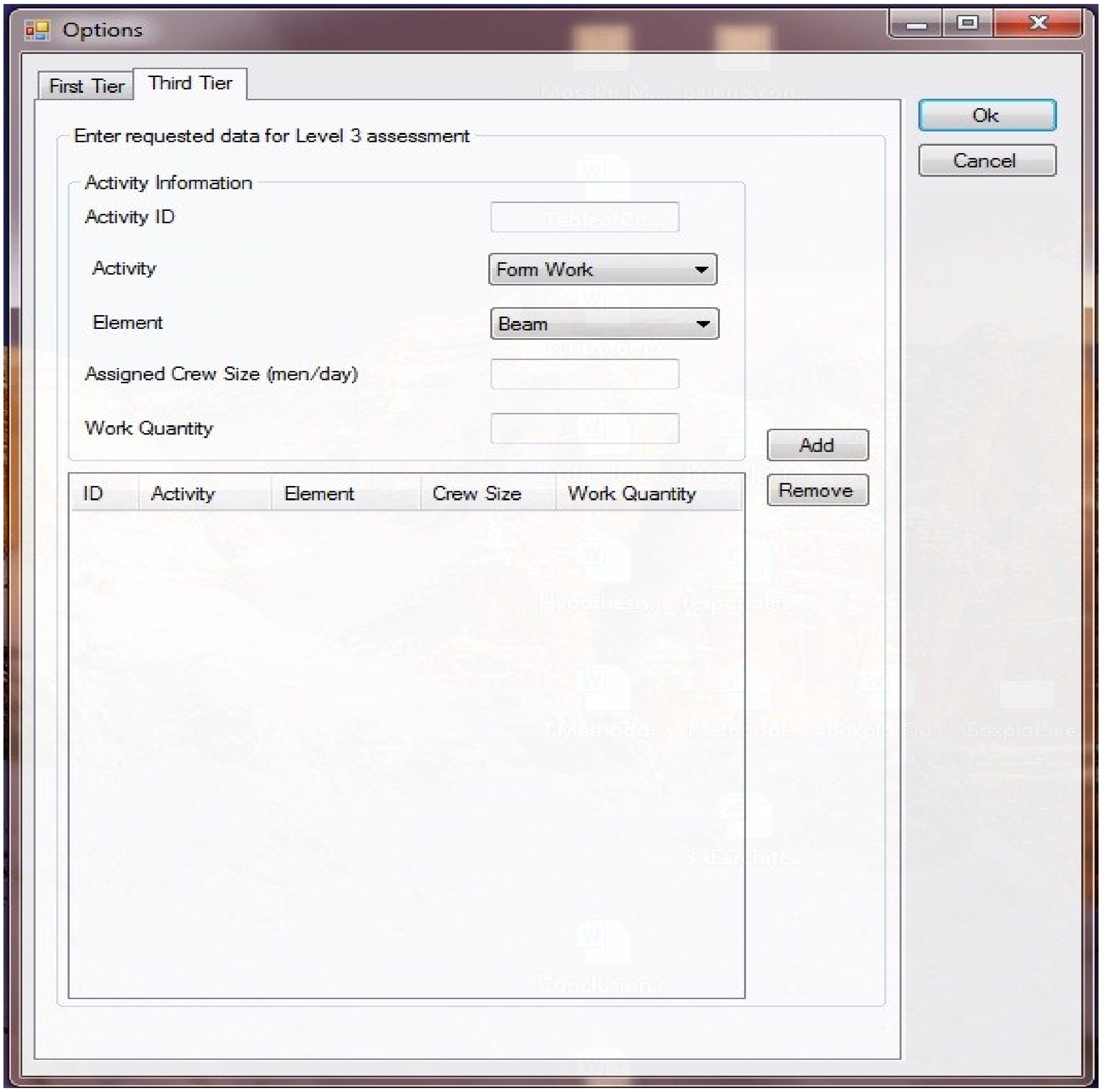
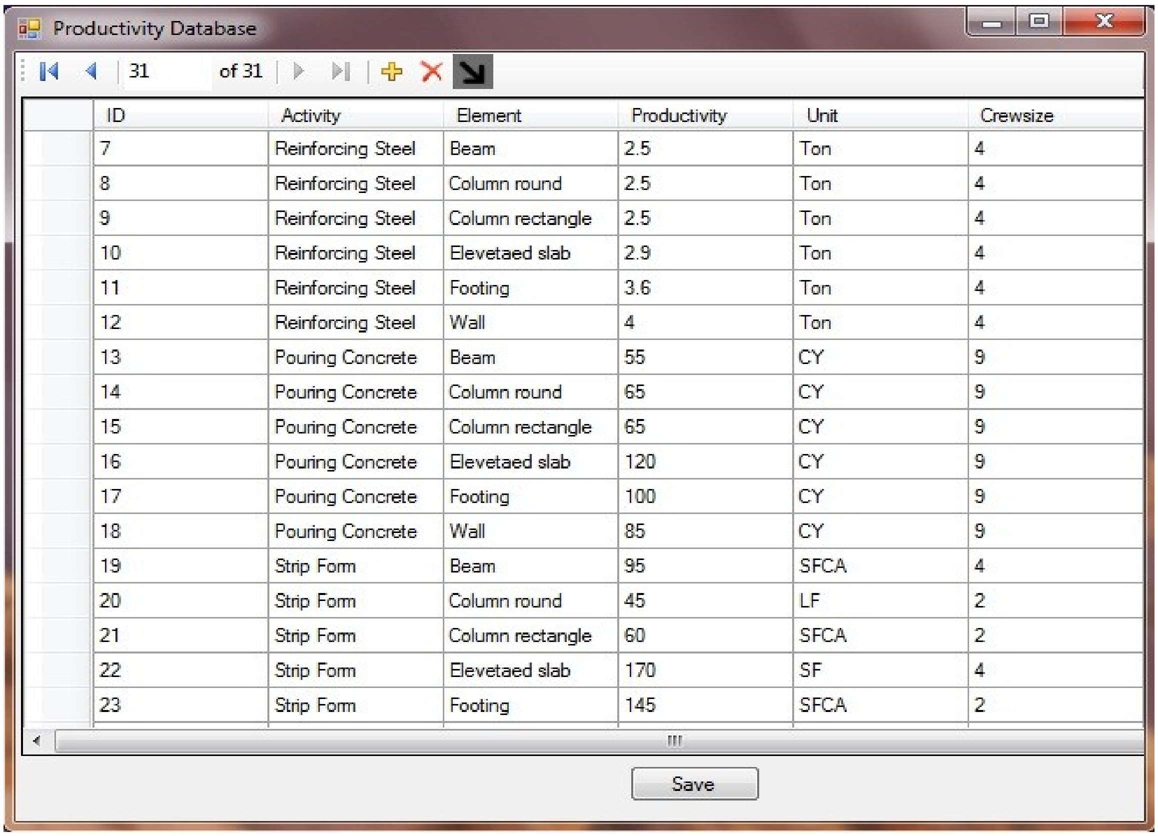


Figure 4.6: Third tier data entry

4.2.2 Database

A database is developed based on the data extracted from RSMeans Building Construction Cost Data (RSMeans 2009) to store the average productivities and typical crew sizes for commonly used activities in reinforced concrete framing of building construction. The database includes activity (Forming, Reinforcing steel, Pouring concrete, Strip forms and Concrete Curing), Element (column, slab, beam, and so forth), average productivity, typical crew size, and unit of measurement for each data set. The database is used in the third tier of assessment for evaluating the reasonability of activities duration.



ID	Activity	Element	Productivity	Unit	Crewsize
7	Reinforcing Steel	Beam	2.5	Ton	4
8	Reinforcing Steel	Column round	2.5	Ton	4
9	Reinforcing Steel	Column rectangle	2.5	Ton	4
10	Reinforcing Steel	Elevetaed slab	2.9	Ton	4
11	Reinforcing Steel	Footing	3.6	Ton	4
12	Reinforcing Steel	Wall	4	Ton	4
13	Pouring Concrete	Beam	55	CY	9
14	Pouring Concrete	Column round	65	CY	9
15	Pouring Concrete	Column rectangle	65	CY	9
16	Pouring Concrete	Elevetaed slab	120	CY	9
17	Pouring Concrete	Footing	100	CY	9
18	Pouring Concrete	Wall	85	CY	9
19	Strip Form	Beam	95	SFCA	4
20	Strip Form	Column round	45	LF	2
21	Strip Form	Column rectangle	60	SFCA	2
22	Strip Form	Elevetaed slab	170	SF	4
23	Strip Form	Footing	145	SFCA	2

Figure 4.7: Database window

4.2.3 Assessment engine

The assessment engine is indeed the coded module developed for automating the three tiers of assessment. This module is coded as a macro by application of VBA for MSP. In fact, this macro is the core part of the developed software system that conducts the assessment and evaluation on schedules. In the course of first tier of assessment, this macro calculates sixteen schedule components and automatically assesses schedules against fourteen provisions. These include, but are not limited to, criticality rate, near criticality rate, project cost ratio, project effort ratio, activities with negative float, and so forth. In essence, the assessment engine calculates a set of health metrics and activities quantitative components then compare them with industry norms or the user input values. Furthermore, a rule-based advising function is incorporated into this macro in order to provide users with typical causes of identified deficiencies and a set of recommended corrective actions. Contractors are the main body who could benefit from this function of the SAE as they could identify probable deficiencies before submission of schedules.

Job logic assessment for a set of common activities associated with reinforced concrete framing of building construction, and evaluation of their duration are another functions of the assessment engine. Conducting the second tier of schedule review, the assessment engine read activities names and recognizes the defined key words and related activities. Relationships among the recognized activities will be identified respectively. The assessment process takes place in two different passes; forward and backward passes, controlling predecessors and successors of the recognized tasks. If SAE does not find the necessary relationships in between them, they will be highlighted as activities with faulty job logic. It is necessary to indicate that the job logic assessment in this stage merely concern hard logic as the rigid sequence of work for the predefined set of activities.

Activities duration are usually estimated considering average productivity for the planned work quantity (Moselhi and Nicholas 1990). In the course of the third tier of schedule review, the assessment engine evaluates the reasonability of activities duration based on comparison of the assumed activities' productivity rates and the industry norms stored in the developed database. The coded macro calculates the productivity for selected activities by dividing the related work quantities by the duration of each activity. The results are then compared by the typical rates retrieved from the database. If the software finds any discordance, related activities will be marked as activities with unreasonable duration. Sample code of the third tier of assessment is provided in Appendix B.

4.3 Input and Output

In order for SAE to provide the desired assistance in the course of schedule review, appropriate input is required. Nonetheless SAE is developed in a way to minimize the amount of user input to ease its application. With the exception of job logic assessment, user input is required for the other tiers of schedule review. However, the user could opt for the default mode as regards the first tier and avoid the data entry stage.

A set of thresholds were extracted based on literature regarding the health metrics and the quantitative schedule components. These values are the default thresholds incorporated into the software. However, users have the opportunity of modifying the desired thresholds in two different levels. For instance, there is an empirical rule requiring the duration of each activity to be lesser than three times the value for the update cycle (PMI 2007).]. Users could either specify the duration of schedule periodic update cycle or proceed keeping the default value. Considering this empirical rule, the maximum suggested duration of activities could be calculated based on the chosen schedule periodic update cycle update cycle. Nonetheless, the user can ignore the default rule and choose directly the desired threshold for the maximum duration of activities according to their specific needs.

The job logic review is a one step process and does not need any user input. The user is only required to browse the proposed schedule, and assessment will be conducted automatically. However, in the course of assessment of activities duration, the user is required to enter the ID, activity type, element, assigned crew size and work quantity of the desired activities. Nevertheless, the software could detect the crew size and work quantity automatically if the schedule is loaded with these data.

After conducting each tier of schedule review, SAE creates a report including the identified problematic activities reflected on an Excel sheet. A typical report of the first tier of assessment comprises the calculated health metrics, typical reasons for the deficiencies identified (if any) and a set of generic recommended corrective actions. Furthermore, name and ID of activities with out of range attributes would be reflected on the report. In addition, SAE highlights those activities on the schedule.

The second and third tiers' reports contain the ID and name of activities with faulty job logic and unreasonable activity duration. As well, the typical related predecessors and/or successors, and the typical crew sizes and productivities of the problematic activities are included. Moreover, similar to first tier, those activities will be highlighted on the schedule.

CHAPTER FIVE: CASE EXAMPLES

5.1 General

This chapter presents four case examples that were implemented in order to demonstrate the use of the developed method, and to illustrate the features of the developed computer application. The four case examples include schedules of three actual projects and one hypothetical project that were analyzed to illustrate how the method evaluates the goodness of schedules. The developed method assesses schedules against industry recommended practices and bench marks. The method evaluates the rationale of schedules' job logic and reasonability of their duration, as well. The three actual schedules were also subject of assessment by an available objective schedule review method (DCMA 14-point assessment) and the results of the two methods were compared.

5.2 Description of the Cases

The three actual schedules were institutional buildings constructed for Concordia University, two of which are high-rises located in downtown Montreal, and the third is a four story building constructed at Loyola campus of the university. The three actual cases are totally different in size. Nonetheless, they benefit from similar technical specifications and have many features in common with only a few exceptions; one of the high-rises has a set of solar panels included in its curtain wall system as well as tension ducts utilized in its framing system, which make the construction process more complex.

The hypothetical schedule represents a three-story office building. This schedule was merely used to test the second and the third tier of assessment. As indicated in the previous chapter, the SAE conducts the job logic assessment for a set of commonly used activities in reinforced concrete framing of building construction. Also, SAE evaluates rationale of productivities and crew sizes for the same selection of activities. Therefore, a schedule should be developed with certain level of detail in order to be evaluated by the SAE. The schedules of the three actual projects were not that detailed, thus a detailed hypothetical schedule was selected in order to test and validate the second and third tiers of assessment. A brief description of each project is presented below.

Project A: This project encompasses two integrated high-rises, one has twelve floors and the other one is a 17-story tower, connected together on each floor by common corridors. Both of the high-rises have reinforced concrete framing and three levels of basement. The reinforced structures include flat slabs with a thickness of 229 mm which have typical spans of 9 m by 9 m. The height of each floor is 4.1 m, and the façade of the complex is a pre-glazed curtain wall with aluminum panels. Steel-structure mechanical floors are built on each roof (Ranjbaran 2007). This 68,000 square meters complex was a $172 M project containing more than 300 labs, administrative offices, and a large number of faculty offices. The project was scheduled to be executed in 1028 working days. The construction of this complex started in the summer of 2001 by the demolition of old buildings. The complex was opened on September 2005(Concordia University 2012). This project benefited from a phased delivery system including three phases, 1) excavation, 2) framing and 3) complex balance (rest of the works) (Ranjbaran 2007).

Project B: This project is a 33,000 square meter, 15-story high-rise that was estimated to cost $120 M. The building has reinforced concrete structure and rests on two levels of basement. This project's schedule consisted of about nine hundred activities with and original duration of 543 working days. The building was officially opened in 2009 and houses the business school of the university including digitally equipped classrooms, amphitheaters, the administrative and faculty offices, and graduate students offices (Concordia University 2012).

Project C: The third case is a $20 M project constructed recently at Loyola campus of Concordia University, which houses the biological laboratories. This project is a 4 story building with reinforced concrete structure and a mechanical room on the top, totaling a net area of more than 6,000 square meters. This schedule has an original duration of 295 working days and consisted of more than two hundred activities.

Project D: This hypothetical schedule is indeed a case example provided with Microsoft Project (Microsoft Corporation 2006) software system as a template. The schedule represents a 7,000 square meter, three-story building. The template schedule consists of more than one hundred and twenty activities and has an original duration of 344 working days. Appendix C shows the schedule of this project.

5.3 Analysis and Evaluation

The three actual schedules were reviewed based on the developed method in two steps. In the first step schedule assessment was carried out automatically using the coded software (SAE), which is mainly concerned with the quantitative provisions. For this purpose, the SAE was installed on a laptop with a Core™2 Duo Processor T7500, and 2GB of RAM. Review of each schedule was done in less than a minute automatically, and the results were printed in a separate report. See bellow one of the reports. The other reports are provided in Appendix D.

SAE (Schedule Assessment & Evaluation)

First Tier Assessment & Evaluation Result

Project Name: Échéancier Campus.mpp

General Information

Project duration = 295 days
Total number of activities = 208
Total number of critical activities = 13
Maximum suggested activity duration = 90 Days
Total number of activities with out of range duration = 26
Maximum suggested critical activity duration = 30 Days
Total number of critical activities with excessive duration = 2
Total number of constraints = 11
Total number of relationships = 200
Relationship per activity = 0.96
Number of open ended activities = 94
Standard deviation of activities duration = 10
Criticality rate(duration of activities) = 13%
Criticality rate (number of activities) = 6%
Near criticality rate = 1%

Total number of activities with excessive total float =
31
Total number of activities with negative total float = 0
This schedule is not loaded with resources
This schedule is not loaded with cost

Recommendations

Notice: This schedule's critical path is not extended from start to the end of the project. Control constraints and/or job logic

Control duration of all out of range activities. Breaking down long activities and/or combining short activities in order to have a manageable schedule is suggested

Control duration of all long critical activities. Breaking down long critical activities to have a more manageable critical path is suggested

Control all constraints to be in compliance with contractual clauses and/or be reasonable

Control job logic and/or activities dependencies to be reasonable

No open ended activity is allowed. Link all open ended activities to appropriate successor/predecessor

Control all activities with excessive total float to have all necessary dependencies

The schedule is strictly suggested to be loaded with resources

The schedule is suggested to be loaded with cost

Detailed Information

Critical Activities With excessive Duration

Activity Name	Activity ID	Activity Duration(Days)
Tuyauterie équipement salle mec.	188	50
Isolation des conduit salle mec	189	45

Activities With Excessive Total Float

Activity Name	Activity ID	Total Float
Ouverture de chantier /CSST,CCQ,	4	260
Implantation	5	246
Aménagement site/ cloture ,roulotte etc.	6	250
DESSINS D'ATELIER	7	295
Dessins coffrage/échafaudage	9	219
Dessins architectures diverse	10	177
Coordination électro-mécanique	11	178
AQUEDUC TEMPORAIRE	17	137
Structure sous passerelle	50	103

Escalier GE-2	52	104
Escalier GE-4&8	54	104
Parapet	59	124
Toiture salle mécanique	67	117
Toiture toit 3e étage	68	117
Mur de fondation	70	134
Terrasse coté nord	71	108
Cadre RDC	95	106
Cloison pose de métal RDC	105	103
Protection inc. conduit primaire RDC	158	111
Protection inc. distribution RDC	159	111
Plomberie sous-terraine SS1	175	119
Plomberie /gaz/eau/air/ roof SS1	176	112
Plomberie /gaz/eau/air/ roof RDC	179	109
Distrib. conduit/gaz/eau air/ roof RDC	180	103
Massif électrique extérieur	216	194
Conduit Électrique SS1 souterrain	217	121
Distribution SS1	218	106
Conduit électrique rdc	221	125
Distribution rdc	222	101
Conduit électrique 2e étage	225	115
Distribution 2e étage	226	112

Activities With Out Of Range Duration

Activity Name	Activity ID	Activity Duration(Days)
Ouverture de chantier /CSST,CCQ,	4	1
Implantation	5	2
Aménagement site/ cloture ,roulotte etc.	6	2
DESSINS D'ATELIER	7	1
AQUEDUC TEMPORAIRE	17	2
DRAINAGE PLUVIAL OUEST	21	4
Alsphatage	26	3
Mur/ colone RDC	31	4
Mur/ colone 2e étage	33	3
Coffrage divers SS1	39	4
Ébénisterie 3e étage	64	3
Porte/quincaillerie 4e étage s. méc.	103	4
Cloison toilettes/ accessoires SS1	139	2
Cloison toilettes/ accessoires RDC	140	2
Cloison toilettes/ accessoires 2e étage	141	2
Cloison toilettes/ accessoires 3e étage	142	2
Cloison grillagé RDC	144	2

