Schedule Health Assessment Criteria for Semi High-Rise Building Construction Projects in Pakistan

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This is to certify that the

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THESIS ACCEPTANCE CERTIFICATE

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This thesis is dedicated to my parents and my respected teachers!

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Above all, I would like to thank Allah Almighty who helped me throughout my life and to get through this degree and thesis.

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ABSTRACT

Construction industry faces many challenges, one key challenge is the timely completion of projects. The same challenge with higher magnitude is faced by the construction industry of Pakistan. Literature reports that 80% of local construction projects face delays, and a mere 20% get completed within the scheduled duration. Two main factors are responsible for timely completion of the project; management and planning. Out of these two, management has been widely covered in the past studies, while very less attention has been given to planning aspect. In particular, planning and scheduling of construction projects in Pakistan are rarely done with the keen intent of its use and implementation. It has been observed that the construction schedule is normally treated as a formality and due consideration is not given to it.

This research aims at the formulation of assessment criteria for work schedules of building construction projects in Pakistan. To form precise and specific criteria, the scope of research is restricted to semi high-rise building projects. Assessment criteria were developed making use of knowledge extracted from the pertinent literature and through the opinion of construction industry professionals. A method has been developed to evaluate the overall fitness of the schedules while accounting for the relative importance of each criterion. To demonstrate the applicability and significance of assessment criteria, it was used to evaluate and benchmark the work schedules of two actual construction projects.

The formulation of criteria has the purpose to facilitate the project planners to prepare and maintain better quality schedules. The evaluation will help to detect deficiencies in project schedules and other critical problems significant for schedule maintenance. The result of this research will provide a foundation for further research towards the development of generic work schedule evaluation criteria which, if added in construction contracts, will deliver an efficient execution plan.

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INTRODUCTION

1.1 PREFACE

Building construction projects are considered as complex endeavors spread over the use of more than 300 materials. The cost required for execution of construction projects varies a lot. Same is the case with the duration for completion of these projects which varies a lot ranging from a few months to decades. Both time and cost are the key determinant for the successful project (Le-Hoai et al., 2008).

Delay in construction industry refers to the time overrun in the specified completion date of the construction project (Assaf and Al-Hejji, 2006). For clients, construction delay translates to the dependency on existing facilities, loss of revenue, lack of rentable facilities etc. For the contractor, construction delay translates to the higher execution costs, longer work durations, increased labor cost, higher material and equipment costs, liquated damages etc. (Haseeb et al., 2011; Kog et al., 1999). Further, contractor is the one who gains or loses much in terms of monetary benefit and reputation as per the final outcome of the project (Bubshait and Cunningham, 1998).

Every construction project is unique in its nature even though a building is constructed again will have a totally different outcome based on the completion time, cost, quality and many other aspects. For construction projects forecasting future events and consequences that are unknown or uncertain is very difficult. Thus, managing a project requires special skills and competencies on part of the client, consultant and contractor. Each party has different role to perform on which the success of the project is based. There are two main factors responsible for timely completion of the project; one is the management throughout the life of the project and the other is the planning of the project. This study focuses on the planning aspect as management has been widely covered in the past studies and literature.

After the award of work contractors are required to furnish detailed work schedule as per contract requirement for the review of clients/consultants. Earlier the schedules are prepared and implemented, better is the outcome of the project (Griffith, 2006). These schedules once approved are essential for the efficient execution of project and progress monitoring. In addition, schedules provide the legal basis for the administration of construction disputes and delay claims. Therefore, it is essential to ensure the fitness of these schedules for their intended purposes. Clients or their agents i.e. consultants review and assess these schedules based on many considerations, which are usually subjective varying from one organization to another and to the experience of the reviewer. Further, reviewers of each party i.e. client, consultant or contract review the schedules with different review aspects to safeguard their own interests (R. Dzeng et al., 2005). Therefore, to standardize the review and evaluation process of work schedule, criteria for work schedule assessment for semi high-rise building projects is made the scope of this study.

Quality indicators applicable to construction work schedules needs to be identified through relevant literature. The formulated schedule assessment criteria can be used for benchmarking schedules and comparing with the actual outcome of the projects. This study delivers a organized methodology to help clients/consultants in schedule review and evaluation, and to assist contractors for assessment at their end before submission to the client/consultant. The aim is to develop a pro-active way to prepare and review the work schedules.

1.2 PLANNING AND SCHEDULING

Planning is an approach to forecast future events and their consequences that are usually uncertain. It is a way to assess the future outcomes and to make necessary actions beforehand to achieve desired results. It involves the logical analysis of the project, its key requirements, and plan of execution. It is the basis for monitoring, controlling and managing project execution, including managing the key relationship between time and cost (Hancher, 2003).

Scheduling, on the other hand, follows the planning process. The schedule is a model constructed to implement the project plan. Detail of execution of activities is calculated by the scheduling. The schedule is a representation of time and it includes key variables such as preferred sequences of work activities, contingency, non-working calendar periods and resource constraints to determine the duration, start and finish dates of activities, and milestones (GAO, 2012).

1.3 CONSTRUCTION INDUSTRY OF PAKISTAN

Construction encompasses the making of buildings, roads, bridges, dams, houses or any other infrastructure. Manufacturing mainly differs from construction, as it involves mass production of similar items in a controlled environment, while construction typically takes place on location which is subject to the environment and many other factors which effect labor and equipment productivity (Mohamed, 2001). Furthermore, every construction project is unique in nature. Typically phases of construction include initial planning, designing, financing, detailed planning and execution. Construction industry contributes heavily in boosting the economy of a country and is a vital portion of GDP in most countries. Through its sub-sectors and linked industries, it has a high impact on the overall development of the country (Oladinrin et al., 2012).