Cloison mobile SS1	145	3
Diffuseur RDC	195	4
Diffuseur 2e étage	199	3
Diffuseur SS1	203	4
Balancement SS1	204	3
Diffuseur 3e étage	207	3
Balancement 3e étage	208	3
Finition 3e étage	232	4
Livraison finale	236	1

Open Ended Activities

Activity Name	Activity ID
Octroit des contrat au sous-traitant	3
Ouverture de chantier /CSST,CCQ,	4
Implantation	5
Aménagement site/ cloture ,roulotte etc.	6
DESSINS D'ATELIER	7
Dessins coffrage/échafaudage	9
Dessins architectures diverse	10
Coordination électro-mécanique	11
AQUEDUC TEMPORAIRE	17
PRÉPARATION pour bloc décoratif	20
Alsphatage	26
Coffrage divers SS1	39
Mur extérieur axe E	47
Enduit acryliques M-57	48
Structure sous passerelle	50
Escalier GE-3	53
Escalier GE-4&8	54
Structure salle mécanique 4e étage	56
Parapet	59
Ébénisterie 3e étage	64
Toiture toit 3e étage	68
Mur de fondation	70
Terrasse coté nord	71
Terrasse coté sud	72
Isolation Axe E	78
Revêtement Axe 20	79
Pose des persiennes	83
Sofites extérieur rdc	89

Sofite intérieur	90
Lames de verre V-3 mur MR-11 et 12	91
Entrée aluminium	92
Cadre SS1	94
Cadre RDC	95
Cadre 2e étage	96
Cadre 3e étage	97
Cadres 4e étage s.mécanique	98
Porte/quincaillerie SS1	99
Porte/quincaillerie RDC	100
Porte/quincaillerie 2e étage	101
Porte/quincaillerie 3e étage	102
Porte/quincaillerie 4e étage s. méc.	103
Plancher surélevés SS1 informatique	137
Cloison toilettes/ accessoires 3e étage	142
Cloison grillagé RDC	144
Cloison mobile SS1	145
Grille gratte pisr RDC	146
Mobilier Laboratoireen acier 3e étage	151
Mise en marche	156
Protection inc. distribution RDC	159
Protection incendie finition RDC	160
Protection incendie finition 2e étage	163
Protection inc. conduit primaire SS1	164
Protection inc. distribution SS1	165
Protection inc. finition SS1	166
Protection inc. finition 3e étage	169
Protection inc. finition 4e étage	172
Plomberie sous-terraine SS1	175
Plomberie /gaz/eau/air/ roof SS1	176
Distrib. des conduit/gaz/eau air/ roof SS1	177
Pôses des accessoires / finition SS1	178
Plomberie /gaz/eau/air/ roof RDC	179
Distrib. conduit/gaz/eau air/ roof RDC	180
Pôses des accessoires / finition RDC	181
Plomberie /gaz/eau/air/ roof 2e étage	182
Distrib. conduit/gaz/eau air/ roof 2e étage	183
Pôses des accessoires/Finition 2e étage	184
Plomberie /gaz/eau/air/ roof 3e étage	185
Distrib. conduit/gaz/eau air/ roof 3e étage	186
Pôses des accessoires /Finition 3e étage	187
Correction des déficiences	191
Diffuseur RDC	195

Diffuseur 2e étage	199
Diffuseur SS1	203
Diffuseur 3e étage	207
Flush-out pour Leed	214
Massif électrique extérieur	216
Conduit Électrique SS1 souterrain	217
Distribution SS1	218
Éclairage SS1	219
Conduit électrique rdc	221
Distribution rdc	222
Éclairage rdc	223
Finition rdc	224
Conduit électrique 2e étage	225
Distribution 2e étage	226
Éclairage 2e étage	227
Finition 2e étage	228
Conduit électrique 3e étage	229
Distribution 3e étage	230
Éclairage 3e étage	231
Finition 3e étage	232
Distribution/conduit salle méc. 4e étage	233
Éclairage salle méc. 4e étage	234
Livraison finale	236

Activities With Negative Total Float

Activity Name	Activity ID

The second step involved the assessment of schedules against the rest of the provisions (i.e. conceptual criteria). A structured interview was conducted with an expert, who was highly involved in construction of these projects, in order to verify if the conceptual provisions were satisfied or not for each of the projects. It is noteworthy to indicate that a minimum level of familiarity with each project environment is necessary to assess the related schedule by means of the developed method. For instance, in order to verify if the provisions included in the contractual compliance part of the compiled checklist are satisfied or not, a minimum knowledge of the related contracts is required.

At the end of the assessment and evaluation process, the SDI for each schedule was calculated, and its level of goodness was reported. The schedule A obtained the highest SDI (562 out of 1000) representing a better schedule and was classified as “Good”. Then schedule B and C obtained 441 and 327 respectively and were classified as “Acceptable.” The SDI was recalculated for each schedule based on the lower and upper bounds of the weights, taking to account the 95% confidence intervals. The results were the same; schedule A had the highest SDI and schedule C the lowest SDI. Thus, it could be argued that the defined weights are robust.

There were a set of deficiencies in common among the three cases that caused these schedules not to be labeled as excellent. These schedules were unable to satisfy the criteria regarding “Resource Loading”, “Responsibility Assignment”, “Trade’s peak resource loading”, “Peak to Average Labor Ratio”, “Duration of Critical Activities”, “Project Cost Ratio”, “Project Effort Ratio”, “Lag Duration”, “Open Ended Activities”, “Activities Float” and so forth. These deficiencies caused the three schedules to lose almost 400 points. Moreover, schedules B and C were not able to fulfill the requirements of more provisions including “Critical Path”, ‘Constraints”, “Permits and Environmental Remediation”, “Relationship Ratio”, “Submittals Review” and so forth. In addition to that, the difference between Schedule B and C originated from four provisions that project B satisfied more than project C. These provisions were “Minimum Milestones”, “Submittal Activities”, “Startup and Testing Activities” and “Procurement Activities”.

The three schedules were also subject of assessment by application of the DCMA 14-point assessment which includes fourteen schedule assessment checks. As indicated in chapter two, this method was developed by Defense Contract Management Agency of US Department Of Defense. This method encompasses a set of quantitative provisions with recommended thresholds introduced on them. The macro developed by the DCMA was used for automatic assessment of schedules based on this method. The number of the test that each schedule was able to pass was identified. The results are reflected on table 5.1.

All the three cases could not pass numerous tests as: 1) there were a multitude of activities with lags in their dependencies, 2) a large number of “start to start” relationships between activities, 3) numerous activities with high total float, 4) poorly developed network, 5) the schedules were not loaded with resources. Schedule C had the worth situation as this case had several activities with leads in their dependencies, and a significant number of open ended activities in addition to the deficiencies indicated above. The schedule A and B passed identical number of tests although those tests were not exactly the same. While the schedule B was not able to pass the “Logic Test” because of several open ended activities, the schedule A failed the “Duration Test” as this schedule had a multitude of activities with high duration.

Table 5.1: Results of the DCMA tests

DCMA 14-Point Assessment			
Test	Project A	Project B	Project C
Logic	✓	×	×
Leads	✓	✓	×
Lags	×	×	×
Relationship Types	×	×	×
Hard Constraints	✓	✓	✓
High Float	×	×	×
Negative Float	✓	✓	✓
High Duration	×	✓	✓
Invalid Dates	NA	NA	NA
Resources	×	×	×
Missed Tasks	NA	NA	NA
Critical Path Test	×	×	×
Critical Path Length Index	NA	NA	NA
Baseline Execution Index	NA	NA	NA

In addition, the hypothetical schedule (project D) was assessed using SAE in order to test the second and the third tier of assessment. Thirty activities regarding the framing trade were subject of automated job logic assessment in this schedule. Originally only one activity "40. Pour concrete elevator walls" missed the required predecessor regarding steel reinforcing. The relationships between ten more activities were deliberately distorted by deleting the predecessors and the successors in order to better test the validity of the SAE. For instance, the necessary relationships between form work and pour concrete activities were deleted. Afterwards, the automated job logic assessment was conducted, which was accomplished in less than a minute. The SAE identified thirteen tasks with faulty dependencies (two activities more than what was expected). All the expected eleven activities were identified and had been highlighted on the schedule (Figure 5.2). Their ID and name were reflected on the assessment report, as well.

The schedule was examined to see why two more activities were marked as activities with faulty job logic. It was noticed that the activity “46. Prepare and pour concrete floor in elevator pit” and “89. Pour lightweight concrete roof fill” were classified as activities that do not have the necessary predecessors regarding rebar installation in the output report. It was indicated that these activities are not succeeded with curing as well. Therefore it was justifiable if the SAE had marked them as activities with problematic dependencies. However, it can be argued that the activity “46. Prepare and pour concrete floor in elevator pit” had the form work and rebar installation inherent in the task name. See the output report below.

SAE (Schedule Assessment & Evaluation)

Job Logic Assessment & Evaluation Result

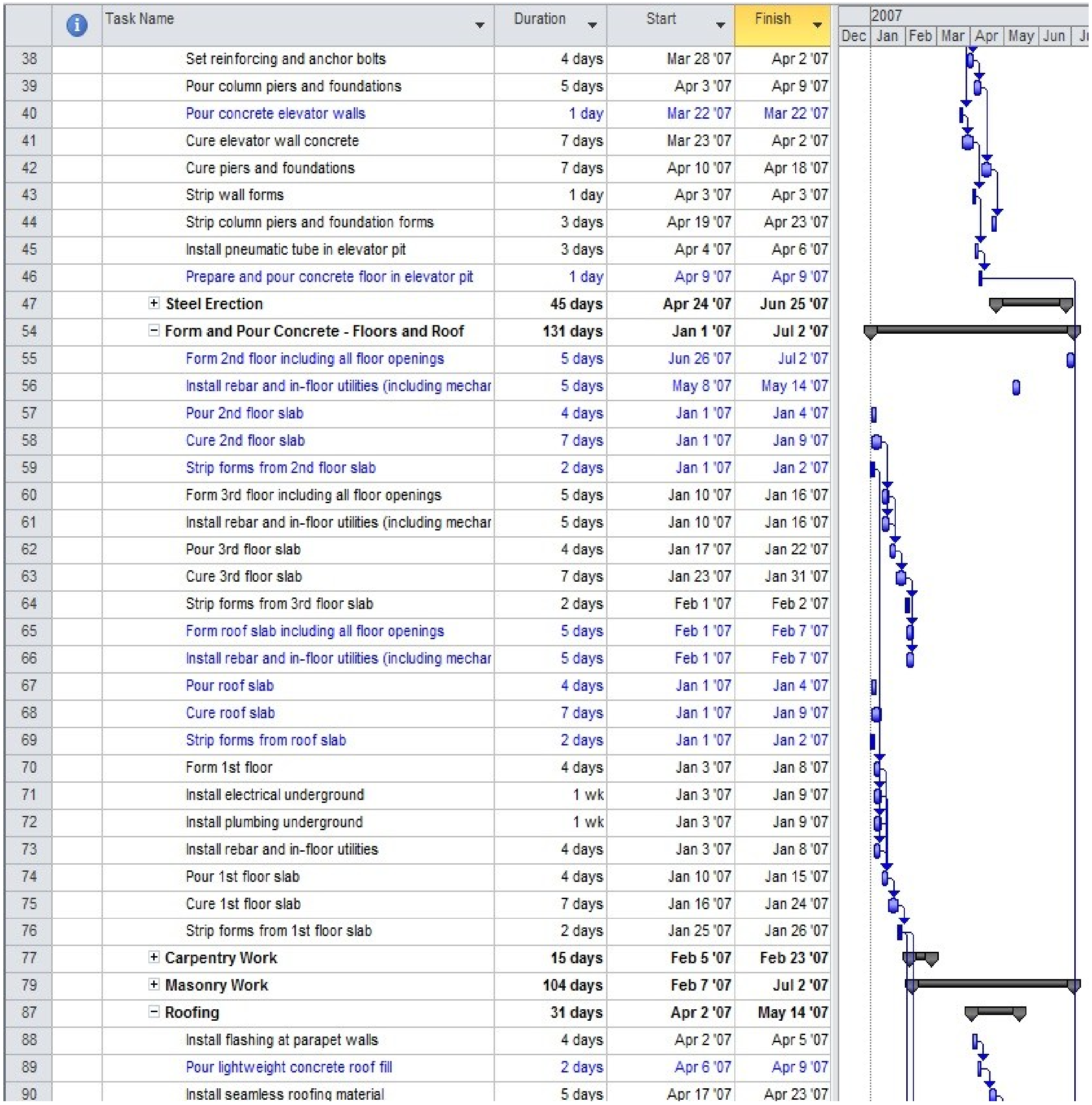
Project Name: Office Building Construction.mpp

Activities With Faulty Job Logic

Activity Name	Activity ID	Notice
Install rebar and in-floor utilities (including mechanical, electrical, plumbing)	56	Control job logic for '56. Install rebar and in-floor utilities (including mechanical, electrical, plumbing)' as Rebar Installation should be succeeded with Pouring Concrete

Install rebar and in-floor utilities (including mechanical, electrical, plumbing)	66	Control job logic for '66. Install rebar and in-floor utilities (including mechanical, electrical, plumbing)' as Rebar Installation should be succeeded with Pouring Concrete
Form 2nd floor including all floor openings	55	Control job logic for '55. Form 2nd floor including all floor openings' as Formwork Installation should be succeeded with Pouring Concrete
Form roof slab including all floor openings	65	Control job logic for '65. Form roof slab including all floor openings' as Formwork Installation should be succeeded with Pouring Concrete
Prepare and pour concrete floor in elevator pit	46	Control job logic for '46. Prepare and pour concrete floor in elevator pit' as Pouring Concrete should be succeeded with Curing
Pour 2nd floor slab	57	Control job logic for '57. Pour 2nd floor slab' as Pouring Concrete should be succeeded with Curing
Pour roof slab	67	Control job logic for '67. Pour roof slab' as Pouring Concrete should be succeeded with Curing
Pour lightweight concrete roof fill	89	Control job logic for '89. Pour lightweight concrete roof fill' as Pouring Concrete should be succeeded with Curing
Cure roof slab	68	Control job logic for '68. Cure roof slab' as Curing should be succeeded with Stripping Formwork
Pour concrete elevator walls	40	Control job logic for '40. Pour concrete elevator walls' as Pouring Concrete should be preceded with Rebar Installation
Prepare and pour concrete floor in elevator pit	46	Control job logic for '46. Prepare and pour concrete floor in elevator pit' as Pouring Concrete should be preceded with Rebar Installation
Pour 2nd floor slab	57	Control job logic for '57. Pour 2nd floor slab' as Pouring Concrete should be preceded with Rebar Installation

Pour roof slab	67	Control job logic for '67. Pour roof slab' as Pouring Concrete should be preceded with Rebar Installation
Pour lightweight concrete roof fill	89	Control job logic for '89. Pour lightweight concrete roof fill' as Pouring Concrete should be preceded with Rebar Installation
Pour roof slab	67	Control job logic for '67. Pour roof slab' as Pouring Concrete should be preceded with Formwork Installation
Pour lightweight concrete roof fill	89	Control job logic for '89. Pour lightweight concrete roof fill' as Pouring Concrete should be preceded with Formwork Installation
Cure 2nd floor slab	58	Control job logic for '58. Cure 2nd floor slab' as Curing should be preceded with Pouring Concrete
Cure roof slab	68	Control job logic for '68. Cure roof slab' as Curing should be preceded with Pouring Concrete
Strip forms from 2nd floor slab	59	Control job logic for '59. Strip forms from 2nd floor slab' as Strip Formwork should be preceded with Curing
Strip forms from roof slab	69	Control job logic for '69. Strip forms from roof slab' as Strip Formwork should be preceded with Curing



	Task Name	Duration	Start	Finish
38	Set reinforcing and anchor bolts	4 days	Mar 28 '07	Apr 2 '07
39	Pour column piers and foundations	5 days	Apr 3 '07	Apr 9 '07
40	Pour concrete elevator walls	1 day	Mar 22 '07	Mar 22 '07
41	Cure elevator wall concrete	7 days	Mar 23 '07	Apr 2 '07
42	Cure piers and foundations	7 days	Apr 10 '07	Apr 18 '07
43	Strip wall forms	1 day	Apr 3 '07	Apr 3 '07
44	Strip column piers and foundation forms	3 days	Apr 19 '07	Apr 23 '07
45	Install pneumatic tube in elevator pit	3 days	Apr 4 '07	Apr 6 '07
46	Prepare and pour concrete floor in elevator pit	1 day	Apr 9 '07	Apr 9 '07
47	+ Steel Erection	45 days	Apr 24 '07	Jun 25 '07
54	− Form and Pour Concrete - Floors and Roof	131 days	Jan 1 '07	Jul 2 '07
55	Form 2nd floor including all floor openings	5 days	Jun 26 '07	Jul 2 '07
56	Install rebar and in-floor utilities (including mechar	5 days	May 8 '07	May 14 '07
57	Pour 2nd floor slab	4 days	Jan 1 '07	Jan 4 '07
58	Cure 2nd floor slab	7 days	Jan 1 '07	Jan 9 '07
59	Strip forms from 2nd floor slab	2 days	Jan 1 '07	Jan 2 '07
60	Form 3rd floor including all floor openings	5 days	Jan 10 '07	Jan 16 '07
61	Install rebar and in-floor utilities (including mechar	5 days	Jan 10 '07	Jan 16 '07
62	Pour 3rd floor slab	4 days	Jan 17 '07	Jan 22 '07
63	Cure 3rd floor slab	7 days	Jan 23 '07	Jan 31 '07
64	Strip forms from 3rd floor slab	2 days	Feb 1 '07	Feb 2 '07
65	Form roof slab including all floor openings	5 days	Feb 1 '07	Feb 7 '07
66	Install rebar and in-floor utilities (including mechar	5 days	Feb 1 '07	Feb 7 '07
67	Pour roof slab	4 days	Jan 1 '07	Jan 4 '07
68	Cure roof slab	7 days	Jan 1 '07	Jan 9 '07
69	Strip forms from roof slab	2 days	Jan 1 '07	Jan 2 '07
70	Form 1st floor	4 days	Jan 3 '07	Jan 8 '07
71	Install electrical underground	1 wk	Jan 3 '07	Jan 9 '07
72	Install plumbing underground	1 wk	Jan 3 '07	Jan 9 '07
73	Install rebar and in-floor utilities	4 days	Jan 3 '07	Jan 8 '07
74	Pour 1st floor slab	4 days	Jan 10 '07	Jan 15 '07
75	Cure 1st floor slab	7 days	Jan 16 '07	Jan 24 '07
76	Strip forms from 1st floor slab	2 days	Jan 25 '07	Jan 26 '07
77	+ Carpentry Work	15 days	Feb 5 '07	Feb 23 '07
79	+ Masonry Work	104 days	Feb 7 '07	Jul 2 '07
87	− Roofing	31 days	Apr 2 '07	May 14 '07
88	Install flashing at parapet walls	4 days	Apr 2 '07	Apr 5 '07
89	Pour lightweight concrete roof fill	2 days	Apr 6 '07	Apr 9 '07
90	Install seamless roofing material	5 days	Apr 17 '07	Apr 23 '07

Figure 5.2: Schedule D after assessment by SAE (Second Tier)

Furthermore, the framing trade activities on the first and the third floor were randomly selected to test the third tier of assessment: evaluating rationale of crew sizes and productivity rates. Those activities were loaded with resources. The activities of the first floor were loaded with the appropriate crew sizes based on typical productivity rates and the activities of the third floor were loaded with inappropriate values. The appropriate crew sizes and the productivity rates were extracted from RSMeans Building Construction Cost Data (RSMeans 2009). After entering the required data, the assessment was conducted automatically. The SAE identified all the five activities with unreasonable attributes in less than a minute. They were highlighted on the schedule (Figure 5.3) and their ID and name were reflected on the output report as follows.