In Pakistan, construction industry as a sub-sector contributes 13.49% in the industrial sector. Further, in Gross Domestic Product (GDP) its share is 2.82% against the share of 2.74% last year, 2017; it absorbs 7.31 percent of the labor force. Construction is one of the key components of industrial sector contributing in the economy of Pakistan. This sub-sector has witnessed a growth of 9.13% against the growth of 9.84% last year, 2017 (Finance Division, 2018). Contribution of construction industry in GDP and percentage growth rate over the past eight years are presented in Figures 1.1 and 1.2 respectively.

Figure 1.1: Representation of Construction Industry of Pakistan share in GDP over past 8 years

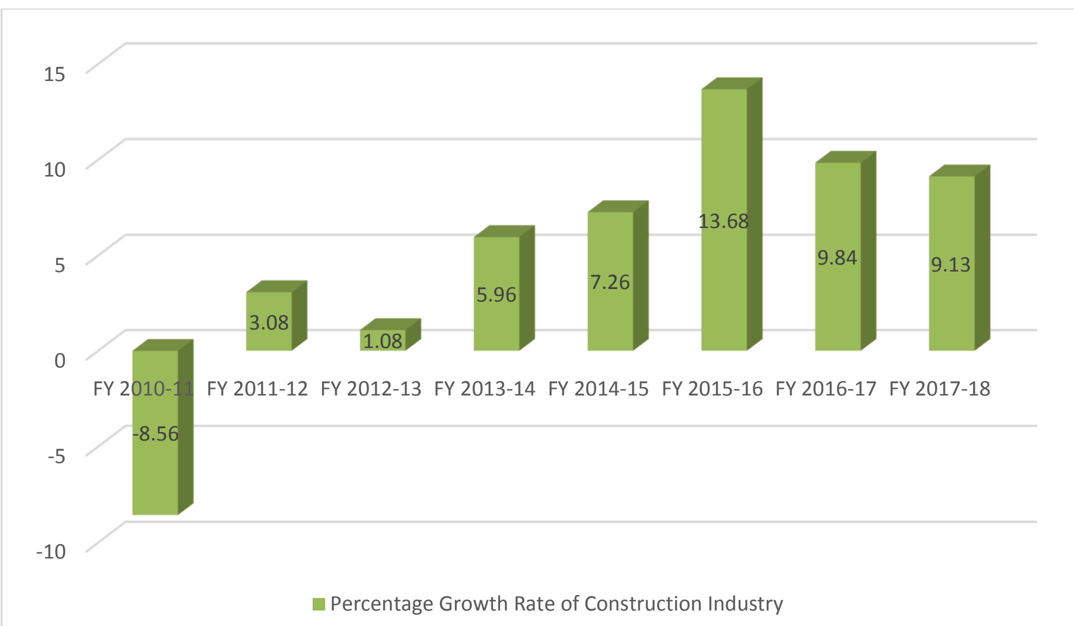

Figure 1.2: Representation of % growth rate of Construction Industry of Pakistan over past 8 years

Iron & steel import bill increased by 18.1% due increase in construction activity during FY 2017-18 which has increased the demand for imported iron and steel products. Non-metallic mineral growth because of cement production growth is recorded at 11.95% during FY 2017-18. The outlook for the construction remains encouraging in view of expected strong demand in allied industries like steel industry (Finance Division, 2018).

Overall the construction industry of Pakistan plays a vital role in the development of the economy. It has more than 40 linked building material industries. The massive employment opportunities it provides directly or indirectly contributes in reducing poverty in Pakistan (Khan, 2008).

1.4 IMPORTANCE OF PLANNING AND SCHEDULING IN CONSTRUCTION INDUSTRY

A detailed work schedule can explain the subtleties of the project and can provide means for several analyses, project monitoring, project control, and cooperation with project stakeholders. Schedule quality is considered one of the important factor which contributes to the success of the construction project.

A detailed project schedule of high quality can contribute to managing construction execution and helps in improving productivity and quality (Bragadin and Kahkonen, 2016). Guidelines demonstrating conduction of the review process are very hard to find and construction contracts do not provide criteria for review of detailed schedules.

1.5 SEMI HIGH-RISE BUILDINGS

Bragadin and Kahkonen (2016), argues that poor implementation of schedule in the construction sector is very common, especially in small and medium-sized (SMEs) projects. This research aims at the formulation of new assessment criteria for the work schedule of building construction projects in Pakistan and is focused on semi high-rise building projects, which help in forming criteria that is more specific and precise. Many researchers used semi high-rise building projects in their study (De La Garza and Ibbs, 1990; R.-J. Dzeng and Lee, 2004; Echeverry et al., 1991).

Usually, completion duration of semi high-rise building construction projects varies from one year to three years. As the schedule is based on the time required for completion thus the nature of different schedules will be same and can be benchmarked on standardized criteria. There is no rule or standard characterization for defining semi high-rise buildings. For this study, semi high-rise buildings are classified as a building of height ranging from 50ft to 150ft or it consist of 4 to 10 floors. After the construction of houses, semi high-rise buildings are the most widely constructed buildings in Pakistan.

1.6 PROBLEM STATEMENT

While scheduling has been around since the mid-twentieth century, acceptance and uniformity related to its application in the construction industry is still an open challenge (Galloway, 2006).

According to Cole (1991) contractors do put effort as far as site management is concerned, however, planning and scheduling are rarely used to its potential. Few efforts have been made by the researchers related to the quality of the schedules and even amongst them construction-oriented research is even rarer (Bragadin and Kahkonen, 2016).

1.7 STUDY OBJECTIVES

The goal of this research is to focus on the planning and scheduling aspects of the construction projects and to establish criteria for assessing the quality of the construction schedule. Objectives of this research include:

i. To identify and shortlist key schedule health indicators.

ii. To formulate work schedule assessment criteria.

iii. To evaluate the work schedule of construction projects using the formulated criteria.

1.8 REASON FOR SELECTION OF TOPIC AND RELEVANCE TO NATIONAL NEEDS

Thorough search on Pakistan Engineering Council (PEC) website reveals that though the bidding documents are available at the website, however, these bidding documents do not cover any aspect related to the planning and scheduling. Further, no clause/material is available for reviewing/assessing the quality of the schedule.