SAE (Schedule Assessment & Evaluation)

Productivity And Crew Size Assessment & Evaluation Result

Project Name: Office Building Construction.mpp

Activities With Untypical Crew Size or Duration

Control assumed crew size of activity: '60. Form 3rd floor including all floor openings' as typical crew size = 6 Persons

Control assumed productivity of activity: '60. Form 3rd floor including all floor openings' as typical productivity = 320 SF Per Day

Control assumed crew size of activity: '61. Install rebar and in-floor utilities (including mechanical, electrical, plumbing)' as typical crew size = 4 Persons

Control assumed productivity of activity: '61. Install rebar and in-floor utilities (including mechanical, electrical, plumbing)' as typical productivity = 2.9 Ton Per Day

Control assumed crew size of activity: '62. Pour 3rd floor slab' as typical crew size = 9 Persons

Control assumed productivity of activity: '62. Pour 3rd floor slab' as typical productivity = 120 CY Per Day

Control assumed crew size of activity: '63. Cure 3rd floor slab' as typical crew size = 2 Persons

Control assumed productivity of activity: '63. Cure 3rd floor slab' as typical productivity = 55 CsF Per Day

Control assumed crew size of activity: '64. Strip forms from 3rd floor slab' as typical crew size = 4 Persons

Control assumed productivity of activity: '64. Strip forms from 3rd floor slab' as typical productivity = 170 SF Per Day

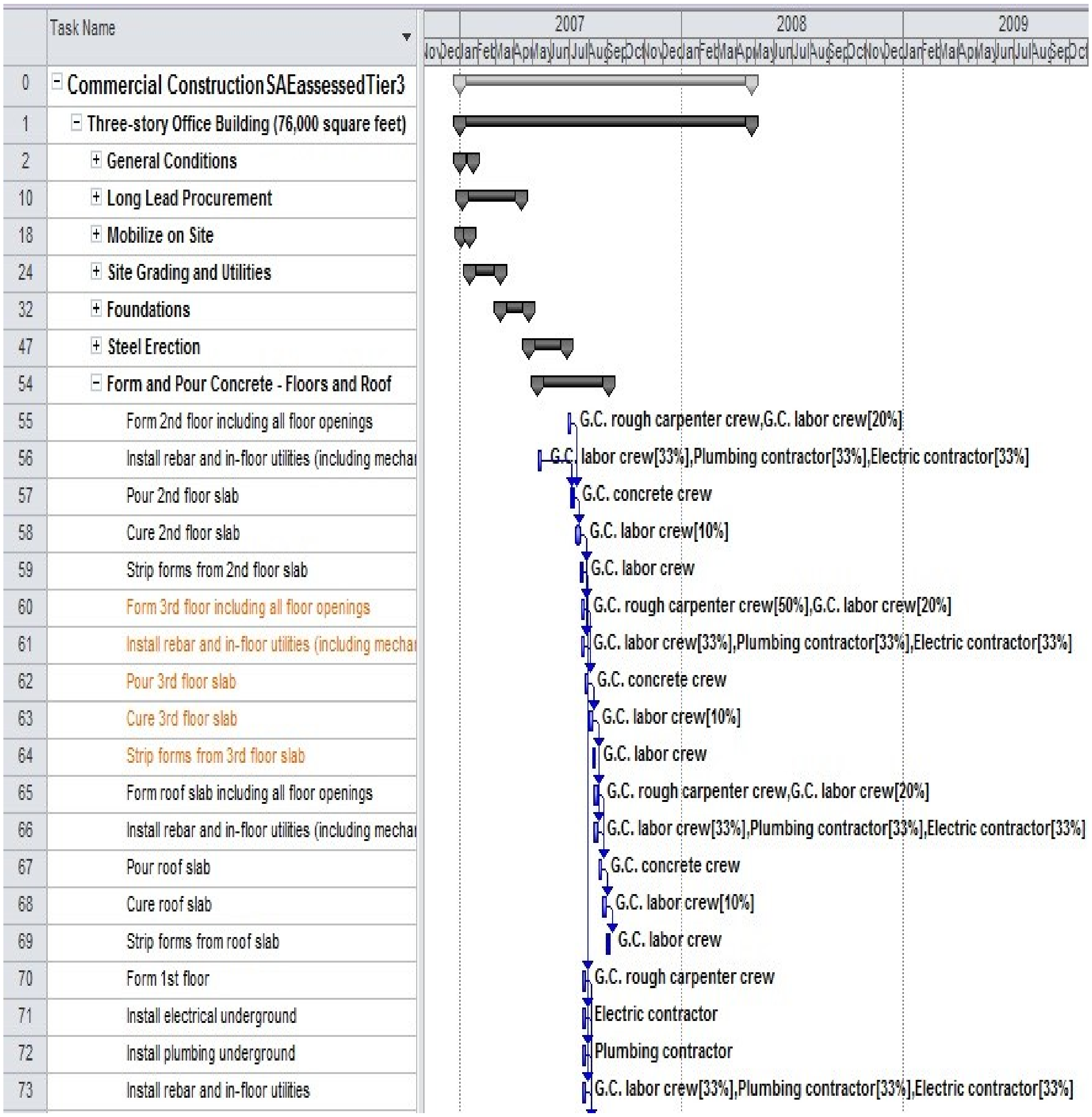


Figure 5.3: Schedule D after assessment by SAE (Third Tier)

5.4 Discussion of Results

The SDI calculated for schedule A and B were relatively higher than schedule C indicating that cases A and B are better-developed schedules in comparison to schedule C (Table 5.2). The same situation was observed when schedules were reviewed by application of the DCMA method. The schedules of cases A and B were able to pass 4 tests in the course of assessment although schedule C only passed 3 tests. This fact could be an indicator that schedule A and B are more mature in comparison to schedule C. Considering the cost of the three projects, it is not unexpected. Project A and B are by far larger and more costly in comparison to project C. Thus, it is rational to spend more effort in the scheduling process and respectively expect better schedules. It is interesting to indicate that project C was finished with a marginal delay. This delay could be partly attributed to the schedule's deficiencies. It is not intended to claim a direct relationship between the inability to satisfy the requirements of the developed method and the time overrun. Nevertheless, this relationship requires further analysis of more case examples.

Table 5.2: Comparison of the results

Comparison of results			
Projects	Project A	Project B	Project C
Number of DCMA tests passed	4	4	3
SDI score	562	441	327

The cases A and B had different SDIs although they passed similar number of tests in DCMA method. The difference in SDI score is rational as schedule A satisfied 7 provisions more than schedule B. The case example A had a reasonable critical path and criticality rate with rational phases' overlap. This schedule also included obtaining of permits, and submittals review as activities. Moreover, this schedule benefited from a reasonable relationship ratio and number of constrained activities. With the exception of constrained activities, the DCMA method is unable to effectively address those issues. Nonetheless, experts strictly recommend consideration of those issues in the course of schedule review. This fact was observed on the analysis of the survey results and is backed up in literature.

Furthermore, assessment of the hypothetical schedule demonstrated that SAE effectively identifies activities with unreasonable productivity rates and crew sizes. The developed software could also identify tasks with faulty job logic. The performance of SAE is not perfect in this domain as a few mistakes are expected because of probable malfunction of the defined keywords which are used to recognize the activities and their required dependencies. Nonetheless, the developed software is helpful for owners when used beside the current process of job logic assessment.

5.5 Summary

This chapter presented the case examples analyzed to demonstrate the application of the developed method and illustrate the computer application and its features. The case examples include three actual and one hypothetical project. The three actual projects although similar regarding the technical specifications, were totally different as regards the size. These cases included different projects from ordinary three-story buildings to integrated high-rises. The cases were assessed by application of DCMA method as an objective method of schedule assessment available, as well. The acquired results were compared, and the differences were identified. The results of the assessment revealed that the developed method is valid and has addressed important issues that the other method is unable to consider. Considering the situations that the other methods cannot distinguish well-developed schedules from poorly-developed schedules, this method could effectively assist owners in decision making. Therefore, according to the complexity and importance of each case, project team could target the appropriate SDI. Moreover, the developed method could be helpful for contractors, providing a set of important issues to be considered while developing schedules.

CHAPTER SIX: SUMMARY AND CONCLUDING REMARKS

6.1 Summary

A structured method for the effective assessment and evaluation of detailed construction schedules has been developed. A set of schedule review provisions was included in the developed method based on analysing and synthesizing the sporadic knowledge of schedule review published in textbooks, dissertations, articles and professional guidelines. Despite the overwhelming number of available provisions, it was not intended to provide an exhaustive list of schedule assessment criteria. What has been presented is a set of imperative schedule assessment criteria, many of which are usually overlooked in the schedule review methods currently in practice. The extracted criteria were classified into two major categories: 1) obligatory and 2) complementary criteria. The extracted criteria were revealed to experts through an online survey. The results of this survey revealed that different schedule assessment and evaluation provisions were not equally important in relation to their impacts on schedule goodness. Therefore, their related weights were defined based on the feedback received from a broad range of experienced professionals through the online questionnaire survey.

Considering the relative weight of each provision, the SDI was defined as a tool that quantitatively evaluates the level of schedule goodness. In addition, an empirical method for job logic assessment for institutional building construction was devised based on the schedules of successful projects. This empirical method introduces a set of thresholds for the duration of major trades and their start dates for the construction of institutional buildings.

The developed schedule assessment and evaluation method has been partly implemented via an automated computer application. The coded software system provides: 1) schedule assessment against quantitative criteria, 2) job logic assessment of selected construction trades, 3) assessment of productivity and crew size for a number of commonly used activities in building construction, 4) a set of recommendation regarding the problems identified.

Three actual schedules and one hypothetical case were analyzed using the developed method and its computer application. The three actual case examples were also the subject of schedule review by means of another available schedule assessment method. The results were compared and the differences were identified. The analysis of the differences revealed that the developed method is valid and is capable of addressing issues that the other method is unable to consider. Keeping in mind the situations that the other method was not able to distinguish well-developed schedules from poorly-developed schedules, the developed method could effectively assist owners in decision making.

6.2 Research Contributions

The main contribution of this study is the development of a method for the specific assessment and evaluation of detailed construction schedules. The developed method assists owners in performing the necessary review and evaluation of detailed schedules that are usually developed by contractors and submitted to owners for approval and acceptance. The development of this method entails the following contributions:

1. Introducing a set of imperative criteria to be considered in the course of schedule review.
2. Defining the relative weight of each criterion in relation to its impact on schedule goodness.
3. Providing a robust and objective basis for making decisions regarding detailed schedules.
4. Automating the process of schedule review.
5. Developing a tool for training novice schedulers.
6. Introducing an empirical method for rapid job logic assessment of institutional building construction schedules.

6.3 Recommendations for Future Work

The database developed for the assessment of productivity and crew size was presented as a test of applicability. This database could be expanded to encompass more activities. Furthermore, the concept behind the empirical method of job logic assessment could be applied to other domains, such as commercial and office building construction. As well, the developed method for schedule review could be applied to more case examples in order to examine the probable relationship between the on-time project completion and the SDI.

In addition, the developed software application could be expanded to enable the direct assessment and evaluation of schedules developed in the Primavera environment and other commercially available scheduling systems.

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APPENDIX A: DATA COLLECTION

Appendix A.1: Structured Interviews

I would like to ensure firstly that the criteria listed below can be clearly understood by engineers in the field. I will read each criterion and its explanation, and you are requested to respond by "Clear" or "Not clear". Secondly, you are requested to indicate whether these criteria are fit for schedule assessment by responding by "Yes" or "No"

No.	Element	Explanation	Source	Clarity	Recommended
	General criteria				
1	Schedule Development	Based on teamwork	Li 2005		
2	Parties involved	All parties involvement	Li 2005		
3	Scheduler/s	well trained professional/s	Li 2005		
4	Scope Covering	All parts of scope are covered	Li 2005 , PMI 2007		
5	Milestones	At least 2, Project Start and Finish	PMI 2007		
6	Schedule Template	Start scheduling based on a typical standard schedule	Bent 1996		
	Structure				
7	Approved WBS	Scheduling based on an approved WBS	PMI 2007		
8	Scope completeness	Support of each WBS item by at least an activity	PMI 2007		

Comments:

No.	Element	Explanation	Source	Clarity	Recommended
	Activity				
9	Definition of activity	At least one verb and an object	PMI 2007		
10	Multi trade activities	Number of Multi trade activities			
11	Duration Estimation	Based on past productivity records and resource availability	PMI 2007		
12	Activity Duration	Not more than two times the update cycle	PMI 2007		
13	Activity Timing	No open end activity	Madl 2010, Li 2005, Winter 2010, Berg et al. 2009		
14	Activity Float	No activity with excessive float	Li 2005, Dzeng et al. 2005, Berg et al. 2009, De La Garza 1988		

Comments:

No.	Element	Explanation	Source	Clarity	Recommended
	Logic				
15	Constraints Usage	Not as the sole source for activity timing	Winter 2010		
16	Number of Constraints	Number of constraints	GAO 2009, Spencer and Lewis 2006, Dzeng et al. 2005		
	Lags				
17	Lags Duration	Not greater than duration of predecessor or successor activity	Winter 2010		
18	Negative Lags	Negative lag only if alternative logic is not applicable	PMI 2007		

Comments:

No.	Element	Explanation	Source	Clarity	Recommended
	Resources				
19	Resource Loading	Loading schedule with resources	Madl 2010, Griffith 2005, Glenwright 2004, Zack 1991		
20	Schedule Leveling	Leveling the schedule according to real resources availability	GAO 2009, Douglas 2009-b		
	Critical Path				
21	Schedule criticality	Criticality rate	O'brien and Plotnick 2010, De La Garza 1988		
22	critical path Verification	Detailed review if procurement or owner review activity included	Li 2005		
23	Near critical paths	Review of near critical paths	Li 2005		
	Calendar				
24	Non-working days	Determining non-working days and holidays	Douglas 2009-b, Li 2005		
25	Weather sensitive activities	Considering appropriate calendar	Douglas 2007, Li 2005, Dzeng 2004, De La Garza 1988		

Comments:

No.	Element	Explanation	Source	Clarity	Recommended
	Schedule review				
26	Schedule review	Detail schedule review by project team	Li 2005		
27	Contractual Compliance	Compliance with contractual requirements	Douglas 2007, Li 2005, De La Garza 1988		
28	Logic review	Review of phases and detailed review or spot check	Li 2005		
29	Phasing and sequence	Compliance with phasing and sequencing requirements	Li 2005		
30	Activity Productivity	Compliance with the averages used in estimation	Russell and Udairpurwala 2000		
31	Measure of congestion	Maximum number of workers per square meter should be limited to avoid congestion	Russell and Udairpurwala 2000, Bent 1996, Kerridge and Vervakin 1986		
32	Parametric Scheduling	Conformance with result of parametric scheduling	Moselhi 2010		
33	Subcontractors' acknowledgement	Having subcontractors signing off the schedule	Li 2005		

Comments:

Appendix A.2: Online Questionnaire

Schedule Assessment And Evaluation Criteria

My name is Farzad Moosavi, working on my MSc thesis research on "Schedule assessment and evaluation" at Concordia University under the supervision of Prof. Osama Moselhi. This questionnaire focuses on "Assessment and evaluation of initial detailed schedules for construction projects" aiming to evaluate their goodness. It takes 20 to 30 minutes of your valuable time to complete. Your timely response will be highly appreciated. Also, I would be thankful if you could forward this link to professionals specialized in project planning and scheduling in your organization.

Forty eight provisions (factors) are included in the questionnaire. Please review the presented criteria, indicate the relative level of importance of each criterion for schedule goodness on scale from 1 to 10 (1: Not important at all, 10: extremely important) and answer to the questions for each criterion to the degree possible.

Note: All information on this questionnaire will be held strictly confidential with no reference made to specific responses. Therefore please answer questions as objectively as possible.

If you have any questions about this survey, please email me at se_moosa@encs.concordia.ca

Do you want to receive a copy of the summary of results?

- Yes
- No

If yes, please write your e-mail address here

In which domain of construction do you have working experience?

- ☐ General
- ☐ Residential
- ☐ Commercial and Institutional
- ☐ Industrial
- ☐ Heavy Construction and Roadwork

Others, please specify

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Schedule Assessment And Evaluation Criteria

1. Contractual Compliance

Obligatory Criteria

Provision 1. Milestones and project duration should be in compliance with contractual provisions (Spencer and Lewis 2006, De La Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 2. Phasing and sequencing should be in compliance with contractual provisions (Li 2005).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 3. Number of activities should be in compliance with contractual provisions (e.g. it could be articulated in contracts that the number of activities should not be less than a specified number to insure that the schedule would be

developed at a suiatble level of details) (Li 2005).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 4. Activities duration should be limited to certain days according to contractual provisions (e.g. Activities duration should not be more than 30 days to force the schedule to be developed in greater detail) (Li 2005).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 5. Activities' codes should be in compliance with coding pattern according to related contractual provision (Li 2005).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 6. Schedule submission date should be in compliance with contractual provisions (Zack 1991).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 7. Scope of the project should be covered by schedule thoroughly based on a rational job logic (Douglas 2009-b, GAO 2009, PMI 2007, Li 2005).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10

Schedule Assessment And Evaluation Criteria

2. Schedule Development

How the schedule was developed

2.1 Scope

Provision 8. All aspects of project scope should be adequately defined before scheduling (PMI 2007) .

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 9. Scheduling should be based on an approved WBS (PMI 2007).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

2.2 Process

Provision 10. Schedule should be developed by participation of parties associated with the project (Li 2005).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 11. Subcontractors should be involved in schedule development to insure and facilitate integration and coordination (Li 2005, Zack 1991, De La Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 12. The schedule should reflect the start and completion dates for each subcontractor scope of work (Douglas 2009-b, De La Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Any comment

« Back Continue »

Schedule Assessment And Evaluation Criteria

3. Schedule Components

3.1 Overview and Job Logic

Provision 13. Project duration should conform with similar projects duration if available (Moselhi 2010).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 14. At least two milestones, start & finish, should be included in each schedule (PMI 2007).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 15. Generated S-Curve should be in line with similar projects S-Curve if

available (De La garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 16. Each phase duration (Engineering, procurement, etc.) should be in line with the duration of similar projects phases (Madl 2010).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 17. Engineering phase should not overlap construction by more than a specified percentage (Madl 2010).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended overlap percentage.

- ○ 20%
- ○ 30%
- ○ 40%
- ○ Does not seem applicable at all

Other, please specify

Provision 18. Number of constraints on activities start and/or finish should be limited (GAO 2009, Spencer and Lewis 2006, Dzeng et al. 2005).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended percentage of constraints(constraints/activities).

- 5%
- 7%
- 10%
- Does not seem applicable at all

Other, please specify

Provision 19. Lags duration should not be greater than the duration of predecessor or sucessor activities (Winter 2010).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 20. Relationship ratio (total number of relationships / total number of activities) should be limited (O'brien and Plotnick 2010, Spencer and Lewis 2006).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended relationship ratio.

- 1.5
- 1.6
- 1.7
- Does nit seem applicable at all

Others, please specify

Provision 21. No activity without predecessor or successor is allowed (Madl 2010, Li 2005, Winter 2010, Berg et al. 2009).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 22. Non-working days should be indicated in the project calendar (Douglas 2009-b, Li 2005).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 23. Assumed working hours for estimating the duration of activities should be compatible with those assumed in preparing the cost estimates (Madl 2010).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 24. Schedules should be loaded with resources (Madl 2010, Griffith 2005, Glenwright 2004, Zack 1991).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 25. A party / person should be responsible for each activity (PMI 2007, De la Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 26. Schedules that are loaded with resources should be leveled (GAO 2009, Douglas 2009-b).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 27.Number of workers per square meter should be limited to avoid congestion (Russell and Udairpurwala 2000, Bent 1996, Kerridge and Vervakin 1986).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended labor density index.