A major portion of Pakistan's economy is dependent on the development project and these projects have been undertaken by each government since the creation of Pakistan. Every government's major focus is on the development projects; however, no such preventive control measures are applied for the timely completion of the project. There is a strong need to introduce schedule health assessment concept in current studies and policies to overcome the problem of schedule overruns.

1.9 ORGANIZATION OF THESIS

This thesis has been organized into five chapters.

Chapter 1 is 'Introduction.' It includes the preface to the research, introduction to planning and scheduling, brief regarding the construction industry of Pakistan, importance of planning and scheduling, semi high-rise buildings, problem statement, study objectives and the reason for selection of topic along with relevance to National needs. This chapter provides a general overview of the research.

Chapter 2 is 'Literature Review.' It explains the previous studies carried out by highlighting the importance of planning and scheduling, development of assessment criteria, shortcoming of assessment criteria highlighted by previous researchers, the shortcomings addressed by researchers and finally gaps still needed to be explored.

Chapter 3 is 'Methodology.' It explains how the research is conducted to obtain research design.

Chapter 4 is ‘Data Analysis and Results.’ It covers the analysis of data after being collected and results according to research objectives. It also encompasses the evaluation of case studies using the formulated criteria.

Finally, Chapter 5 is ‘Conclusions and Recommendations.’ Final conclusions and recommendations have been summarized in this chapter.

Chapter 2

LITERATURE REVIEW

2.1 PLANNING AND SCHEDULING

PMI (2017) defines the success of the project in applying intuition, knowledge and experience in project planning and focus all efforts to execute the project according to the plan.

A high focus has been given to the factors causing the delays in the timely execution of the project in previous researches. Chan and Kumaraswamy (1997) identified 83 potential factors contributing to delays in construction projects in Hong Kong and examined the reasons for these delays. Kaming et al. (1997) highlighted key factors contributing to time overruns that includes poor labor productivity, design changes, resource shortages and inadequate planning. Assaf and Al-Hejji (2006) identified 73 causes of delays and classified them in nine groups. Al-Momani (2000) identified causes of delay in 130 public projects in Jordan. Iyer and Jha (2006) investigated 55 causes responsible for impacting the performance of the projects. These causes were then segregated into success and failure group. Faridi and El-Sayegh (2006) developed a questionnaire survey to get the input of professionals associated with the construction industry of UAE. Their research revealed that almost 50% of the construction projects in UAE face delays. Sambasivan and Soon (2007) identified 28 causes and 6 effects of delays in the construction industry of Malaysia. In another study conducted by Endut et al. (2009), related to the delays in the construction industry of Malaysia, it was revealed that the time overrun is a more serious issue with 49.71% average time deviation than cost overrun with 2.08% average cost deviation. Haseeb et al. (2011) studied the causes of delay and its effects in Pakistan. Sixteen important causes and five main effects of delay were discussed. Gunduz et al. (2012) identified 83 potential causes of delays and categorized them in nine different groups. Relative importance was assigned based on the feedback of Turkish construction industry professionals. They also provided 12 recommendations to minimize construction delays. It is pertinent to mention here that all these researches indicate that poor planning is one of the important cause of delay.

Many researchers gave huge importance to planning for the timely completion of the construction projects. Bragadin and Kahkonen (2016) in their research argues that project work schedule is a key yield of the planning. A better quality project schedule with high overall fitness is highly important in the selection of a form of project organization and construction plan (Kenley, 2014). Schedule quality survey is considered as a key constituent of construction project management and an indicator of overall process quality (Zwikael and Globerson, 2004). A project schedule has a crucial importance as for project management and thus these planning outputs are to be properly developed and maintained. Poor implementation of schedule in the construction industry is very common, especially in medium-small sized projects (Bragadin and Kahkonen, 2016). Scheduling provides a detailed guide that answers to an important question that is how and when the project will deliver the required results defined in the scope of the project (PMI, 2017).

A roadmap can be formulated using detailed work schedule which defines when a specific work will be executed as per the defined scope. This can be achieved through preparation and implementation of schedule which is a representation of the project's strategy for executing the project's activities. Scheduling process includes but not limited to the formation of work break down structure, activity coding, definition of activity, sequence of activities, resource loading on activities along with leveling, estimation of activity duration, schedule preparation, monitoring and control (Echeverry et al., 1991; PMI, 2017). A quality project schedule incorporates cost, resource and other technical data to help project management team in making decisions and actions for successful execution of the project (Kenley, 2014). A significant relationship is present between good scheduling practices used in the initial stage of the project to prepare the project plan and the ultimate success of the project. The success of a project depends on the fitness of its work schedule and it can be used to identify potential issues (GAO, 2012). The importance of fitness of the schedules, places a question: how can schedule be checked for its completeness and correctness.

2.2 EFFORTS IN THE DEVELOPMENT OF ASSESSMENT CRITERIA

To improve planning of the construction project efforts were made to establish criteria against which the schedule will be evaluated and to develop artificial intelligence-based computer programs that will check the schedules against the specified criteria.

De La Garza and Ibbs (1990) presented a computer-based system called CRITEX, for reviewing schedules of mid-rise commercial building construction projects. CRITEX incorporates 34 general schedule review provisions. R. Dzeng et al. (2005) proposed an automated schedule review system for expressway construction projects from owner's point of view, called NRA. NRA encompasses both rule-based and case-based reasoning to review the schedules. Zwikael and Globerson (2004) introduced a method to access the fitness of project planning called 'Project Management Planning Quality (PMPQ)'. The method consists of two components; (i) project manager's know-how and (ii) organizational support offered by the performing organization. The PMPQ model classifies sixteen know-how process and outputs, and seventeen organizational support processes.

PMI (2017) details the good practices and components of schedule making. The guideline can be used for schedule health evaluation, and it is based upon 28 attributes, categorized into 7 indicator groups: process and toolset; structure and hierarchy; integration; resource/cost integration; risk; update and maintenance; and environment.