- ○ 20 square meter / man
- ○ 25 square meter / man
- ○ 30 square meter / man
- ○ Does not seem applicable at all

Other, please specify

Any comment

Schedule Assessment And Evaluation Criteria

3.2 Critical Path

Provision 28.Each critical activity should have a predecessor reflecting a physical dependency (O'brien and Plotnick 2010).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 29-1. The ratio [Number of critical activities / Total number of activities] should be limited (O'brien and Plotnick 2010, De La Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended ratio.

- ○ 20%
- ○ 25%

- 30%
- Does not seem applicable at all

Other, please specify

Provision 29-2. The ratio [Duration of critical activities / Total duration of activities] should be limited (Spencer and Lewis 2006).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended ratio.

- 20%
- 25%
- 30%
- Does not seem applicable at all

Other, please specify

Provision 30. The ratio [Number of near critical activities (Total Float <10 working days) / Total number of activities] should be limited (O'brien and Plotnick 2010).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended ratio

- 5%
- 10%
- 15%
- Does not seem applicable at all

Other, please specify

Provision 31. The ratio [Project critical path effort (number of labors) / Total project effort] should be within a minimum/maximum range (Spencer and Lewis 2006).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended maximum ratio.

- 20%
- 25%
- 35%
- Does not seem applicable at all

Other, please specify

Mark the recommended minimum ratio.

- 5%
- 10%
- 15%
- Does not seem applicable at all

Other, please specify

Provision 32. The ratio [Project critical path cost / Total project cost] should be within a min/max range (De la Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended maximum cost ratio

- 20%
- 25%
- 30%
- Does not seem applicable at all

Other, please specify

Mark the recommended minimum cost ratio

- 5%
- 10%
- 15%
- Does not seem applicable at all

Other, please specify

Provision 33. Critical activities, to be well manageable, should have a limited duration (e.g. critical activities duration should be less than two pay period) (De la Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended maximum duration of critical activities.

- 1 pay period
- 2 pay period
- 3 pay period
- Does not seem applicable at all

Other, please specify

Schedule Assessment And Evaluation Criteria

3.3 Trades

Provision 34. The peak of the resource loading curve of each trade should be in line with historical norms of similar projects if available (Madl 2010).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 35. The relationship of the trades' peaks of the resource loading curves to each other should be in line with historical norms of similar projects if available (Madl 2010).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 36. The planned rate of completion per week for each trade should be in line with historical norms of similar projects if available (Madl 2010).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 37. Peak to average labor ratio of each trade should be limited (Madl 2010).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended peak to average labor ratio

- 2
- 3
- 4
- Does not seem applicable at all

Other, please specify

Any comment

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Schedule Assessment And Evaluation Criteria

3.4 Supplementary Activities

Provision 38. Permits & environmental impact assessments should be included in the schedule (if applicable) (Nabros 1994, De La Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 39. Start up and testing activities should be included in the schedule (Douglas 2009-b, Zack 1991).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 40. Materials and methods requiring prior approval should have their submittal activities in the schedule (De la Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Importan

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 41. Submittals reviews should be reflected in the schedule as activities (Fredlund and king 1992, Zack 1991, De La Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Importan

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 42. Procurement activities should precede its installation tasks (De la Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Importan

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Any comment

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Schedule Assessment And Evaluation Criteria

3.5 Activities

Provision 43. If the number of activties has not been indicated in the contract, it has to be within a min/max range (O'brien and Plotnick 2010, De La Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended maximum number of activities.

- 250
- 700
- 1000
- Does not seem applicable at all

Other, please specify

Mark the recommended minimum number of activities.

- One activity for each 1,000$ of contract value

- One activity for each 5,000$ of contract value
- One activity for each 10,000$ of contract value
- Does not seem applicable at all

Other, please specify

Provision 44. Activities with excessive Total Float should be avoided (Li 2005, Dzeng et al. 2005, Berg et al. 2009, De La Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Excessive total float is a total float greater than

- 30 days
- 60 days
- 100 days
- Does not seem applicable at all

Other, please specify

Provision 45. No acitivity with negative float is allowed (Madl 2010, GAO 2009, Berg et al. 2009, Winter 2008).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Importan

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 46. Special measures should be taken for weather sensitive activities (e.g. adjusting productivity according to seasonal conditions) (Douglas 2007, Li 2005, Dzeng 2004, De La Garza 1988)..

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Provision 47. Duration of individual activities should be within a minimum/maximum range, in relation to the progress reporting period (Berg et al. 2009, PMI 2007, De La Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Mark the recommended maximum duration for activities.

- ○ 1 progress reporting period
- ○ 2 progress reporting period
- ○ 3 progress reporting period
- ○ Does not seem applicable at all

Other, please specify

Mark the recommended minimum duration for activities.

- ○ 1 days
- ○ 5 days
- ○ 10 days
- ○ Does not seem applicable at all

Other, please specify

Provision 48. Subcontractors should be involved in schedule development to insure and facilitate needed integration and coordination (Li 2005, Zack 1991, De La Garza 1988).

Choose the relative level of importance of this provision for schedule goodness. 1= not important at all 10 = Extremely Important

Schedule Assessment And Evaluation Criteria

4. Other Criteria

Please specify

What is your current position in the firm?

How many years of related working experience do you have?

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Appendix A.3: Evaluation Interview

The schedules of EV, JMSB and biological laboratories projects were evaluated using the developed method and its software application (SAE). Being in-charge and overseeing the management and delivery of these projects, you will be requested to provide your assessment as to correctness and validity of the results obtained.

Part A. Deficiencies Identified

For instance, in evaluating the schedule of the JMSB project, the results indicate:

- 369 open ended activities including:
  - Activities regarding shop drawings (such as Reinforcing steel / accessories, Fabricated Metals / foot grilles, Finishing carpentry, Drywall / ceiling / suspension / timber / accessories, etc.)
  - Activities regarding plumbing and mechanical rooms on the floors (from B-2 to 15th floor)
  - Activities regarding fire fighting (protection) test & proof (from B-2 to 15th floor)
  - Almost all activities regarding electrical side rooms on floors (from B-2 to 15th floor)
  - Delivery of the generator
  - Delivery of the transformation equipment
  - Switching the lighting control system

- 184 activities with out of range duration:
  - installation of seismic dampers (duration: 120 days)
  - metallic coating of aluminum panels from the ground floor to level 15 (duration: 135 days)
  - Network installation of the riser of ventilation system (150 days)
  - Main riser for plumbing, heating and cooling systems (150 days)
  - Main riser of fire fighting system (150 days)
  - Installation and connection of fire alarm panel (160 days)
  - Installation of elevators 1 to 3 (120 days)
  - Installation of elevators 4 to 6 (120 days)
  - Delivery of documents (120 days)
- 577 activities with excessive total float:

  Majority of them are the open ended activities with total floats up to 500 days

- A low criticality rate of 5% (although the norm is about 25%)

Do you agree that schedules could be more reliable if they were free from the above issues?

Yes □ No □

Part B. Schedule Assessment Criteria

A set of expressions are included in this section; considering the schedules of the three projects, please answer by “True”, “False” or “Not applicable”

Section 1: Contractual Compliance

Project duration and interim milestones were in compliance with contractual provisions.	True	False	Not applicable
Project phasing and sequencing were in compliance with contractual provisions.	True	False	Not applicable
Number of activities was in compliance with contractual provisions.	True	False	Not applicable
Activities durations were limited to certain days in compliance with contractual provisions.	True	False	Not applicable
Schedule submission date was in compliance with related contractual clause.	True	False	Not applicable
Activities duration were examined to be reasonable	True	False	-
Project scope was covered by the schedule thoroughly.	True	False	-

Section 2: Schedule Development

All aspects of project scope were adequately defined before scheduling.	True	False
Scheduling was based on an approved WBS.	True	False
Scheduling was based on teamwork, the participants (Owner, Engineer, Contractors) involved.	True	False
Subcontractors were involved in schedule development.	True	False

Section 3: Schedule Components

The generated s-curve was in line with similar projects s-curves.	True	False	Wasn't applied
Each phase duration (Engineering, Procurement, etc.) was in line with the duration of similar projects phases.	True	False	Wasn't applied
Assumed working hours for estimating the duration of activities were compatible with those assumed in preparing the cost estimates.	True	False	Wasn't applied
The planned rate of completion per week for each trade was in line with historical norms of similar projects.	True	False	Wasn't applied
Special measures were taken for weather sensitive activities (e.g., adjusting productivity with seasonal conditions)	True	False	-

Part C: Projects' Results

Do you recall …..

Whether the EV project was finished on time?

If not, do you recall the percentage (the length) of the delay?

Whether the JMSB project was finished on time?

If not, do you recall the percentage (the length) of the delay?

Whether the Loyola campus biological laboratories project was finished on time?

If not, do you recall the percentage (the length) of the delay?

Part D: The thresholds (Empirical job logic assessment)

The three projects' schedules were closely examined. It was observed that there are correlations among projects' and major trades' duration as well as their start dates. The major findings are listed below. Please respond to each question by "Agree', "Don't agree" or "Don't know"

Description	Yes	No	NA
Duration of foundation activities is approximately 5% of framing activities duration			
Typically once more than 70% of foundation is performed, framing activities can start			

Duration of framing activities is approximately 35% of project duration			
Typically once framing of five floors is performed, curtain wall activities could start			

Duration of curtain wall activities is approximately 30% of project duration			
Typically once 30% of curtain wall is performed, architectural activities start			
Duration of architectural activities is approximately 40% of project duration			

Typically HVAC and electrical activities start at the same time, once 55% of framing is performed			
Duration of electrical activities (main vertical risers, installation of equipment, electrical rooms on floors, etc.) is approximately 60% of project duration			
Duration of HVAC activities is approximately 65% of project duration			
Once 10% of HVAC is performed, fire fighting activities start			

Duration of fire fighting activities is approximately 30% of project duration			

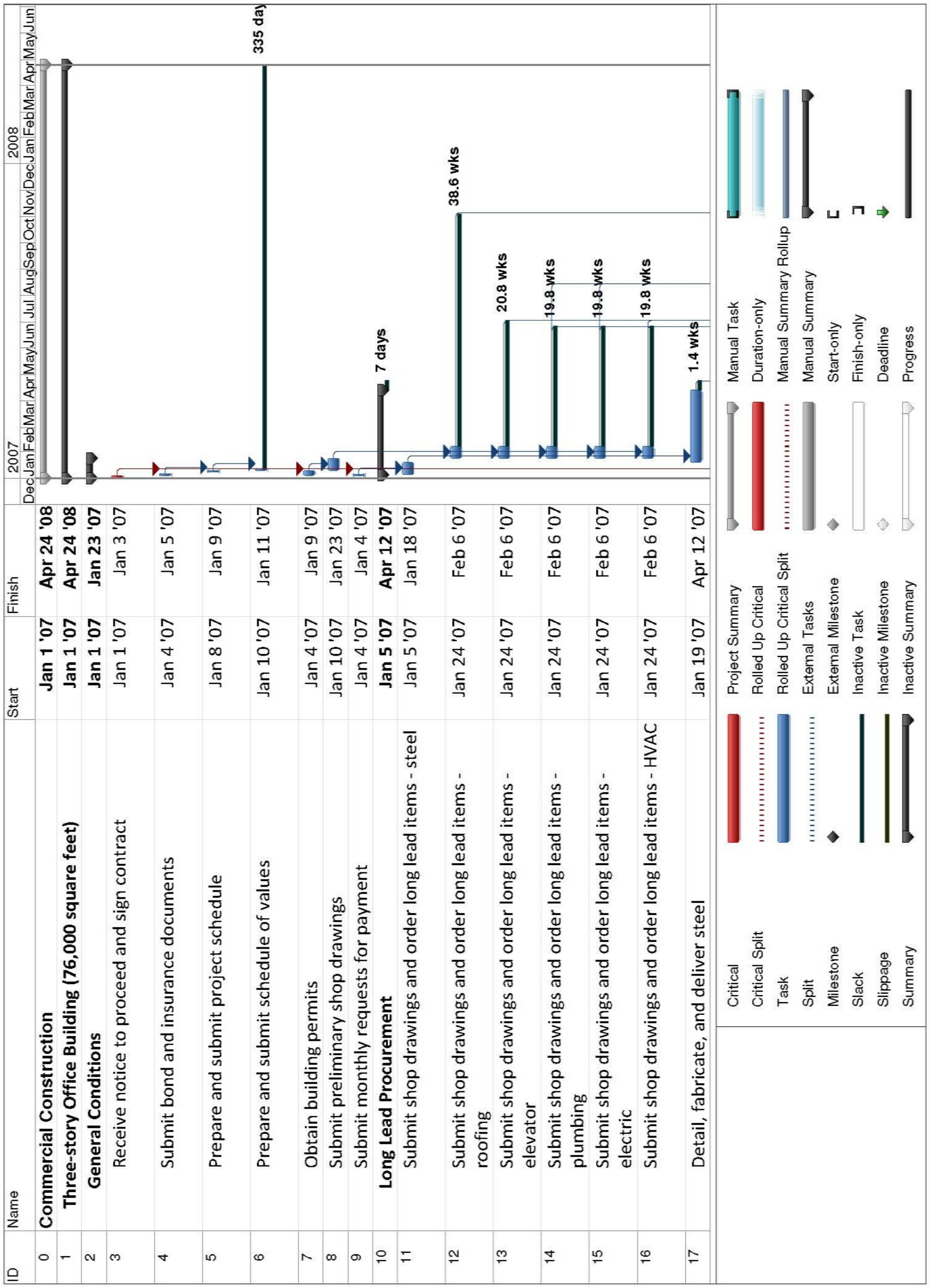
Typically once framing is done, elevator & escalator activities start			
Duration of elevator & escalator activities is approximately 30% of project duration			

APPENDIX B: SAMPLE VB CODE FOR THIRD TIER OF ASSESSMENT

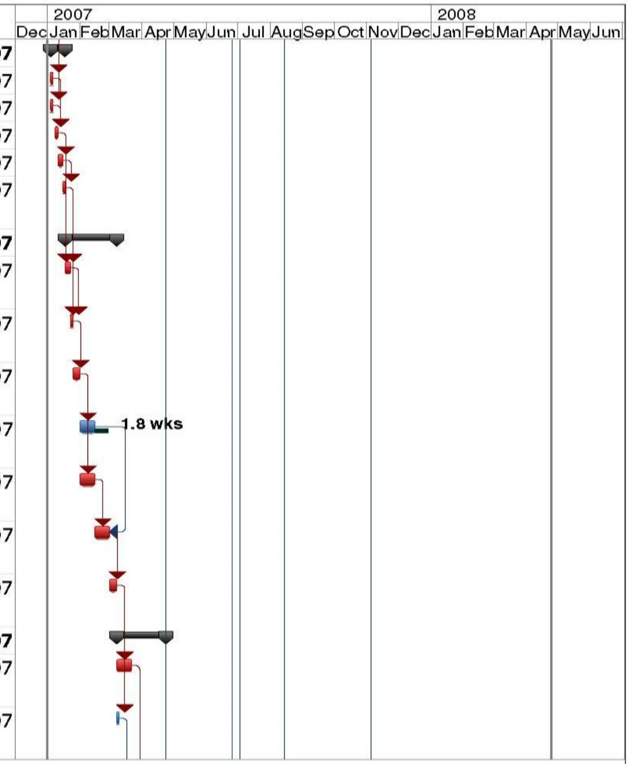
```
E:\Copy of SAE(ver.1.6)\SAE(Schedule Assessment and Evaluation)\SAEMain.vb                    1

Private Sub Level3AssessmentToolStripMenuItem_Click(ByVal sender As System.Object, ByVal e As ↙
    System.EventArgs) Handles Level3AssessmentToolStripMenuItem.Click
        'Code for 3rd level assessment
        Dim objmsp As New MSProject.Application
        ' If no data has been added about productivity and crew size notify the user
        If I = 0 Then
            MsgBox("Enter Activity Data For Productivity And Crew Size Assessment")
            Level3Options.Show()
        Else
            ' Open dialogue box to locate the schedule
            If openMSP.ShowDialog = DialogResult.OK Then
                objmsp.FileOpenEx(openMSP.FileName)
                objmsp.Visible = True
                ' Open Excel File and save DataArray Data to be accessible for the related    ↙
    macro in MSP (The required data for assessment of productivity & crew size: Activity ID,  ↙
    assumed crew size, work volume)
                Dim objexcel As New Excel.Application
                Try

                    objexcel.Visible = False
                    objexcel.Workbooks.Add()
                    Dim M As Integer = 0
                    objexcel.Range("A1").Select()
                    For M = 0 To I
                        objexcel.ActiveCell.FormulaR1C1 = dataArray2(M, 1)
                        objexcel.ActiveCell.Offset(1, 0).Select()
                    Next
                    objexcel.Range("B1").Select()
                    For M = 0 To I
                        objexcel.ActiveCell.FormulaR1C1 = dataArray2(M, 2)
                        objexcel.ActiveCell.Offset(1, 0).Select()
                    Next
                    objexcel.Range("C1").Select()
                    For M = 0 To I
                        objexcel.ActiveCell.FormulaR1C1 = dataArray2(M, 3)
                        objexcel.ActiveCell.Offset(1, 0).Select()
                    Next
                    objexcel.Range("D1").Select()
                    For M = 0 To I
                        objexcel.ActiveCell.FormulaR1C1 = dataArray2(M, 4)
                        objexcel.ActiveCell.Offset(1, 0).Select()
                    Next
                    objexcel.Range("E1").Select()
                    For M = 0 To I
                        objexcel.ActiveCell.FormulaR1C1 = dataArray2(M, 5)
                        objexcel.ActiveCell.Offset(1, 0).Select()
                    Next
                    objexcel.Range("F1").Select()
                    objexcel.ActiveCell.FormulaR1C1 = I
                    objexcel.Workbooks(1).SaveAs("C:\Temp\data3.XLSX")
                    objexcel.Application.Quit()
                    'Me.WindowState = FormWindowState.Minimized
                    'run the macro of the 3rd level assessment in MSP
                    objmsp.Macro("MSPtoVB1.functionLevel3")

                Catch Ex As System.Runtime.InteropServices.COMException
                Finally

                    objexcel = Nothing
                    ' Delete the excel file that has been used to transfer the thresholds
                    System.IO.File.Delete("C:\Temp\data3.XLSX")
                End Try
            End If
        End If
    End Sub
```

APPENDIX C: HYPOTHETICAL PROJECT'S SCHEDULE

A template from MSP 2007 (Microsoft Corporation 2006).