In 2009, U.S Government Accountability Office published GAO Cost Estimating and Assessment Guide based on good practices that can be used across the government projects to prepare, manage, and review projects cost estimates (GAO, 2009). After that a companion guide named GAO Schedule Assessment Guide was published in 2012, aiming that a reliable schedule can be produced that will contribute to an understanding of the cost impact if the program does not complete within the specified time (GAO, 2012). This guide set a new benchmark for standardizing the schedule. It contains ten best practices with components of each practice. Ten best practices along with number of their components are indicated in Figure 2.1.

Figure 2.1: Ten Best Practices for Schedule Development (GAO, 2012)

In 2012, US Defense Contract Management Agency introduced a 14-point schedule assessment guide to assist the planners of the agency in reviewing huge number of work schedules that they were tasked. Since then DCMA 14-points for schedule review has become a guide that is extensively followed and has been incorporated in many software. 14-point metrics focus in identifying problematic areas with a contractor's submitted schedule (DCMA, 2012). The

DCMA 14-point supports the schedule analysis to determine whether the schedule is a realistic one or not. The 14-points assessment metrics is shown in Figure 2.2.

Figure 2.2: 14-Points Assessment Metrics (DCMA, 2012)

In 2012, the National Defense Industrial Association (NDIA), issued the 'Planning and Scheduling Excellence Guide (PASEG)' to provide the planners and schedulers a practical approach for preparing and maintaining the project schedules. The guide incorporates 'Generally Accepted Scheduling Principles' (GASP), which are ten quality control steps to check the work schedules (NDIA, 2012).

2.3 SHORTCOMINGS OF ASSESSMENT CRITERIA

Previous studies addressed the matter of schedule quality and its control with the main attention to schedule mechanics and not to on-site construction processes. Farzad Moosavi and Moselhi

(2014) argues that the assessment of schedule job logic and activity durations were not addressed effectively in previous researches because the assessment criteria were too generic.

The quality of the work schedules have been the scope of research of many researchers, however, most of these standards/guideline given in past studies are outside the construction context. Zwikael and Globerson (2004) structured a model to develop all assessment criterion into an overall schedule fitness indicator. For this, a relative importance was assigned to each process. For both the groups and knowledge areas equal weights were assumed. Overall weight of a particular process within a certain group depends on the number of processes in that area. The Project Management Planning Quality (PMPQ) index, that evaluates the quality of project planning process in the organization, was calculated as a weighted average of the 33 project know-how and organizational support products.

DCMA 14-point assessment criteria focused on schedule components such as lags, leads, floats, constraints etc. by assigning threshold values. However, no indication was made on how these thresholds are formulated and thus have been in debate by construction experts and planners. All these guidelines focus on the mechanics of the schedule and are generic. Construction field professionals might argue on many points discussed in these guidelines. The purpose of schedule review process is not to check whether the contractor can accomplish the work as per defined scope or not, but that the project's work schedule is technically right and implementable (Bragadin and Kahkonen, 2016). According to Bragadin and Kahkonen (2016) the guidelines proposed by PASEG, DCMA and GAO focus only on the 'mechanics' of the work schedule, and it is not construction oriented.

2.4 HOW DIFFERENT RESEARCHERS ADDRESSED THESE SHORTCOMINGS

R.-J. Dzeng and Lee (2004) worked on developing a schedule assessment application called Schedule Coach using case-based and rule-based reasoning. The aim of the Schedule Coach was to analyze a project schedule and provide suggestions for revisions. They also critiqued other applications available for automatic construction planning. R.-J. Dzeng and Lee (2004) argues that many planning applications were based only on rule-based reasoning, and generate an activity network for a given project, described using predefined set of hierarchical mechanisms and these applications mainly depends on the planner's experience and partialities. While critiquing schedule assessment system developed by De La Garza and Ibbs (1990), called Critex, it was observed that the output of Critex is a set of critique statements and the reports do not include the suggestions and methods regarding how the schedules should be revised (R.-J. Dzeng and Lee, 2004).

R.-J. Dzeng and Lee (2004) used their developed application Schedule Coach to review the schedules. They found out that the application took very less time when compared to the time taken by experts to review the same schedules. Further, the aim of Schedule Coach is not to optimize a construction schedule, but to find the human errors in a schedule, and suggest appropriate modifications using case-based and rule-based reasoning.

Moosavi and Moselhi (2012) developed the methodology for schedule assessment and implemented it in automated computer application to facilitate effective review of work schedules. This is particularly useful in performing schedule review of large projects, which have hundreds, if not thousands, of activities. Classification of schedule health indicators in different groups and sub-groups is presented in Figure 2.4.

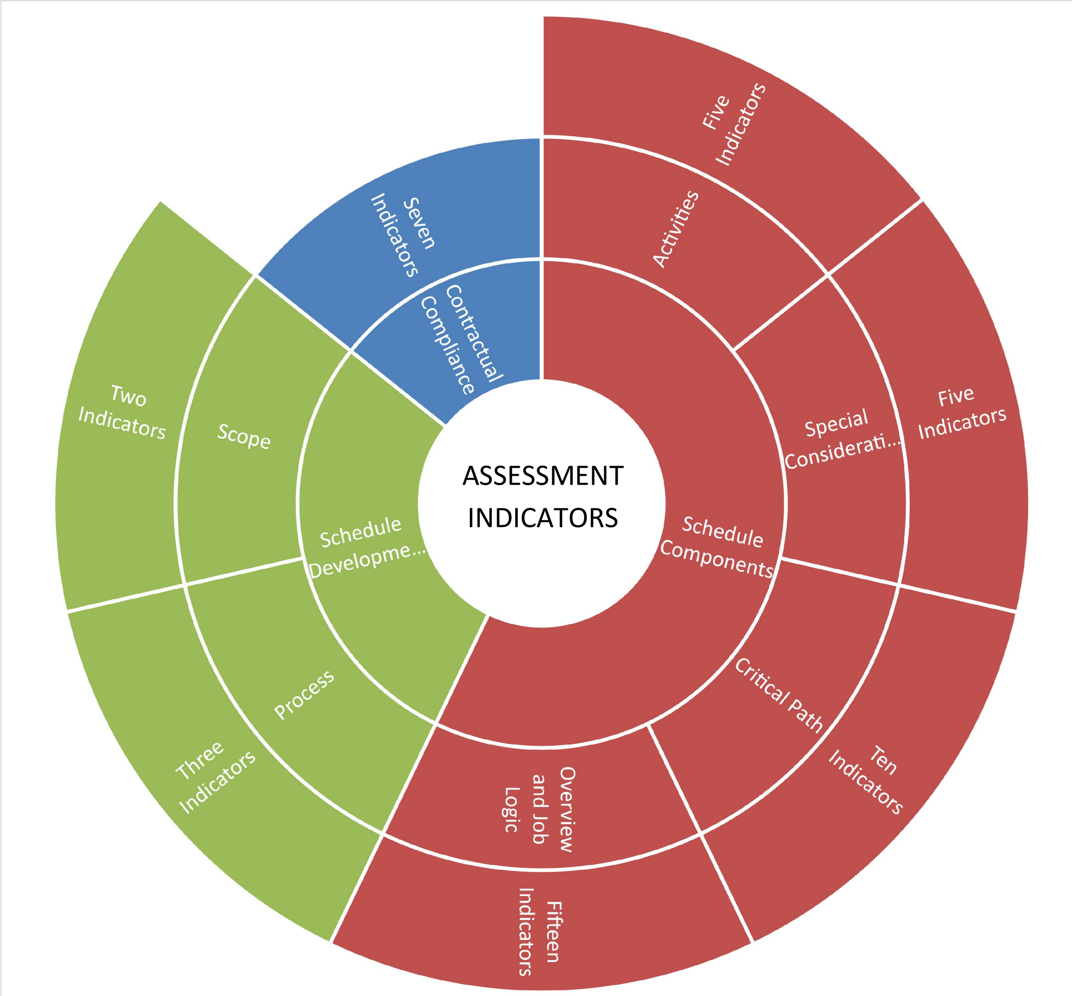

Figure 2.3: Schedule Assessment Indicators (Moosavi and Moselhi, 2012)

A method was introduced by Farzad Moosavi and Moselhi (2014) to assist owners or consultants in assess and evaluating work schedules submitted by contractors.. An index was introduced to evaluate the overall fitness of the schedule, considering the importance of each evaluation criterion. Work schedules of three actual construction project and one hypothetical projects were examined to represent the key components of the developed strategy and to highlight its abilities. The schedule health indicators used in their research were grouped and sub-groups as indicated in Figure 2.5.

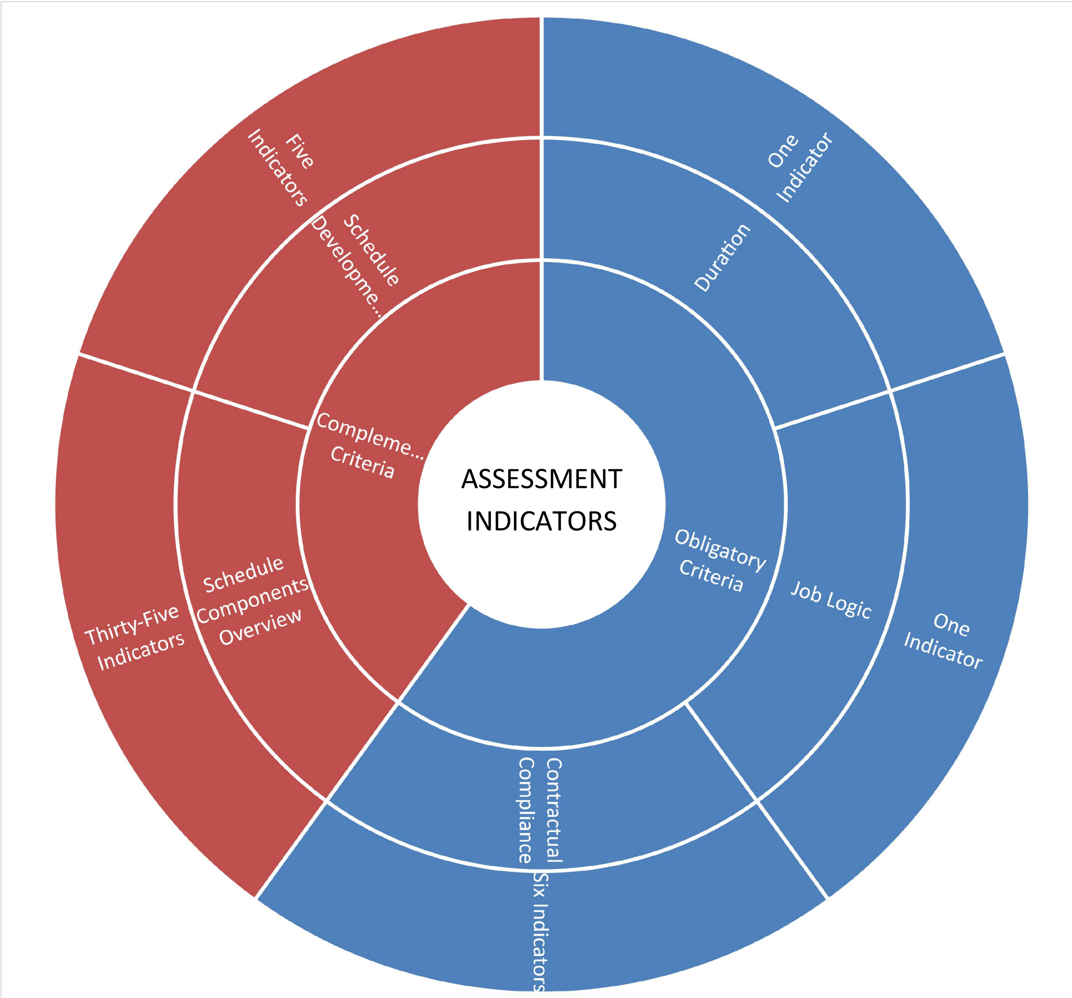

Figure 2.4: Schedule Assessment Indicators (Farzad Moosavi and Moselhi, 2014)

Bragadin and Kahkonen (2016) first gathered 75 quality Indicators for the construction schedule. In the next phase, these Indicators were classified into five groups as depicted in Figure 2.6. Weights were then given to these classified Indicators and finally, the procedure was tested on sample case studies. Schedule performance graph was also developed to efficiently indicate the performance of schedule with respect of each group.