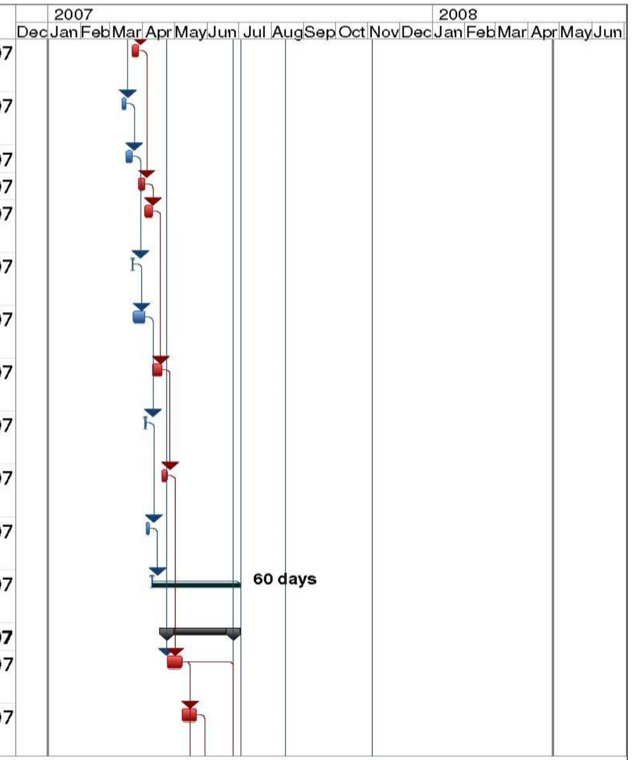


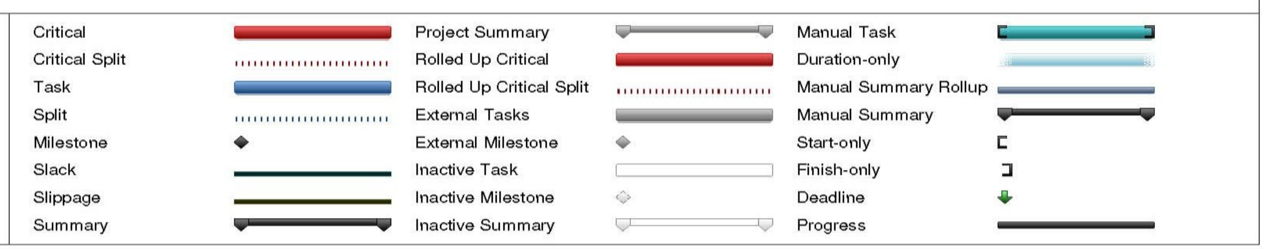
ID	Name	Start	Finish
18	**Mobilize on Site**	**Jan 4 '07**	**Jan 17 '07**
19	Install temporary power	Jan 4 '07	Jan 5 '07
20	Install temporary water service	Jan 4 '07	Jan 5 '07
21	Set up site office	Jan 8 '07	Jan 10 '07
22	Set line and grade benchmarks	Jan 11 '07	Jan 15 '07
23	Prepare site - lay down yard and temporary fencing	Jan 16 '07	Jan 17 '07
24	**Site Grading and Utilities**	**Jan 18 '07**	**Mar 7 '07**
25	Clear and grub site	Jan 18 '07	Jan 22 '07
26	Stone site access and temporary parking area	Jan 23 '07	Jan 24 '07
27	Rough grade site (cut and fill)	Jan 25 '07	Jan 31 '07
28	Install storm drainage	Feb 1 '07	Feb 14 '07
29	Install exterior fire line and building fire riser	Feb 1 '07	Feb 14 '07
30	Perform final site grading	Feb 15 '07	Feb 28 '07
31	Erect building batter boards and layout building	Mar 1 '07	Mar 7 '07
32	**Foundations**	**Mar 8 '07**	**Apr 23 '07**
33	Excavate foundations	Mar 8 '07	Mar 21 '07
34	Excavate elevator pit	Mar 8 '07	Mar 9 '07



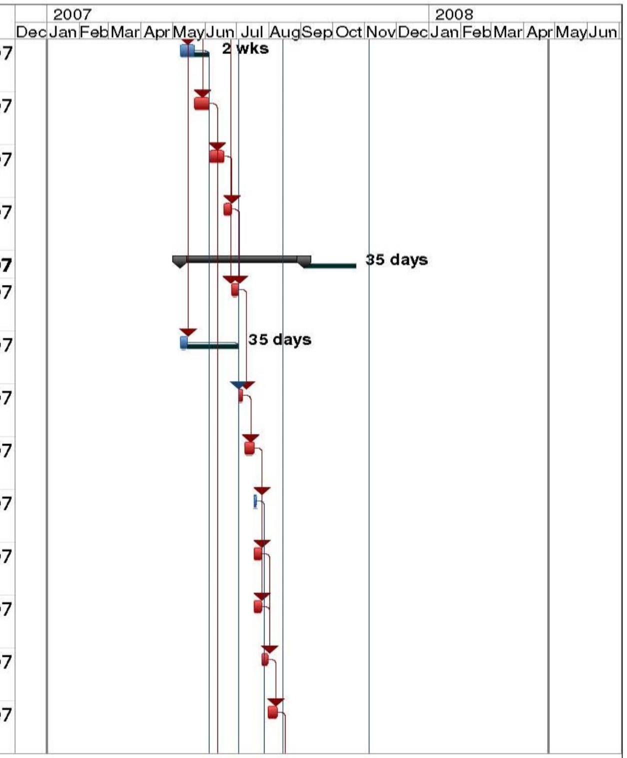
- Critical
- Critical Split
- Task
- Split
- Milestone
- Slack
- Slippage
- Summary
- Project Summary
- Rolled Up Critical
- Rolled Up Critical Split
- External Tasks
- External Milestone
- Inactive Task
- Inactive Milestone
- Inactive Summary
- Manual Task
- Duration-only
- Manual Summary Rollup
- Manual Summary
- Start-only
- Finish-only
- Deadline
- Progress

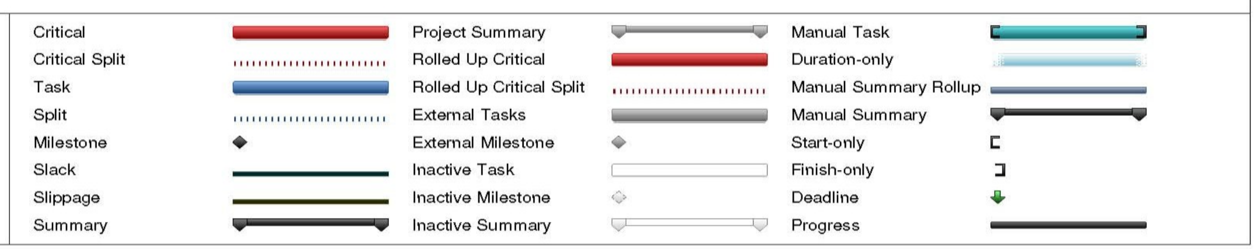
ID	Name	Start	Finish
35	Form column piers and spread foundations	Mar 22 '07	Mar 27 '07
36	Rough-in electric and plumbing in elevator	Mar 12 '07	Mar 15 '07
37	Form elevator pit walls	Mar 16 '07	Mar 21 '07
38	Set reinforcing and anchor bolts	Mar 28 '07	Apr 2 '07
39	Pour column piers and foundations	Apr 3 '07	Apr 9 '07
40	Pour concrete elevator walls	Mar 22 '07	Mar 22 '07
41	Cure elevator wall concrete	Mar 23 '07	Apr 2 '07
42	Cure piers and foundations	Apr 10 '07	Apr 18 '07
43	Strip wall forms	Apr 3 '07	Apr 3 '07
44	Strip column piers and foundation forms	Apr 19 '07	Apr 23 '07
45	Install pneumatic tube in elevator pit	Apr 4 '07	Apr 6 '07
46	Prepare and pour concrete floor in elevator pit	Apr 9 '07	Apr 9 '07
47	**Steel Erection**	**Apr 24 '07**	**Jun 25 '07**
48	Erect steel columns, beams, and joist - 1st and 2nd floors	Apr 24 '07	May 7 '07
49	Erect steel columns, beams, and joist - 3rd floor and roof	May 8 '07	May 21 '07



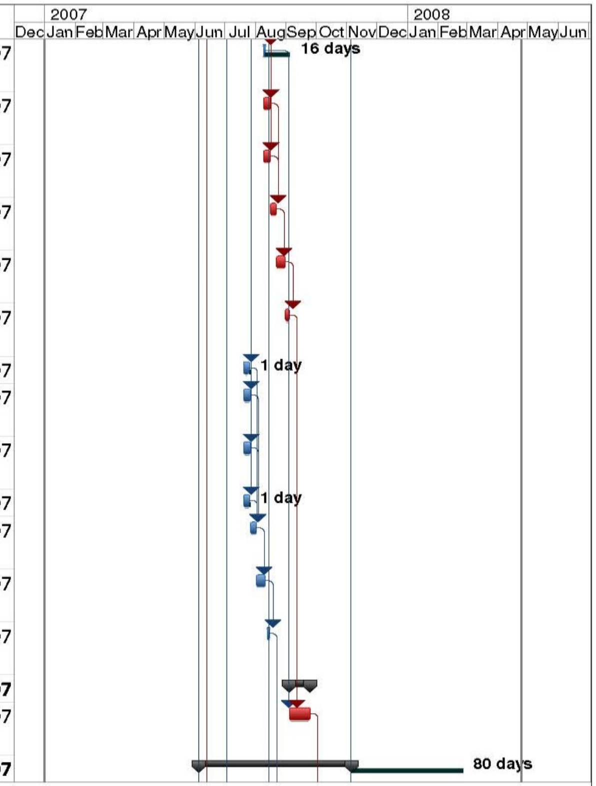


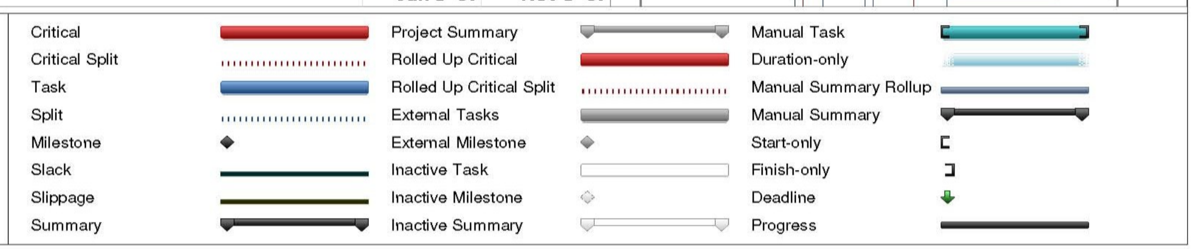
ID	Name	Start	Finish
50	Install miscellaneous iron and bracing - 1st and 2nd floors	May 8 '07	May 21 '07
51	Install miscellaneous iron and bracing - 3rd floor and roof	May 22 '07	Jun 4 '07
52	Install stairs and miscellaneous iron railing	Jun 5 '07	Jun 18 '07
53	Touch-up paint on steel	Jun 19 '07	Jun 25 '07
54	**Form and Pour Concrete - Floors and Roof**	**May 8 '07**	**Sep 3 '07**
55	Form 2nd floor including all floor openings	Jun 26 '07	Jul 2 '07
56	Install rebar and in-floor utilities (including mechanical, electrical, plumbing)	May 8 '07	May 14 '07
57	Pour 2nd floor slab	Jul 3 '07	Jul 6 '07
58	Cure 2nd floor slab	Jul 9 '07	Jul 17 '07
59	Strip forms from 2nd floor slab	Jul 18 '07	Jul 19 '07
60	Form 3rd floor including all floor openings	Jul 18 '07	Jul 24 '07
61	Install rebar and in-floor utilities (including mechanical, electrical, plumbing)	Jul 18 '07	Jul 24 '07
62	Pour 3rd floor slab	Jul 25 '07	Jul 30 '07
63	Cure 3rd floor slab	Jul 31 '07	Aug 8 '07



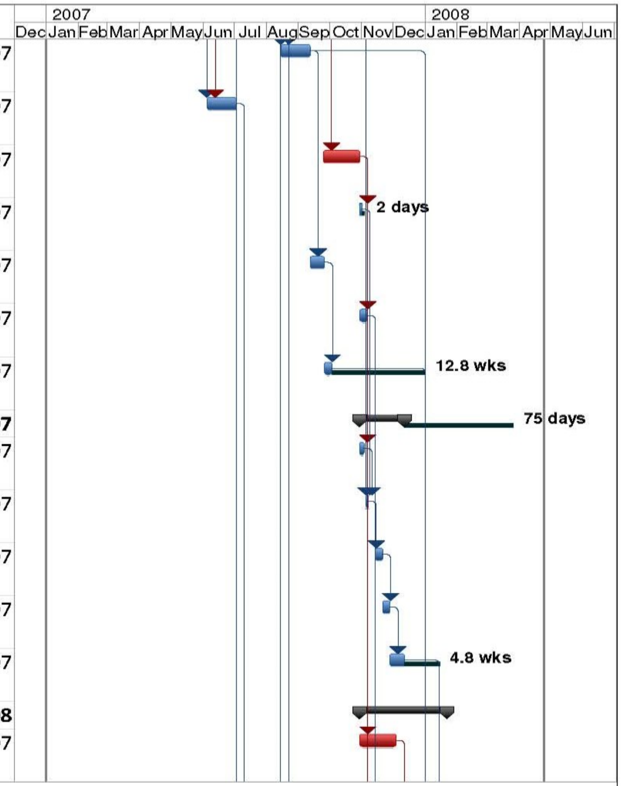


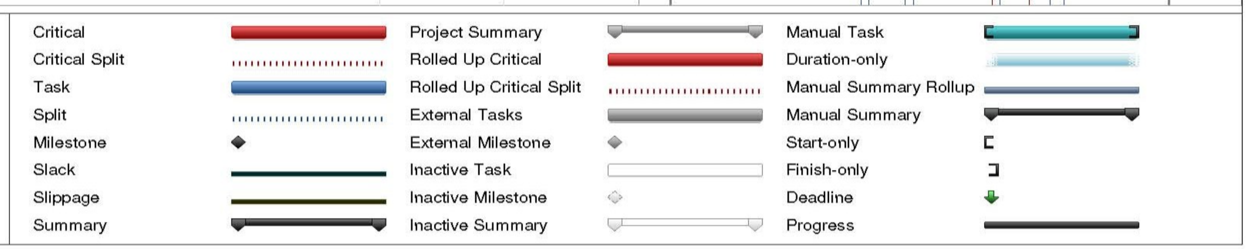
ID	Name	Start	Finish
64	Strip forms from 3rd floor slab	Aug 9 '07	Aug 10 '07
65	Form roof slab including all floor openings	Aug 9 '07	Aug 15 '07
66	Install rebar and in-floor utilities (including mechanical, electrical, plumbing)	Aug 9 '07	Aug 15 '07
67	Pour roof slab	Aug 16 '07	Aug 21 '07
68	Cure roof slab	Aug 22 '07	Aug 30 '07
69	Strip forms from roof slab	Aug 31 '07	Sep 3 '07
70	Form 1st floor	Jul 20 '07	Jul 25 '07
71	Install electrical underground	Jul 20 '07	Jul 26 '07
72	Install plumbing underground	Jul 20 '07	Jul 26 '07
73	Install rebar and in-floor utilities	Jul 20 '07	Jul 25 '07
74	Pour 1st floor slab	Jul 27 '07	Aug 1 '07
75	Cure 1st floor slab	Aug 2 '07	Aug 10 '07
76	Strip forms from 1st floor slab	Aug 13 '07	Aug 14 '07
77	**Carpentry Work**	**Sep 4 '07**	**Sep 24 '07**
78	Install exterior sheathing and metal studs	Sep 4 '07	Sep 24 '07
79	**Masonry Work**	**Jun 5 '07**	**Nov 5 '07**



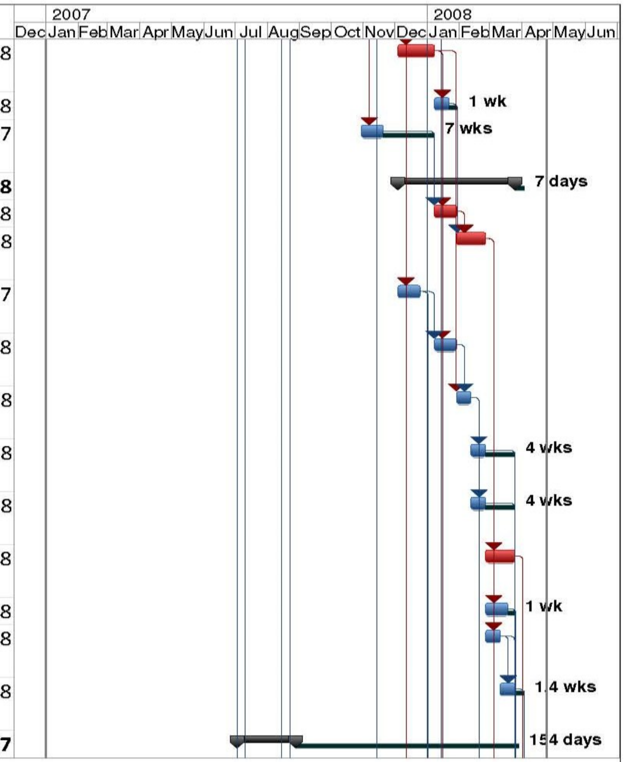


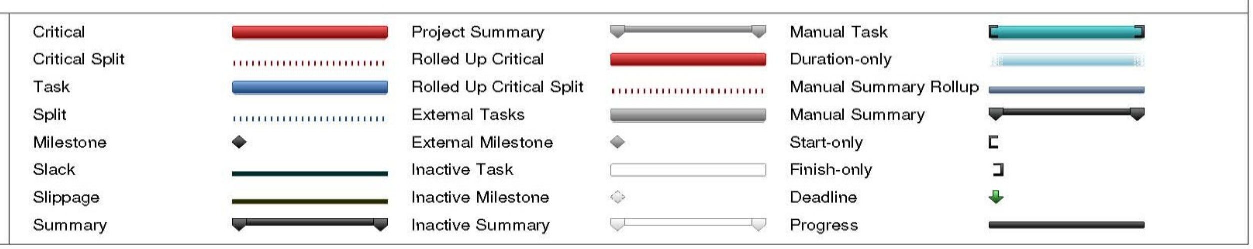
ID	Name	Start	Finish
80	Rough-in plumbing at toilets and masonry walls	Aug 15 '07	Sep 11 '07
81	Lay masonry at core, mechanical, and toilets	Jun 5 '07	Jul 2 '07
82	Install exterior masonry work	Sep 25 '07	Oct 29 '07
83	Install roof drains	Oct 30 '07	Oct 31 '07
84	Install tile in toilet rooms	Sep 12 '07	Sep 25 '07
85	Clean masonry	Oct 30 '07	Nov 5 '07
86	Clean toilet room tile	Sep 26 '07	Oct 2 '07
87	**Roofing**	**Oct 30 '07**	**Dec 11 '07**
88	Install flashing at parapet walls	Oct 30 '07	Nov 2 '07
89	Pour lightweight concrete roof fill	Nov 5 '07	Nov 6 '07
90	Install seamless roofing material	Nov 14 '07	Nov 20 '07
91	Spread stone ballast on seamless roof	Nov 21 '07	Nov 27 '07
92	Set rooftop equipment	Nov 28 '07	Dec 11 '07
93	**Window Wall and Store Front Closures**	**Oct 30 '07**	**Jan 21 '08**
94	Install window wall aluminum and glass	Oct 30 '07	Dec 3 '07



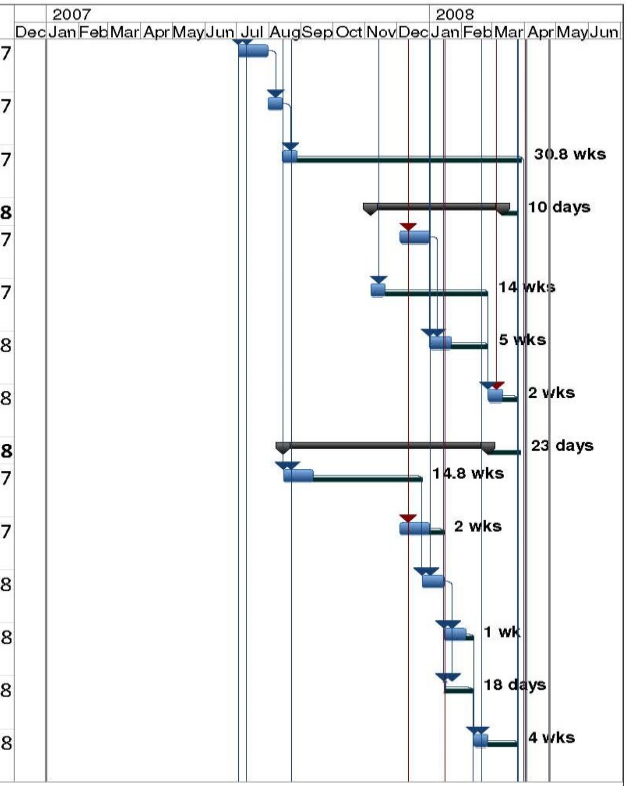


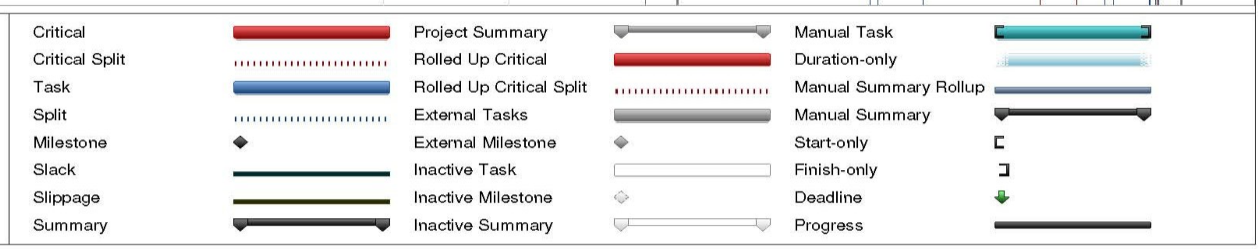
ID	Name	Start	Finish
95	Install interior stud walls and drywall	Dec 4 '07	Jan 7 '08
96	Install interior doors and hardware	Jan 8 '08	Jan 21 '08
97	Install store front doors and hardware	Oct 30 '07	Nov 19 '07
98	**Building Finishes**	**Dec 4 '07**	**Mar 24 '08**
99	Install millwork and wood trim	Jan 8 '08	Jan 28 '08
100	Paint walls and woodwork	Jan 29 '08	Feb 25 '08
101	Install conduit at ceiling plenum space	Dec 4 '07	Dec 24 '07
102	Install duct in ceiling plenum space	Jan 8 '08	Jan 28 '08
103	Install ceiling grid	Jan 29 '08	Feb 11 '08
104	Install ceiling tile	Feb 12 '08	Feb 25 '08
105	Hang wallpaper	Feb 12 '08	Feb 25 '08
106	Install building carpet	Feb 26 '08	Mar 24 '08
107	Install hardware and accessories	Feb 26 '08	Mar 17 '08
108	Complete interior and exterior sod and plantings	Feb 26 '08	Mar 10 '08
109	Pave, curb, and stripe parking lot	Mar 11 '08	Mar 24 '08
110	**Elevators**	**Jul 3 '07**	**Aug 27 '07**



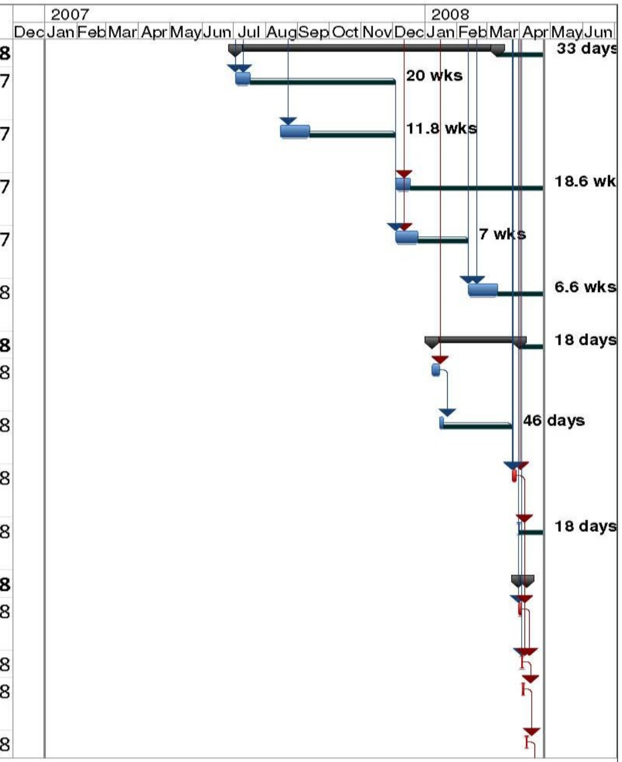


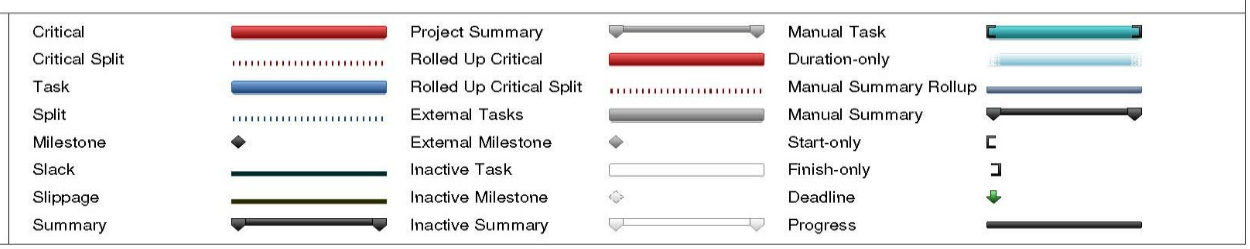
ID	Name	Start	Finish
111	Set elevator equipment in shafts	Jul 3 '07	Jul 30 '07
112	Set equipment in mechanical room	Jul 31 '07	Aug 13 '07
113	Test and align doors and equipment	Aug 14 '07	Aug 27 '07
114	**Plumbing**	**Nov 6 '07**	**Mar 10 '08**
115	Rough-in plumbing in drywall walls	Dec 4 '07	Dec 31 '07
116	Tie-in fire line riser and set valves	Nov 6 '07	Nov 19 '07
117	Set plumbing fixtures and trim	Jan 1 '08	Jan 21 '08
118	Flush, test, and clean piping and fixtures	Feb 26 '08	Mar 10 '08
119	**Electrical**	**Aug 15 '07**	**Feb 25 '08**
120	Rough-in electrical in masonry walls	Aug 15 '07	Sep 11 '07
121	Rough-in electrical in drywall walls	Dec 4 '07	Dec 31 '07
122	Pull wire in conduit and set area transformers	Dec 25 '07	Jan 14 '08
123	Install and terminate electrical devices	Jan 15 '08	Feb 4 '08
124	Make electrical terminations for HVAC equipment	Jan 15 '08	Jan 16 '08
125	Install light fixtures - test and clean	Feb 12 '08	Feb 25 '08



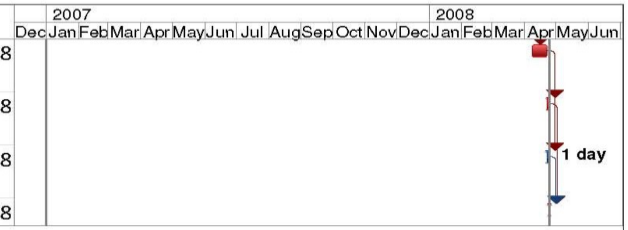


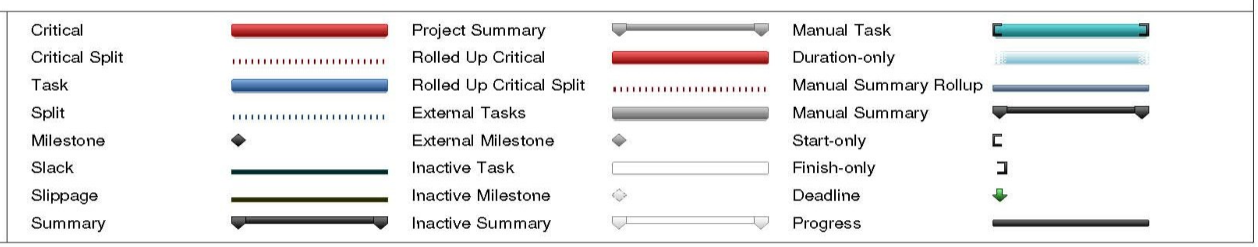
ID	Name	Start	Finish
126	**Heating and Ventilating - AC**	**Jul 3 '07**	**Mar 10 '08**
127	Set equipment in mechanical room	Jul 3 '07	Jul 16 '07
128	Rough-in mechanical in masonry walls	Aug 15 '07	Sep 11 '07
129	Rough-in mechanical in drywall walls	Dec 4 '07	Dec 17 '07
130	Install duct in building chase	Dec 4 '07	Dec 24 '07
131	Set HVAC trim and test and balance system	Feb 12 '08	Mar 10 '08
132	**Final Clean-up and Occupancy**	**Jan 8 '08**	**Mar 31 '08**
133	Install hard tile flooring in common areas	Jan 8 '08	Jan 14 '08
134	Clean hard tile floors	Jan 15 '08	Jan 18 '08
135	Remove debris from building and do final clean-up	Mar 25 '08	Mar 28 '08
136	Substantial completion date	Mar 31 '08	Mar 31 '08
137	**Complete Final Inspections**	**Mar 31 '08**	**Apr 7 '08**
138	Complete elevator inspection and certification	Mar 31 '08	Apr 2 '08
139	Perform architect's inspection	Apr 3 '08	Apr 3 '08
140	Perform local building agency inspection	Apr 4 '08	Apr 4 '08
141	Perform fire marshal's inspection	Apr 7 '08	Apr 7 '08





ID	Name	Start	Finish
142	Complete punch list items from all inspections	Apr 8 '08	Apr 21 '08
143	Obtain certificate of occupancy	Apr 22 '08	Apr 23 '08
144	Issue final completion documents including warranties	Apr 22 '08	Apr 22 '08
145	Issue final request for payment	Apr 24 '08	Apr 24 '08





APPENDIX D: ASSESSMENT REPORTS

SAE (Schedule Assessment & Evaluation)

First Level Assessment & Evaluation Result

Project Name: Sci sched 17-3Lots 2002-05-06.mpp

General Information

Project duration = 1004 days
Total number of activities = 141

Total number of critical activities = 41
Maximum suggested activity duration = 90 Days
Total number of activities with out of range duration = 24
Maximum suggested critical activity duration = 30 Days
Total number of critical activities with excessive duration = 18
Total number of constraints = 2
Total number of relationships = 244
Relationship per activity = 1.73
Number of open ended activities = 3
Standard deviation of activities duration = 41
Criticality rate(duration of activities) = 14%
Criticality rate (number of activities) = 29%
Near criticality rate = 4%
Total number of activities with excessive total float = 47
Total number of activities with negative total float = 0
This schedule is not loaded with resources
This schedule is not loaded with cost

Recommendations

Control duration of all out of range activities. Breaking down long activities and/or combining short activities in order to have a manageable schedule is suggested

Control duration of all long critical activities. Breaking down long critical activities to have a more manageable critical path is suggested

No open ended activity is allowed. Link all open ended activities to appropriate successor/predecessor

There are considerable fluctuations in activities duration. Control activities duration to be reasonable and/or consistency of schedule level of details

Control all critical activities to be reasonable and/or have a predecessor reflecting a physical dependency

Control all activities with excessive total float to have all necessary dependencies

The schedule is strictly suggested to be loaded with resources

The schedule is suggested to be loaded with cost

Detailed Information

Activities With Out Of Range Duration

Activity Name	Activity ID	Activity Duration(Days)
Tender Evaluation Excav. & Shoring	45	2
Award of Contract Excav. & Shoring	46	4
Plans & Specs Building Tender at 100%	53	100
F/D elevators	83	100
F/D curtain wall & fenestration	84	100
F/D doors & hardware	86	120
F/D lab equipment	95	120
Interior perimeter masonary	132	130
Curtain wall & fenestration	137	140
Rough plumbing	144	100
Rough ventilation	146	130
Rough electrical	147	120
Concrete blocks	148	100
V.A. Rough Work	159	160
Gypse wall finishes	163	160
Ceilings	165	120
Misc. Metals	166	120
Built-ins	167	100
Doors & hardware	170	100
Painting	171	120
Ventilation finishes	174	100
Controls	175	100
Electrical finishes	176	100
V.A. Fit-Up	188	260

Critical Activities With excessive Duration

Activity Name	Activity ID	Activity Duration(Days)
Architectural Design- Part 1	15	45
Architectural Design- Part 2	16	35
Structural	18	40
Mechanical	19	40
Electrical	20	40
Mechanical	24	41
Electrical	25	41
Excavation Permit	31	53
Plans & Specs Excav. & Shoring at 100%	43	51
Piling	102	40
Shoring (2800m2)	103	80
Excavation (earth 47500m3, roc13433m3)	104	90
Ground floor slab +/-5062sm	111	35
Rough plumbing	144	100
V.A. Rough Work	159	160
V.A. Fit-Up	188	260
Commissioning Visual arts	196	60
Move in Visual Arts	197	60

Open Ended Activities

Activity Name	Activity ID
Stairs	149
Deficiencies Visual Arts	195
Move in Visual Arts	197

Activities With Excessive Total Float

Activity Name	Activity ID	Total Float
Concordia Prelim. Design & Budget Approval	28	182
Construction Permit	32	182
Cost Estimate	37	151
Concordia Constn. Docs. Approval	39	151
S/D structural steel	66	236
S/D elevators	67	386
S/D curtain wall & fenestration	68	146
S/D door frames	69	316
S/D doors & hardware	70	356

S/D sprinklers	72	306
S/D ventilation	73	206
S/D electricity	74	246
S/D misc. metals	75	346
S/D counters	76	386
S/D millwork	77	396
S/D toilet partitions	78	446
S/D lab equipment	79	376
F/D structural steel	82	236
F/D elevators	83	386
F/D curtain wall & fenestration	84	146
F/D door frames	85	316
F/D doors & hardware	86	356
F/D sprinklers	88	306
F/D ventilation	89	206
F/D electricity	90	246
F/D misc. metals	91	346
F/D counters	92	386
F/D millwork	93	396
F/D toilet partitions	94	446
F/D lab equipment	95	376
Backfill exterior	112	545
Level 16 slab +/-1686sm	127	170
Level 17 slab +/-1050sm (Mech.PH floor)	128	170
Exterior masonary	136	330
Roof membrane	138	150
Rough sprinklers	145	240
Rough ventilation	146	215
Rough electrical	147	155
Concrete blocks	148	315
Stairs	149	405
Door frames	151	140
Rough elevators	152	205
Electrical entry	155	246
Elect. Sub-station	156	246
Mech. equip't P.H.	157	150
Ceilings	165	110
Landscaping	183	160

Activities With Negative Total Float

Activity Name	Activity ID

SAE (Schedule Assessment & Evaluation)

First Level Assessment & Evaluation Result

Project Name: Echeancier_approb_20070206.mpp

General Information

Project duration = 543 days
Total number of activities = 870

Total number of critical activities = 40
Maximum suggested activity duration = 90 Days
Total number of activities with out of range duration = 184
Maximum suggested critical activity duration = 30 Days
Total number of critical activities with excessive duration = 16
Total number of constraints = 57
Total number of relationships = 946
Relationship per activity = 1.09
Number of open ended activities = 369
Standard deviation of activities duration = 18
Criticality rate(duration of activities) = 4%
Criticality rate (number of activities) = 5%
Near criticality rate = 3%
Total number of activities with excessive total float = 502
Total number of activities with negative total float = 0
This schedule is not loaded with resources
This schedule is not loaded with cost

Recommendations

Control duration of all out of range activities. Breaking down long activities and/or combining short activities in order to have a manageable schedule is suggested

Control duration of all long critical activities. Breaking down long critical activities to have a more manageable critical path is suggested

Control all constraints to be in compliance with contractual clauses and/or be reasonable

Control job logic and/or activities dependencies to be reasonable

No open ended activity is allowed. Link all open ended activities to appropriate successor/predecessor

There are considerable fluctuations in activities duration. Control activities duration to be reasonable and/or consistency of schedule level of details

Control all activities with excessive total float to have all necessary dependencies

The schedule is strictly suggested to be loaded with resources
The schedule is suggested to be loaded with cost

Detailed Information

Activities With Out Of Range Duration

Activity Name	Activity ID	Activity Duration(Days)
OCTROI DU CONTRAT À VERREAULT	1	1
PLANS ÉMIS POUR CONSTRUCTION	3	1
PRÉSENTATION DE LA DEMANDE D'OUVERTURE DE CHANTIER A LA CSST	5	1
PRÉSENTATION DE L'ÉCHÉANCIER PRÉLIMINAIRE	6	1
PRÉSENTATION DE LA LISTE DES DESSINS D'ATELIERS	7	1
PRÉSENTATION DE LA LISTE DES VALEURS DU CONTRAT	8	1
PRÉSENTATION U PROGRAMME DE PRÉVENTION	9	1
Coupe de rue no. 1 rue Guy	68	1
Coupe de rue no. 2 rue Guy	69	1
Coupe de rue no. 3 boul. de Maisonneuve	70	1
Réfection trottoirs et asphalte rues Guy et Maisonneuve	72	1
Excavations exploratoires	74	1
Excavation/remblai du radier	77	2
Dalle de propreté	78	1
Membrane sous radier	79	1
Coffrage/bétonnage du radier	80	2
Membrane d'imperméabilisation	83	2
Béton de protection et remblais	84	2
Réfection de la surface de la ruelle	85	3
Excavations exploratoires	87	4
Construction du pont temporaire	89	4
Installation des ancrages au roc 1er rang	92	2
Excavation/remblai du radier	95	3
Plomberie sous dalle	96	1
Électricité sous dalle	97	4
Dalle de propreté	98	2
Membrane sous radier	99	2
Coffrage/bétonnage du radier	100	3
Membrane d'imperméabilisation	103	2

Béton de protection	104	2
Remblai	105	2
Infrastructure de route + asphalte	106	4
Installation des gaines de post-tension Axe ''D''	117	2
Installation des gaines de post-tension Axe ''D''	122	2
Système de support de la poutre en post-tension axe ''D''	128	4
Installation des gaines de post-tension Axe ''D''	129	2
Installation des gaines de post-tension Axe ''D''	134	2
Installation des gaines de post-tension Axe ''D''	139	2
Installation des gaines de post-tension Axe ''D''	144	2
Dalle	190	4
Parement de pierre extérieure au rez-de-chaussée	200	1
Niveaux B-2 @ niveau 4	204	1
Niveau 5 @ niveau 10	205	1
Niveau 11 @ niveau 16	206	1
Niveaux B-2 @ niveau 4	208	1
Niveau 5 @ niveau 10	209	1
Niveau 11 @ niveau 16	210	1
Escalier no. 3	212	1
Escalier no. 4	213	1
Escalier no. 5	214	1
Escalier no. 6	215	1
Escalier no. 7	216	1
Escalier no. 9	217	1
Escalier no. 10	218	1
Escalier no. 11	219	1
Escalier no. 12	220	1
Escalier no. 13	221	1
Escalier no. 14	222	1
Escalier no. 15 & 16	223	1
Escalier no. 17	224	1
Escalier no. 18	225	1
Escalier no. 19	226	1
Escalier no. 20	227	1
Escalier no. 21	228	1
Escalier no. 22	229	1
Escalier no. 23	230	1
Echelles fosses d'ascenseurs	231	1
Garde-corps terrasse niveau 4 & 15	232	1
Cadres d'acier inoxydable aux portes d'ascenseurs	233	1
Garde-corps et support des pare-fumée dans les atriums	234	1