Figure 2.5: Schedule Quality Indicators (Bragadin and Kahkonen, 2016)

2.5 GAPS NEEDED TO BE EXPLORED

In-depth review suggests that in past researches consideration to the weight of each criterion is not given thus effective benchmarking of a schedule is not possible. All previous criteria are very generic and non-construction oriented.

R.-J. Dzeng and Lee (2004) developed a computer application called Schedule Coach for construction projects work schedule review. Their study lacks the generation of the criteria against which the schedules are to be assessed and uses previous literature. Furthermore, as it is a computer program it needs to be adjusted for each new schedule that uses different vocabulary for naming activities.

Moosavi and Moselhi (2012) developed a computer-based application that uses schedule quality Indicators threshold for published material and encouraged firms to develop their own database as research did not focus on the formulation of threshold even though it is an integral part of the evaluation. Efforts were made to develop job logic assessment criteria in a software application called Schedule Assessment and Evaluation (SAE) whose workability is very limited, and it recognizes only limited activities and their logical relationship.

Many of the previous researches addressed the schedule quality with only the control-oriented approach and do not assist the planner in the development of the work schedules. Further, very few consider the execution dimension of the production process (Bragadin and Kahkonen, 2016).

The weights or relative importance assigned to different quality Indicators were assumed to be same. Zwikael and Globerson (2004) implemented the same logic to structure the weights of the model. According to Bragadin and Kahkonen (2016) weights or relative importance can be changed based on the nature of the project. The definition of such project-oriented weights will be the object of future research.

2.5 IDENTIFICATION AND SHORTLISTING OF SCHEDULE HEALTH INDICATORS

Based on the literature review conducted on various aspects related to the research topic. 87 schedule health indicators were identified. The indicators are presented in Table 2.1.

Table 2.1: All gathered Schedule Health Indicators

Sr. No.	Schedule Requirement	Authors	No. of times cited
1	Project calendar identification and verification	Bragadin and Kahkonen (2016); GAO (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	4

2	Activity coding structure	Bragadin and Kahkonen (2016); GAO (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	4
3	Participation of major subcontractors	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012); Song et al. (2009)	4
4	Standardized schedule procedure	Bragadin and Kahkonen (2016)	1
5	Milestones	Bragadin and Kahkonen (2016); GAO (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	4
6	Project duration	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
7	Master schedule & critical path id	Bragadin and Kahkonen (2016)	1
8	Schedule logic integration	Bragadin and Kahkonen (2016)	1
9	Realistic network logic	Bragadin and Kahkonen (2016); GAO (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	4
10	Activity easy to monitor	Bragadin and Kahkonen (2016)	1
11	Total number of manager	Bragadin and Kahkonen (2016)	1
12	Activity duration reasonable	Bragadin and Kahkonen (2016); DCMA (2012); GAO (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	5
13	Activity name reasonable	Bragadin and Kahkonen (2016); GAO (2012)	2

14	Total scope as defined by WBS	Bragadin and Kahkonen (2016); GAO (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	4
15	Submission date	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
16	Responsibility assignment	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
17	Special / Submittal / Submittal review / Procurement activities included	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
18	Reasonable activity sequencing	Bragadin and Kahkonen (2016);GAO (2012)	2
19	Network logic used for all activities	Bragadin and Kahkonen (2016)	1
20	Predecessor relation indicated	Bragadin and Kahkonen (2016)	1
21	Duration definition	Bragadin and Kahkonen (2016)	1
22	Duration estimation	Bragadin and Kahkonen (2016); GAO (2012)	2
23	Continuity of production	Bragadin and Kahkonen (2016)	1
24	Weather sensitive activities	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
25	Building enclosure dependencies	Bragadin and Kahkonen (2016)	1
26	Work continuity	Bragadin and Kahkonen (2016)	1
27	Work flow	Bragadin and Kahkonen (2016)	1
28	Safe & non-congested work areas	Bragadin and Kahkonen (2016)	1

29	Open ended activities	Bragadin and Kahkonen (2016); DCMA (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	4
30	Summary tasks logic	Bragadin and Kahkonen (2016); GAO (2012)	2
31	Missing logic	Bragadin and Kahkonen (2016)	1
32	Relationship ratio	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
33	Relationship types	Bragadin and Kahkonen (2016); DCMA (2012)	2
34	Critical path & critical activities	Bragadin and Kahkonen (2016); GAO (2012) Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	4
35	Critical activities feature	Bragadin and Kahkonen (2016)	1
36	Multiple critical paths	Bragadin and Kahkonen (2016)	1
37	Critical path test	Bragadin and Kahkonen (2016); DCMA (2012); GAO (2012)	3
38	Critical path length index (CPLI)	Bragadin and Kahkonen (2016); DCMA (2012); GAO (2012)	3
39	Critical path logic	Bragadin and Kahkonen (2016)	1
40	Schedule criticality rate	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
41	Near criticality rate	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
42	Critical activity duration	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
43	Float computation	Bragadin and Kahkonen (2016); GAO (2012)	2
44	Reasonable float dimensions	Bragadin and Kahkonen (2016); GAO (2012)	2

45	Excessive total float	Bragadin and Kahkonen (2016); DCMA (2012); GAO (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	5
46	Negative float	Bragadin and Kahkonen (2016); DCMA (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	4
47	ASAP & ALAP computation	Bragadin and Kahkonen (2016)	1
48	Constraints	Bragadin and Kahkonen (2016); GAO (2012)	2
49	Number of Constraints	Bragadin and Kahkonen (2016); DCMA (2012); GAO (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	5
50	Buffers	Bragadin and Kahkonen (2016)	1
51	No activity miss-assignment	Bragadin and Kahkonen (2016)	1
52	No empty milestones	Bragadin and Kahkonen (2016)	1
53	Number of Lags / lag durations	Bragadin and Kahkonen (2016); DCMA (2012); GAO (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	5
54	Number of Leads	Bragadin and Kahkonen (2016); DCMA (2012); GAO (2012)	3
55	Monetary value of activities	Bragadin and Kahkonen (2016)	1
56	Total monetary value	Bragadin and Kahkonen (2016)	1
57	Progress payment	Bragadin and Kahkonen (2016)	1
58	Project cost ratio range	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
59	Resource loading	Bragadin and Kahkonen (2016); DCMA (2012); GAO (2012); Farzad Moosavi and	6

		Moselhi (2014); Moosavi and Moselhi (2012); Leu and Yang (1999)	
60	Resource productivity	Bragadin and Kahkonen (2016)	1
61	Resource levelling and conflicts	Bragadin and Kahkonen (2016); GAO (2012); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012); Leu and Yang (1999)	5
62	Total amount of working hours/day	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
63	Project effort ratio	Bragadin and Kahkonen (2016); Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	3
64	Percentage complete	Bragadin and Kahkonen (2016)	1
65	Schedule slippage	Bragadin and Kahkonen (2016)	1
66	Schedule maintenance	Bragadin and Kahkonen (2016)	1
67	Actual progress	Bragadin and Kahkonen (2016)	1
68	Variance report	Bragadin and Kahkonen (2016)	1
69	Baseline execution index	Bragadin and Kahkonen (2016); DCMA (2012)	2
70	Schedule projections	Bragadin and Kahkonen (2016)	1
71	Corrective actions	Bragadin and Kahkonen (2016)	1
72	Invalid dates	Bragadin and Kahkonen (2016); DCMA (2012)	2
73	Missed tasks	Bragadin and Kahkonen (2016); DCMA (2012)	2
74	Out of sequence activities	Bragadin and Kahkonen (2016); US GAO (2012)	2
75	No. of activities	Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	2
76	Verification of subcontractors' scope of work	Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	2

77	Verification of project performance	Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	2
78	Congestion Index (Labor)	Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	2
79	Trades peak resource loading	Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	2
80	Trades peak resource loading relation	Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	2
81	Trades rate of completion per week	Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	2
82	Peak to average labor ratio	Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	2
83	Critical Path Affiliation	Farzad Moosavi and Moselhi (2014); Moosavi and Moselhi (2012)	1
84	Schedule risk analysis	GAO (2012)	1
85	Updating and documenting Schedule risk analysis	GAO (2012)	1
86	Progress status and updates	GAO (2012)	1
87	Maintaining baseline	GAO (2012)	1

The identified schedule health indicators were shortlisted based on the frequency of occurrence. For this frequency analysis was carried out. Shortlisting was done in order to avoid repetition of schedule health indicators under different name and similar nature. Further, there is a need to formulate criteria that constitutes only the most important indicators, and it do not increase the time to carry out the evaluation process. Indicators which were used in minimum three researches were shortlisted and presented in Table 2.2. A total of 30 Indicators were shortlisted and which will form the criteria.

Table 2.2: Shortlisted Schedule Health Indicators

Sr. No.	Schedule Health Requirement	Used by Researchers (No.)
1	Resource loading	6
2	Activity duration reasonable	5
3	Excessive total float	5
4	Number of Constraints	5
5	Number of Lags / lag durations	5
6	Resource levelling and conflicts	5
7	Realistic network logic	4
8	Project calendar identification and verification	4
9	Activity coding structure	4
10	Milestones	4
11	Total scope as defined by WBS	4
12	Critical path & critical activities	4
13	Negative float	4
14	Open ended activities	4
15	Participation of major subcontractors	4
16	Project duration	3
17	Submission date	3
18	Responsibility assignment	3
19	Special / Submittal / Submittal review / Procurement activities included	3
20	Weather sensitive activities	3
21	Relationship ratio	3
22	Critical path test	3
23	Critical path length index (CPLI)	3
24	Schedule criticality rate	3
25	Near criticality rate	3
26	Critical activity duration	3
27	Number of Leads	3
28	Project cost ratio range	3

29	Total amount of working hours/day	3
30	Project effort ratio	3

Many researchers characterized the schedule health indicators in various groups based on their nature. Table 2.3 indicates those schedule requirement groups, along with number of schedule requirements used in the research and scope of study. It is evident from Table 2.3 that most of the researches carried out related to the scope of schedule health assessment are relatively new, compared to the researches in planning field in general.

Table 2.3: Literature on Schedule Health Assessment

Sr. No.	Authors	Scope of Study	Schedule Requirement Groups	Number of Schedule Indicators
1	Leu and Yang (1999)	GA-Based Multicriteria Optimal Model for Construction Scheduling	N/A	2
2	Song et al. (2009)	Early Contractor Involvement in Design and its Impact on Schedule Performance	N/A	1
3	GAO (2012)	Schedule Assessment Guide	1. Capturing all activities 2. Sequencing all activities 3. Assigning Resources to all activities 4. Establishing the durations of all activities	53

			5. Verifying that the schedule is traceable horizontally and vertically 6. Confirming that the critical path is valid 7. Ensuring reasonable total float 8. Conducting a schedule risk analysis 9. Updating the schedule with actual progress and logic 10. Maintaining a baseline schedule -	
4	Moosavi and Moselhi (2012)	Schedule Assessment and Evaluation	1. Contractual Compliance 2. Schedule Development 3. Schedule Components	47
5	DCMA (2012)	Earned Value Management System (Evms)	N/A	14
6	Farzad Moosavi and Moselhi (2014)	Review of Detailed Schedule in Building Construction	1. Obligatory Criteria 2. Complementary Criteria	48
7	Bragadin and Kahkonen (2016)	Schedule Health Assessment of Construction Projects	1. General Requirements 2. Construction Process 3. Schedule Mechanics 4. Cost and Resources 5. Control Process	75

Chapter 3

METHODOLOGY

3.1 BACKGROUND

Methodological grounds for assessing schedule quality were studied via literature review for the formulation of suitable criteria to assess the health of construction work schedules. The shortcomings of previous researchers were highlighted in the literature review. In an effort to overcome these shortcomings, the methodology will set a path which will help in achieving the objectives of this research as stated in Chapter 1.