Plaques pliées à la base des mur rideau du rez-de-chausée	235	1
Cadrage d'acier des vestibules 001 & 199 & rdc	236	1
Linteau de support du mur de pierre extérieure	237	1
Bollars du débarcadère	238	1
Métal tramé des escaliers 6 & 10 & 15 & 16	239	1
Acier préfini des comptoirs de services	240	1
Sabots en acier pour garde-corps des atriums et terrasses	241	1
Plinthes en acier inoxydable	242	1
Contre-marches des gradins et des salles de classes	243	1
Cadres et supports à craie pour tableaux	244	1
Caillebotis du débarcadère	245	1
Pose des amortisseurs seismiques aux étages	248	120
Niveau 4	250	3
Niveau 5	251	3
Niveau 6	252	3
Niveau 7	253	3
Niveau 8	254	3
Niveau 9	255	3
Niveau 10	256	3
Niveau 11	257	3
Niveau 12	258	3
Niveau 13	259	3
Niveau 14	260	3
Niveau 15	261	3
Niveau 16	262	3
Toit bas	263	3
Panneaux d'aluminium du rez-de-chaussée @ niveau 15	292	135
ISOLATION THERMIQUE	322	1
Démarrage des systèmes	358	3
Nettoyage final	360	1
Démarrage des systèmes	394	3
Nettoyage final	396	2
Blocs de béton des gradins rez-de-chausée	400	3
Pontage d'acier et béton des gradins rez-de-chausée	401	2
Béton des gradins du rez-de-chausée	402	2
Démarrage des systèmes	435	3
Nettoyage final	437	2
Blocs de béton des gradins niveau 2	440	3
Pontage d'acier et béton des gradins niveau 2	441	2
Béton des gradins du niveau 2	442	2

Démarrage des systèmes	474	3
Nettoyage final	476	2
Blocs de béton des gradins niveau 3	479	3
Pontage d'acier et béton des gradins niveau 3	480	2
Béton des gradins du niveau 3	481	2
Démarrage des systèmes	513	3
Nettoyage final	515	2
Démarrage des systèmes	548	3
Nettoyage final	550	2
Démarrage des systèmes	586	3
Nettoyage final	588	2
Blocs de béton des gradins niveau 6	591	4
Pontage d'acier et béton des gradins niveau 6	592	3
Béton des gradins du niveau 6	593	3
Démarrage des systèmes	623	3
Nettoyage final	625	2
Pose des portes et de la quincaillerie	633	3
Nettoyage final	639	2
Pose des portes et de la quincaillerie	647	3
Nettoyage final	653	2
Pose des portes et de la quincaillerie	661	3
Mise en marche et balancement final	666	3
Nettoyage final	667	2
Pose des portes et de la quincaillerie	675	3
Nettoyage final	681	2
Panneaux insonorisants	715	2
Démarrage des systèmes	717	3
Nettoyage final	719	2
Panneaux insonorisants	750	2
Démarrage des systèmes	752	3
Nettoyage final	754	2
Panneaux insonorisants	784	2
Démarrage des systèmes	786	3
Nettoyage final	788	2
Panneaux insonorisants	819	2
Démarrage des systèmes	821	3
Nettoyage final	823	2
Panneaux insonorisants	855	2
Démarrage des systèmes	857	3
Nettoyage final	859	2
Compacteur à déchets	862	1
Équipement et plate-forme de quais	863	1
Grilles gratte-pieds	864	1

Système de lavage de vitres	865	1
Installation du réseau de gaines verticales (risers)	868	150
Conduites principales verticales (risers)	895	150
Conduites principales verticales (risers)	925	150
Niveau B-2	929	2
Niveau B-1	930	2
Niveau rez-de-chaussée	931	2
Niveau 2	932	2
Niveau 3	933	2
Niveau 4	934	2
Niveau 5	935	2
Niveau 6	936	2
Niveau 7	937	2
Niveau 8	938	2
Niveau 9	939	2
Niveau 10	940	2
Niveau 11	941	2
Niveau 12	942	2
Niveau 13	943	2
Niveau 14	944	2
Niveau 15	945	2
Mise en marche finale	946	1
Installation des conduites principales verticales (risers)	949	150
Branchement à l'artère existante au Pavillon de Génie	951	1
Installation et raccordement du panneau d'alarme incendie	972	160
Ascenseurs 1@3	983	120
Ascenseurs 4@6	984	120
Test du département d'incendie de la Ville de Montréal	987	3
Reception provisoire	989	1
Remise des documents et garanties	990	120
Réception définitive	991	1

Critical Activities With excessive Duration

Activity Name	Activity ID	Activity Duration(Days)
Acier d'armature / accessoires	14	80
Maconnerie / accessoires / mortier / pierre et blocs	17	40
Acier de charpente / poutrelles / pontage	18	60
Métaux ouvrés / grilles gratte-pieds	19	60
Menuiserie de finition	20	60

Parements métalliques / aluminium / zinc	23	60
Portes / cadres / quincaillerie	25	40
Vitrage intérieur	29	70
Mur rideau / entrées d'aluminium	30	90
Accessoires et cloisons de toilettes	38	35
Ascenseurs / escaliers mobiles	46	70
Plomberie	47	60
Ventilation	48	80
Gicleurs	49	60
Electricité	50	60
Remise des documents et garanties	990	120

Open Ended Activities

Activity Name	Activity ID
OCTROI DU CONTRAT À VERREAULT	1
PLANS ÉMIS POUR CONSTRUCTION	3
OCTROI DES SOUS-CONTRATS	4
PRÉSENTATION DE LA DEMANDE D'OUVERTURE DE CHANTIER A LA CSST	5
PRÉSENTATION DE L'ÉCHÉANCIER PRÉLIMINAIRE	6
PRÉSENTATION DE LA LISTE DES DESSINS D'ATELIERS	7
PRÉSENTATION DE LA LISTE DES VALEURS DU CONTRAT	8
PRÉSENTATION U PROGRAMME DE PRÉVENTION	9
Soutennement / remblais / services extérieurs / accessoires	12
Formules de béton	13
Acier d'armature / accessoires	14
Durcisseur / scellant	15
Précontrainte	16
Maconnerie / accessoires / mortier / pierre et blocs	17
Acier de charpente / poutrelles / pontage	18
Métaux ouvrés / grilles gratte-pieds	19
Menuiserie de finition	20
Membranes d'étanchéité / pare-air-vapeur / calfeutrages	21
Isolants / panneaux / coupe-feu / matelas	22
Parements métalliques / aluminium / zinc	23
Couvertures / solin / ballast / accessoires	24
Portes / cadres / quincaillerie	25
Portes de garage multi-lames	26
Cloisons pliantes	27

Volets et portes à enroulement	28
Vitrage intérieur	29
Mur rideau / entrées d'aluminium	30
Gypse / plafond / suspension / colombage / accessoires	31
Céramique	32
Plafonds et panneaux Barrisol	33
Revêtements souples / moulures / accessoires	34
Panneaux insonorisants	35
Peinture	36
Tableaux d'écriture et d'affichage	37
Accessoires et cloisons de toilettes	38
Planchers surélevés	39
Armoires vestiaires	40
Sièges d'auditorium	41
Cloisons pliantes	42
Système de lavage de vitre	43
Compacteur à déchets	44
Stores à enroulement	45
Ascenseurs / escaliers mobiles	46
Plomberie	47
Ventilation	48
Gicleurs	49
Electricité	50
Remblais côté rues	55
Installation des ancrages au roc 2eme rang	60
Pose des barbacannes	66
Coupe de rue no. 1 rue Guy	68
Coupe de rue no. 2 rue Guy	69
Coupe de rue no. 3 boul. de Maisonneuve	70
Excavation/arrasement des pieux du batiment/remblais.	71
Réfection trottoirs et asphalte rues Guy et Maisonneuve	72
Réfection de la surface de la ruelle	85
Excavations exploratoires	87
Support des services existants	91
Infrastructure de route + asphalte	106
Installation et mise en marche des 2 grues	110
Imperméabilisation des murs de fondation périphériques	112
Installation des gaines de post-tension Axe ''D''	117
Installation des gaines de post-tension Axe ''D''	122

Imperméabilisation des murs de fondation périphériques	123
Système de support de la poutre en post-tension axe ''D''	128
Installation des gaines de post-tension Axe ''D''	129
Installation des gaines de post-tension Axe ''D''	134
Installation des gaines de post-tension Axe ''D''	139
Installation des gaines de post-tension Axe ''D''	144
Passage des câbles et post-tension	145
Bases de mécanique et de propreté	193
Rez-de chaussée murs extérieurs	198
Débarcadère	199
Parement de pierre extérieure au rez-de-chaussée	200
Niveaux B-2 @ niveau 4	204
Niveau 5 @ niveau 10	205
Niveau 11 @ niveau 16	206
Niveaux B-2 @ niveau 4	208
Niveau 5 @ niveau 10	209
Niveau 11 @ niveau 16	210
Escalier no. 3	212
Escalier no. 4	213
Escalier no. 5	214
Escalier no. 6	215
Escalier no. 7	216
Escalier no. 9	217
Escalier no. 10	218
Escalier no. 11	219
Escalier no. 12	220
Escalier no. 13	221
Escalier no. 14	222
Escalier no. 15 & 16	223
Escalier no. 17	224
Escalier no. 18	225
Escalier no. 19	226
Escalier no. 20	227
Escalier no. 21	228
Escalier no. 22	229
Escalier no. 23	230
Echelles fosses d'ascenseurs	231
Garde-corps terrasse niveau 4 & 15	232
Cadres d'acier inoxydable aux portes d'ascenseurs	233
Garde-corps et support des pare-fumée dans les atriums	234

Plaques pliées à la base des mur rideau du rez-de-chausée	235
Cadrage d'acier des vestibules 001 & 199 & rdc	236
Linteau de support du mur de pierre extérieure	237
Bollars du débarcadère	238
Métal tramé des escaliers 6 & 10 & 15 & 16	239
Acier préfini des comptoirs de services	240
Sabots en acier pour garde-corps des atriums et terrasses	241
Plinthes en acier inoxydable	242
Contre-marches des gradins et des salles de classes	243
Cadres et supports à craie pour tableaux	244
Caillebotis du débarcadère	245
Pose des amortisseurs seismiques aux étages	248
Niveau 5	251
Niveau 6	252
Niveau 7	253
Niveau 8	254
Niveau 9	255
Niveau 10	256
Niveau 11	257
Niveau 12	258
Niveau 13	259
Niveau 14	260
Niveau 15	261
Niveau 16	262
Toit bas	263
Charpente des tours d'eau	264
Solins	276
Protection	277
Solins	281
Solins	286
Protection	287
Marquise niveau 4	291
Panneaux d'aluminium du rez-de-chaussée @ niveau 15	292
Salle de mécanique élévation est	298
Salle de mécanique élévation nord	299
Panneaux d'acier du niveau 2 @ niveau 4 élévation ouest	300
Finition des murs rideaux	320
ISOLATION THERMIQUE	322
'Brut'' gicleurs / lignes principales horizontales & distribution	329

Plomberie / distribution étage	331
Vitrage intérieur	334
Pose des portes et de la quincaillerie	342
Volets et portes à enroulement	343
Finis dalle du hall d'ascenseurs	345
Électricité / finition	351
Cloisons et divisions de toilettes	352
Sièges d'amphithéatre et des classes	357
Mise en marche et balancement final	359
Nettoyage final	360
'Brut'' gicleurs / lignes principales horizontales & distribution	366
Plomberie / distribution étage	368
Vitrage intérieur	371
Suspension des plafonds	372
Pose des portes et de la quincaillerie	379
Finis dalle du hall d'ascenseurs	381
Cloisons et divisions de toilettes	388
Sièges d'amphithéatre et des classes	393
Mise en marche et balancement final	395
Nettoyage final	396
Portes de garage multi-lames	399
Béton des gradins du rez-de-chausée	402
'Brut'' gicleurs / lignes principales horizontales & distribution	406
Plomberie / distribution étage	408
Vitrage intérieur	411
Pose des portes et de la quincaillerie	419
Volets et portes à enroulement	420
Finis dalle du hall d'ascenseurs	422
Cloisons et divisions de toilettes	429
Sièges d'amphithéatre et des classes	433
Mise en marche et balancement final	436
Nettoyage final	437
Béton des gradins du niveau 2	442
'Brut'' gicleurs / lignes principales horizontales & distribution	446
Plomberie / distribution étage	448
Vitrage intérieur	451
Suspension des plafonds	452
Pose des portes et de la quincaillerie	459
Revêtements de plancher souples	460
Finis dalle du hall d'ascenseurs	461

Ébénisterie	462
Cloisons et divisions de toilettes	468
Sièges d'amphithéatre et des classes	472
Mise en marche et balancement final	475
Nettoyage final	476
Béton des gradins du niveau 3	481
'Brut'' gicleurs / lignes principales horizontales & distribution	485
Plomberie / distribution étage	487
Vitrage intérieur	490
Suspension des plafonds	491
Pose des portes et de la quincaillerie	498
Ébénisterie	501
Cloisons et divisions de toilettes	507
Sièges d'amphithéatre et des classes	511
Mise en marche et balancement final	514
Nettoyage final	515
'Brut'' gicleurs / lignes principales horizontales & distribution	521
Plomberie / distribution étage	523
Vitrage intérieur	526
Pose des portes et de la quincaillerie	534
Volets et portes à enroulement	535
Plancher surélevé	536
Ébénisterie	539
Cloisons et divisions de toilettes	545
Mise en marche et balancement final	549
Nettoyage final	550
Béton des gradins du niveau 5	555
'Brut'' gicleurs / lignes principales horizontales & distribution	559
Plomberie / distribution étage	561
Vitrage intérieur	564
Suspension des plafonds	565
Pose des portes et de la quincaillerie	572
Ébénisterie	575
Cloisons et divisions de toilettes	581
Mise en marche et balancement final	587
Nettoyage final	588
Béton des gradins du niveau 6	593
'Brut'' gicleurs / lignes principales horizontales & distribution	597
Plomberie / distribution étage	599

Vitrage intérieur	602
Suspension des plafonds	603
Pose des portes et de la quincaillerie	610
Ébénisterie	613
Cloisons et divisions de toilettes	619
Mise en marche et balancement final	624
Nettoyage final	625
Pose des portes et de la quincaillerie	633
Finis dalle du hall d'ascenseurs	635
Mise en marche et balancement final	638
Nettoyage final	639
Pose des portes et de la quincaillerie	647
Finis dalle du hall d'ascenseurs	649
Mise en marche et balancement final	652
Nettoyage final	653
Pose des portes et de la quincaillerie	661
Finis dalle du hall d'ascenseurs	663
Mise en marche et balancement final	666
Nettoyage final	667
Pose des portes et de la quincaillerie	675
Finis dalle du hall d'ascenseurs	677
Mise en marche et balancement final	680
Nettoyage final	681
Plomberie / distribution étage	689
Vitrage intérieur	692
Pose des portes et de la quincaillerie	700
Ébénisterie	703
Cloisons et divisions de toilettes	709
Tableaux d'écriture et d'affichage	710
Structure	712
Pose	713
Mise en marche et balancement final	718
Nettoyage final	719
'Brut'' gicleurs / lignes principales horizontales & distribution	725
Plomberie / distribution étage	727
Vitrage intérieur	730
Suspension des plafonds	731
Pose des portes et de la quincaillerie	738
Ébénisterie	741
Cloisons et divisions de toilettes	747
Mise en marche et balancement final	753
Nettoyage final	754

'Brut'' gicleurs / lignes principales horizontales & distribution	760
Plomberie / distribution étage	762
Vitrage intérieur	765
Suspension des plafonds	766
Pose des portes et de la quincaillerie	773
Ébénisterie	776
Cloisons et divisions de toilettes	782
Mise en marche et balancement final	787
'Brut'' gicleurs / lignes principales horizontales & distribution	794
Plomberie / distribution étage	796
Vitrage intérieur	799
Suspension des plafonds	800
Pose des portes et de la quincaillerie	807
Ébénisterie	810
Cloisons et divisions de toilettes	816
Panneaux insonorisants	819
Mise en marche et balancement final	822
Nettoyage final	823
'Brut'' gicleurs / lignes principales horizontales & distribution	829
Plomberie / distribution étage	831
Vitrage intérieur	834
Pose des portes et de la quincaillerie	842
Volets et portes à enroulement	843
Ébénisterie	846
Cloisons et divisions de toilettes	852
Tableaux d'écriture et d'affichage	853
Plafonds et panneaux Barrisol	854
Panneaux insonorisants	855
Stores à enroulement	856
Mise en marche et balancement final	858
Nettoyage final	859
Compacteur à déchets	862
Équipement et plate-forme de quais	863
Grilles gratte-pieds	864
Système de lavage de vitres	865
Installation du réseau de gaines verticales (risers)	868
Conduites principales verticales (risers)	895
Niveau B-2	897
Niveau B-1	898
Niveau rez-de-chaussée	899

Niveau 2	900
Niveau 3	901
Niveau 4	902
Niveau 5	903
Niveau 6	904
Niveau 7	905
Niveau 8	906
Niveau 9	907
Niveau 10	908
Niveau 11	909
Niveau 12	910
Niveau 13	911
Niveau 14	912
Niveau 15	913
Livraison des refroidisseurs	915
Livraison des tours d'eau	916
Livraison de la chaudière	917
Livraison du système de traitement de l'eau	918
Mise en marche et balancement final	921
Conduites principales verticales (risers)	925
Livraison des pompes à incendie	926
Livraison du système à préaction	927
Niveau B-2	929
Niveau B-1	930
Niveau rez-de-chaussée	931
Niveau 2	932
Niveau 3	933
Niveau 4	934
Niveau 5	935
Niveau 6	936
Niveau 7	937
Niveau 8	938
Niveau 9	939
Niveau 10	940
Niveau 11	941
Niveau 12	942
Niveau 13	943
Niveau 14	944
Niveau 15	945
Installation des conduites principales verticales (risers)	949
Livraison/installation des équipements de l'entrée électrique de 25KV	950

Branchement à l'artère existante au Pavillon de Génie	951	
Niveau B-1	954	
Niveau rez-de-chaussée	955	
Niveau 2	956	
Niveau 3	957	
Niveau 4	958	
Niveau 5	959	
Niveau 6	960	
Niveau 7	961	
Niveau 8	962	
Niveau 9	963	
Niveau 10	964	
Niveau 11	965	
Niveau 15	969	
Livraison du groupe électrogène	970	
Livraison des équipements de transformation 600/347	971	
Raccordements dans la salle de mécanique principale au niveau 16	973	
Groupe électrogène	975	
Système de controle de l'éclairage	977	
Système de controle des accès	978	
Système de controles des caméras de sécurité	979	
Escaliers mécaniques	982	
Correction de défisciences	988	
Remise des documents et garanties	990	
Réception définitive	991	
Activities With Excessive Total Float		
Activity Name	Activity ID	Total Float
OCTROI DES SOUS-CONTRATS	4	448
PRÉSENTATION U PROGRAMME DE PRÉVENTION	9	475
Précontrainte	16	483
Portes de garage multi-lames	26	420
Volets et portes à enroulement	28	382
Armoires vestiaires	40	357
Sièges d'auditorium	41	357
Cloisons pliantes	42	357
Système de lavage de vitre	43	352
Remblais côté rues	55	462
Excavation de masse dans sol meuble	56	413
Installation des ancrages au roc 1er rang	58	440

Installation des ancrages au roc 2eme rang	60	440
Pose des barbacannes	66	399
Excavation et remblai de la plomberie sous dalle et drain francais	67	204
Coupe de rue no. 1 rue Guy	68	494
Coupe de rue no. 2 rue Guy	69	494
Coupe de rue no. 3 boul. de Maisonneuve	70	494
Excavation/arrasement des pieux du batiment/remblais.	71	139
Réfection trottoirs et asphalte rues Guy et Maisonneuve	72	494
Excavations exploratoires	74	413
Foncage des pieux pour le tunnel TD	75	413
Excavation et boisage	76	413
Excavation/remblai du radier	77	413
Dalle de propreté	78	413
Membrane sous radier	79	413
Coffrage/bétonnage du radier	80	413
Coffrage/bétonnage des murs	81	413
Coffrage/bétonnage du toit	82	413
Membrane d'imperméabilisation	83	413
Béton de protection et remblais	84	413
Réfection de la surface de la ruelle	85	413
Foncage des pieux	88	361
Construction du pont temporaire	89	361
Excavation/boisage 1er ''lift''	90	361
Support des services existants	91	422
Installation des ancrages au roc 1er rang	92	361
Excavation/boisage 2eme ''lift''	93	361
Installation des ancrages au roc 2eme rang	94	361
Excavation/remblai du radier	95	361
Plomberie sous dalle	96	361
Électricité sous dalle	97	361
Dalle de propreté	98	361
Membrane sous radier	99	361
Coffrage/bétonnage du radier	100	361
Coffrage/bétonnage des murs	101	361
Coffrage/bétonnage du toit	102	361
Membrane d'imperméabilisation	103	361
Béton de protection	104	361
Remblai	105	361
Infrastructure de route + asphalte	106	361
Bases de grue	109	408

Installation et mise en marche des 2 grues	110	408
Imperméabilisation des murs de fondation périphériques	112	397
Installation des gaines de post-tension Axe ''D''	117	394
Secteur centre	120	148
Installation des gaines de post-tension Axe ''D''	122	379
Imperméabilisation des murs de fondation périphériques	123	375
Secteur centre	126	148
Système de support de la poutre en post-tension axe ''D''	128	360
Installation des gaines de post-tension Axe ''D''	129	360
Secteur centre	132	148
Installation des gaines de post-tension Axe ''D''	134	346
Secteur centre	137	148
Installation des gaines de post-tension Axe ''D''	139	331
Secteur centre	142	148
Installation des gaines de post-tension Axe ''D''	144	317
Passage des câbles et post-tension	145	279
Secteur centre	148	148
Secteur centre	152	148
Secteur centre	156	148
Secteur centre	160	203
Secteur centre	164	203
Secteur centre	168	203
Secteur centre	172	203
Secteur centre	176	203
Secteur centre	180	203
Secteur centre	184	203
Bases des tours d'eau	192	184
Bases de mécanique et de propreté	193	115
Dalles sur le sol B-2	194	204
Rez-de chaussée murs extérieurs	198	281
Débarcadère	199	281
Parement de pierre extérieure au rez-de-chaussée	200	494
Niveaux B-2 @ niveau 4	204	494
Niveau 5 @ niveau 10	205	494
Niveau 11 @ niveau 16	206	494
Niveaux B-2 @ niveau 4	208	494
Niveau 5 @ niveau 10	209	494
Niveau 11 @ niveau 16	210	494
Escalier no. 3	212	494
Escalier no. 4	213	494

Escalier no. 5	214	494
Escalier no. 6	215	494
Escalier no. 7	216	494
Escalier no. 9	217	494
Escalier no. 10	218	494
Escalier no. 11	219	494
Escalier no. 12	220	494
Escalier no. 13	221	494
Escalier no. 14	222	494
Escalier no. 15 & 16	223	494
Escalier no. 17	224	494
Escalier no. 18	225	494
Escalier no. 19	226	494
Escalier no. 20	227	494
Escalier no. 21	228	494
Escalier no. 22	229	494
Escalier no. 23	230	494
Echelles fosses d'ascenseurs	231	494
Garde-corps terrasse niveau 4 & 15	232	494
Cadres d'acier inoxydable aux portes d'ascenseurs	233	494
Garde-corps et support des pare-fumée dans les atriums	234	494
Plaques pliées à la base des mur rideau du rez-de-chausée	235	494
Cadrage d'acier des vestibules 001 & 199 & rdc	236	494
Linteau de support du mur de pierre extérieure	237	494
Bollars du débarcadère	238	494
Métal tramé des escaliers 6 & 10 & 15 & 16	239	494
Acier préfini des comptoirs de services	240	494
Sabots en acier pour garde-corps des atriums et terrasses	241	494
Plinthes en acier inoxydable	242	494
Contre-marches des gradins et des salles de classes	243	494
Cadres et supports à craie pour tableaux	244	494
Caillebotis du débarcadère	245	494
Pose des amortisseurs seismiques aux étages	248	148
Niveau 4	250	148
Niveau 5	251	261
Niveau 6	252	251
Niveau 7	253	241
Niveau 8	254	231
Niveau 9	255	221
Niveau 10	256	211

Niveau 11	257	203
Niveau 12	258	197
Niveau 13	259	192
Niveau 14	260	187
Niveau 15	261	182
Niveau 16	262	177
Toit bas	263	174
Charpente des tours d'eau	264	169
Solins	276	137
Protection	277	142
Parapets métal et bois	279	164
Membranes	280	156
Solins	281	156
Parapets métal et bois	283	222
Étanchéité temporaire	284	279
Membranes permanentes	285	130
Solins	286	130
Protection	287	279
Marquise niveau 4	291	256
Panneaux d'aluminium du rez-de-chaussée @ niveau 15	292	136
Salle de mécanique élévation est	298	127
Salle de mécanique élévation nord	299	146
Panneaux d'acier du niveau 2 @ niveau 4 élévation ouest	300	266
R-d-c	303	269
Niveau 2	304	259
Niveau 3	305	136
Niveau 4	306	178
Niveau 5	307	178
Niveau 6	308	168
Niveau 7	309	153
Niveau 8	310	143
Niveau 9	311	133
Niveau 10	312	125
Finition des murs rideaux	320	103
ISOLATION THERMIQUE	322	494
'Brut'' électricité / alimentations et panneaux	326	178
'Brut'' plomberie / lignes principales horizontales	327	178
'Brut'' ventilation / gaines principales horizontales & distribution	328	178
'Brut'' gicleurs / lignes principales horizontales & distribution	329	238

Colombages métalliques et câdres d'acier	330	178
Plomberie / distribution étage	331	234
Électricité / distribution étage & éclairage	332	178
Gypse sur colombages + joints	333	190
Vitrage intérieur	334	201
Suspension des plafonds	335	214
Couche d'apprêt	337	190
Correction des joints	338	190
2ième couche	339	190
Pose céramique et finis de plancher durs	341	195
Pose des portes et de la quincaillerie	342	210
Volets et portes à enroulement	343	229
Finis dalle du hall d'ascenseurs	345	154
Plafonds / finition	347	178
Ventilation / finition	348	178
Plomberie / finition	349	190
Gicleurs / finition	350	195
Cloisons et divisions de toilettes	352	190
Démarrage des systèmes	358	178
'Brut'' électricité / alimentations et panneaux	363	178
'Brut'' plomberie / lignes principales horizontales	364	178
'Brut'' ventilation / gaines principales horizontales & distribution	365	178
'Brut'' gicleurs / lignes principales horizontales & distribution	366	233
Colombages métalliques et câdres d'acier	367	178
Plomberie / distribution étage	368	229
Électricité / distribution étage & éclairage	369	178
Gypse sur colombages + joints	370	185
Vitrage intérieur	371	196
Suspension des plafonds	372	209
Couche d'apprêt	374	185
Correction des joints	375	185
2ième couche	376	185
Pose céramique et finis de plancher durs	378	190
Pose des portes et de la quincaillerie	379	205
Finis dalle du hall d'ascenseurs	381	152
Plafonds / finition	383	178
Ventilation / finition	384	178
Plomberie / finition	385	185
Gicleurs / finition	386	190
Cloisons et divisions de toilettes	388	185
Démarrage des systèmes	394	178

Portes de garage multi-lames	399	286
Blocs de béton des gradins rez-de-chausée	400	269
Pontage d'acier et béton des gradins rez-de-chausée	401	269
Béton des gradins du rez-de-chausée	402	269
'Brut'' électricité / alimentations et panneaux	403	168
'Brut'' plomberie / lignes principales horizontales	404	168
'Brut'' ventilation / gaines principales horizontales & distribution	405	168
'Brut'' gicleurs / lignes principales horizontales & distribution	406	223
Colombages métalliques et câdres d'acier	407	168
Plomberie / distribution étage	408	219
Électricité / distribution étage & éclairage	409	168
Gypse sur colombages + joints	410	175
Vitrage intérieur	411	186
Suspension des plafonds	412	199
Couche d'apprêt	414	175
Correction des joints	415	175
2ième couche	416	175
Pose céramique et finis de plancher durs	418	180
Pose des portes et de la quincaillerie	419	195
Volets et portes à enroulement	420	214
Finis dalle du hall d'ascenseurs	422	150
Plafonds / finition	424	168
Ventilation / finition	425	168
Plomberie / finition	426	175
Gicleurs / finition	427	180
Cloisons et divisions de toilettes	429	175
Démarrage des systèmes	435	168
Blocs de béton des gradins niveau 2	440	259
Pontage d'acier et béton des gradins niveau 2	441	259
Béton des gradins du niveau 2	442	259
'Brut'' électricité / alimentations et panneaux	443	153
'Brut'' plomberie / lignes principales horizontales	444	153
'Brut'' ventilation / gaines principales horizontales & distribution	445	153
'Brut'' gicleurs / lignes principales horizontales & distribution	446	213
Colombages métalliques et câdres d'acier	447	153
Plomberie / distribution étage	448	209
Électricité / distribution étage & éclairage	449	153
Gypse sur colombages + joints	450	165
Vitrage intérieur	451	176

Suspension des plafonds	452	189
Couche d'apprêt	454	165
Correction des joints	455	165
2ième couche	456	165
Pose céramique et finis de plancher durs	458	170
Pose des portes et de la quincaillerie	459	185
Finis dalle du hall d'ascenseurs	461	148
Plafonds / finition	463	153
Ventilation / finition	464	153
Plomberie / finition	465	165
Gicleurs / finition	466	170
Cloisons et divisions de toilettes	468	165
Démarrage des systèmes	474	153
Blocs de béton des gradins niveau 3	479	249
Pontage d'acier et béton des gradins niveau 3	480	249
Béton des gradins du niveau 3	481	249
'Brut'' électricité / alimentations et panneaux	482	143
'Brut'' plomberie / lignes principales horizontales	483	143
'Brut'' ventilation / gaines principales horizontales & distribution	484	143
'Brut'' gicleurs / lignes principales horizontales & distribution	485	203
Colombages métalliques et câdres d'acier	486	143
Plomberie / distribution étage	487	199
Électricité / distribution étage & éclairage	488	143
Gypse sur colombages + joints	489	154
Vitrage intérieur	490	166
Suspension des plafonds	491	179
Couche d'apprêt	493	155
Correction des joints	494	155
2ième couche	495	155
Pose céramique et finis de plancher durs	497	160
Pose des portes et de la quincaillerie	498	175
Revêtements de plancher souples	499	135
Finis dalle du hall d'ascenseurs	500	135
Ébénisterie	501	137
Plafonds / finition	502	143
Ventilation / finition	503	143
Plomberie / finition	504	155
Gicleurs / finition	505	160
Cloisons et divisions de toilettes	507	155
Sièges d'amphithéatre et des classes	511	135
Démarrage des systèmes	513	143

'Brut'' électricité / alimentations et panneaux	518	133
'Brut'' plomberie / lignes principales horizontales	519	133
'Brut'' ventilation / gaines principales horizontales & distribution	520	133
'Brut'' gicleurs / lignes principales horizontales & distribution	521	193
Colombages métalliques et câdres d'acier	522	133
Plomberie / distribution étage	523	189
Électricité / distribution étage & éclairage	524	133
Gypse sur colombages + joints	525	135
Vitrage intérieur	526	151
Suspension des plafonds	527	156
Couche d'apprêt	529	135
Correction des joints	530	135
2ième couche	531	135
Pose céramique et finis de plancher durs	533	145
Pose des portes et de la quincaillerie	534	160
Volets et portes à enroulement	535	171
Plancher surélevé	536	162
Revêtements de plancher souples	537	135
Finis dalle du hall d'ascenseurs	538	135
Ébénisterie	539	135
Plafonds / finition	540	133
Ventilation / finition	541	133
Plomberie / finition	542	140
Gicleurs / finition	543	142
Cloisons et divisions de toilettes	545	140
Démarrage des systèmes	548	133
Blocs de béton des gradins niveau 5	553	223
Pontage d'acier et béton des gradins niveau 5	554	223
Béton des gradins du niveau 5	555	223
'Brut'' électricité / alimentations et panneaux	556	125
'Brut'' plomberie / lignes principales horizontales	557	125
'Brut'' ventilation / gaines principales horizontales & distribution	558	125
'Brut'' gicleurs / lignes principales horizontales & distribution	559	185
Colombages métalliques et câdres d'acier	560	125
Plomberie / distribution étage	561	181
Électricité / distribution étage & éclairage	562	125
Gypse sur colombages + joints	563	129
Vitrage intérieur	564	148
Suspension des plafonds	565	161

Couche d'apprêt	567	137
Correction des joints	568	137
2ième couche	569	137
Pose céramique et finis de plancher durs	571	142
Pose des portes et de la quincaillerie	572	157
Revêtements de plancher souples	573	124
Finis dalle du hall d'ascenseurs	574	124
Ébénisterie	575	133
Plafonds / finition	576	125
Ventilation / finition	577	125
Plomberie / finition	578	137
Gicleurs / finition	579	142
Électricité / finition	580	103
Cloisons et divisions de toilettes	581	137
Sièges d'amphithéatre et des classes	584	124
Démarrage des systèmes	586	125
Nettoyage final	588	103
Blocs de béton des gradins niveau 6	591	221
Pontage d'acier et béton des gradins niveau 6	592	221
Béton des gradins du niveau 6	593	221
'Brut'' électricité / alimentations et panneaux	594	117
'Brut'' plomberie / lignes principales horizontales	595	117
'Brut'' ventilation / gaines principales horizontales & distribution	596	117
'Brut'' gicleurs / lignes principales horizontales & distribution	597	177
Colombages métalliques et câdres d'acier	598	117
Plomberie / distribution étage	599	173
Électricité / distribution étage & éclairage	600	117
Gypse sur colombages + joints	601	126
Vitrage intérieur	602	140
Suspension des plafonds	603	153
Couche d'apprêt	605	129
Correction des joints	606	129
2ième couche	607	129
Pose céramique et finis de plancher durs	609	134
Pose des portes et de la quincaillerie	610	149
Revêtements de plancher souples	611	126
Finis dalle du hall d'ascenseurs	612	127
Ébénisterie	613	130
Plafonds / finition	614	117
Ventilation / finition	615	117
Plomberie / finition	616	129

Gicleurs / finition	617	134
Cloisons et divisions de toilettes	619	129
Sièges d'amphithéatre et des classes	621	126
Démarrage des systèmes	623	117
'Brut'' électricité / alimentations et panneaux	628	118
'Brut'' plomberie / lignes principales horizontales	629	166
'Brut'' gicleurs / lignes principales horizontales & distribution	630	166
Colombages métalliques et câdres d'acier	631	118
Gypse sur colombages + joints	632	118
Pose des portes et de la quincaillerie	633	162
Plafond du hall d'ascenseurs	634	130
Finis dalle du hall d'ascenseurs	635	130
Peinture	636	118
Stores à enroulement	637	118
Nettoyage final	639	118
'Brut'' électricité / alimentations et panneaux	642	110
'Brut'' plomberie / lignes principales horizontales	643	158
'Brut'' gicleurs / lignes principales horizontales & distribution	644	158
Colombages métalliques et câdres d'acier	645	110
Gypse sur colombages + joints	646	110
Pose des portes et de la quincaillerie	647	154
Plafond du hall d'ascenseurs	648	122
Finis dalle du hall d'ascenseurs	649	122
Peinture	650	110
Stores à enroulement	651	110
Nettoyage final	653	110
'Brut'' électricité / alimentations et panneaux	656	102
'Brut'' plomberie / lignes principales horizontales	657	150
'Brut'' gicleurs / lignes principales horizontales & distribution	658	150
Colombages métalliques et câdres d'acier	659	102
Gypse sur colombages + joints	660	102
Pose des portes et de la quincaillerie	661	146
Plafond du hall d'ascenseurs	662	114
Finis dalle du hall d'ascenseurs	663	114
Peinture	664	102
Stores à enroulement	665	102
Nettoyage final	667	102
'Brut'' plomberie / lignes principales horizontales	671	142
'Brut'' gicleurs / lignes principales horizontales & distribution	672	142

Pose des portes et de la quincaillerie	675	138
Plafond du hall d'ascenseurs	676	106
Finis dalle du hall d'ascenseurs	677	106
'Brut'' gicleurs / lignes principales horizontales & distribution	687	137
Plomberie / distribution étage	689	133
Pose des portes et de la quincaillerie	700	104
Structure	712	125
'Brut'' gicleurs / lignes principales horizontales & distribution	725	122
Plomberie / distribution étage	727	118
'Brut'' gicleurs / lignes principales horizontales & distribution	760	107
Plomberie / distribution étage	762	103
Compacteur à déchets	862	494
Équipement et plate-forme de quais	863	494
Grilles gratte-pieds	864	494
Système de lavage de vitres	865	494
Installation du réseau de gaines verticales (risers)	868	162
Niveau B-2	870	243
Niveau B-1	871	248
Niveau rez-de-chaussée	872	271
Niveau 2	873	261
Niveau 3	874	251
Niveau 4	875	241
Niveau 5	876	231
Niveau 6	877	221
Niveau 7	878	211
Niveau 8	879	201
Niveau 9	880	191
Niveau 10	881	183
Niveau 11	882	175
Niveau 12	883	167
Niveau 13	884	159
Niveau 14	885	151
Niveau 15	886	143
Plomberie sous dalle sur sol	894	204
Conduites principales verticales (risers)	895	172
Niveau B-2	897	266
Niveau B-1	898	271
Niveau rez-de-chaussée	899	276
Niveau 2	900	266
Niveau 3	901	256

Niveau 4	902	246
Niveau 5	903	236
Niveau 6	904	226
Niveau 7	905	216
Niveau 8	906	206
Niveau 9	907	196
Niveau 10	908	188
Niveau 11	909	180
Niveau 12	910	172
Niveau 13	911	164
Niveau 14	912	156
Niveau 15	913	148
Livraison des refroidisseurs	915	137
Livraison des tours d'eau	916	137
Livraison de la chaudière	917	137
Livraison du système de traitement de l'eau	918	137
Entrée principale de gicleurs	924	241
Conduites principales verticales (risers)	925	167
Livraison des pompes à incendie	926	246
Livraison du système à préaction	927	140
Niveau B-2	929	195
Niveau B-1	930	190
Niveau rez-de-chaussée	931	180
Niveau 2	932	170
Niveau 3	933	160
Niveau 4	934	142
Niveau 5	935	142
Niveau 6	936	134
Niveau 7	937	166
Niveau 8	938	158
Niveau 9	939	150
Niveau 10	940	142
Installation des conduites principales verticales (risers)	949	162
Livraison/installation des équipements de l'entrée électrique de 25KV	950	226
Branchement à l'artère existante au Pavillon de Génie	951	494
Niveau B-2	953	183
Niveau B-1	954	236
Niveau rez-de-chaussée	955	226
Niveau 2	956	216
Niveau 3	957	206

Niveau 4	958	196
Niveau 5	959	188
Niveau 6	960	180
Niveau 7	961	172
Niveau 8	962	164
Niveau 9	963	156
Niveau 10	964	148
Niveau 11	965	140
Livraison du groupe électrogène	970	137
Livraison des équipements de transformation 600/347	971	183
Escaliers mécaniques	982	201

Activities With Negative Total Float

Activity Name	Activity ID