3.2 METHODOLOGY STRUCTURE

The research structure defines the layout showing how the research is going to be carried out to achieve the objectives of the research (Saunders et al., 2009). The methodology is divided into three phases, coinciding with the three objectives of the research:

1. Phase - 1 (Identification of Key Schedule Health Indicators)
2. Phase - 2 (Criteria Formulation)
3. Phase – 3 (Schedule Health Assessment and Implementation)

Detailed elaboration of methodology in the form of illustration is presented in Figure 3.1 at the end of this chapter.

3.2.1 PHASE 1 (IDENTIFICATION OF KEY SCHEDULE HEALTH INDICATORS)

In the first phase, after the development of research proposal, an extensive review of the literature was carried out to identify the schedule health Indicators. Google Scholar, Scopus, Wiley Online Library and ASCE was mainly used as the search tools to find potential research papers and articles related to the topic.

Phase 1 constitutes of the following steps:

i. Review past literature and identification of gaps.

ii. Identification of schedule health requirement used in past studies.

iii. Shortlisting of schedule health Indicators based on the frequency of occurrence.

Phase 1 has been effectively covered in Chapter 2.

3.2.2 PHASE 2 (CRITERIA FORMULATION)

Phase 2 constitutes of the following step:

i. A survey questionnaire was developed and floated among construction professionals for threshold values assignment to each criterion along with the weight or relative importance assignment. Bragadin and Kahkonen (2016) argues that there is a need to assign relative importance to quality indicators, to develop a good quality assessment procedure.

3.2.2 (i) Sample selection and size

The purpose of the sampling is to collect data and carry out research objectives on condition that the sample is the true representation of the whole population (Fellows and Liu, 2015). To know whether the sample size is truly representing the population or not, table of Dillman (2000) was used which represents sample sizes required for various population sizes and characteristics at three level of precision. For 95% confidence and taking into account 10% sampling error, the sample size required was 96.

3.2.2 (ii) Questionnaire formulation

A questionnaire is an organized way to approach stakeholders to gather required data through the questions in the pre-organized way.

The questionnaire was divided into following sections:

a. The covering letter (indicating topic and its purpose)

b. Respondents profile (information about respondent)

c. The body of questionnaire; Part 1 (threshold values assignment) and Part 2 (assignment of weightage to each health indicator)

3.2.2 (iii) Statistical analysis using MS-Excel

Computation of Relative Importance Index (RII) and Benchmarking factor out hundred will be computed in MS-Excel using equation (I) and (II) respectively:

- **Relative Importance Index (RII)**

$$RII = \frac{\sum w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(I)}$$

Where:

w = Weightage given by the respondent (Very Low = 0 to Very High = 5)

n_5 = no. of respondents opted for very high

n_4 = no. of respondents opted for high

n_3 = no. of respondents opted for moderate

n_2 = no. of respondents opted for low

n_1 = no. of respondents opted for very low

A = Highest weight (In this research it is 5)

N = Total number of respondents (118 in this research)

- **Benchmarking factor out of 100**

$$BM = \frac{RII_n}{\sum RII} \; x \; 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(II)}$$

Where:

BM = Benchmarking factor out of 100

RII n = Relative importance index of considered criterion

∑RII = Sum of RIIs of all individual criterion

3.2.2 (iv) Statistical analysis using SPSS

Following test on the data will be carried out in SPSS 16:

- **Reliability of Data**

Reliability defines the overall consistency of the data. Data is said to have a high reliability if it produces similar results under consistent conditions. Data that is highly reliable is accurate, reproducible, and consistent for testing under different conditions. Which means, if the testing process were repeated with different group of respondents, same results would be obtained.

- **Normality of Data**

An evaluation of the data normality is a pre-condition for use of numerous statistical tests. It is performed to know whether data is normally distributed or not, i.e. is the data parametric or non-parametric in nature. Shapiro-Wilk test is considered a more thorough examination of normality for datasets of about two thousand (2000) elements or less. For the dataset consisting of more than 2,000 values Kolmogorov-Smirnov test is more suitable. Hence considering the sample size, for this study Shapiro-Wilk test is performed to check the data for normality. For the dataset to be considered as normally distributed, the significance value should be larger than 0.05.

- **Tests for consistency in perception**

The Kruskal-Wallis test and one-way ANOVA are used to determine whether three or more independent groups (e-g client, consultant and contractor) have similar or different opinion on a particular matter. It is a better way of finding statistical evidence of inconsistency or differences in perception, using mean values or indices, of various groups. The Kruskal-Wallis test is used for non-parametric data whereas one-way ANOVA is used for parametric data. The results are tested against the significance limit of 0.05. Stakeholder will have similar perception if significance value is more than 0.05.

3.2.3 PHASE 3 (SCHEDULE HEALTH ASSESSMENT AND IMPLEMENTATION)

Phase 3 constitutes the following steps:

i. As case studies, work schedules of two completed real semi high-rise building construction projects and other related data will be gathered. Soft file of work schedule will be acquired for analysis.

ii. These work schedules will be evaluated using the formulated criteria. Benchmarking of the schedules will be carried out. Conclusion will be drawn based on the results of evaluation in comparison with the actual outcome of the project.

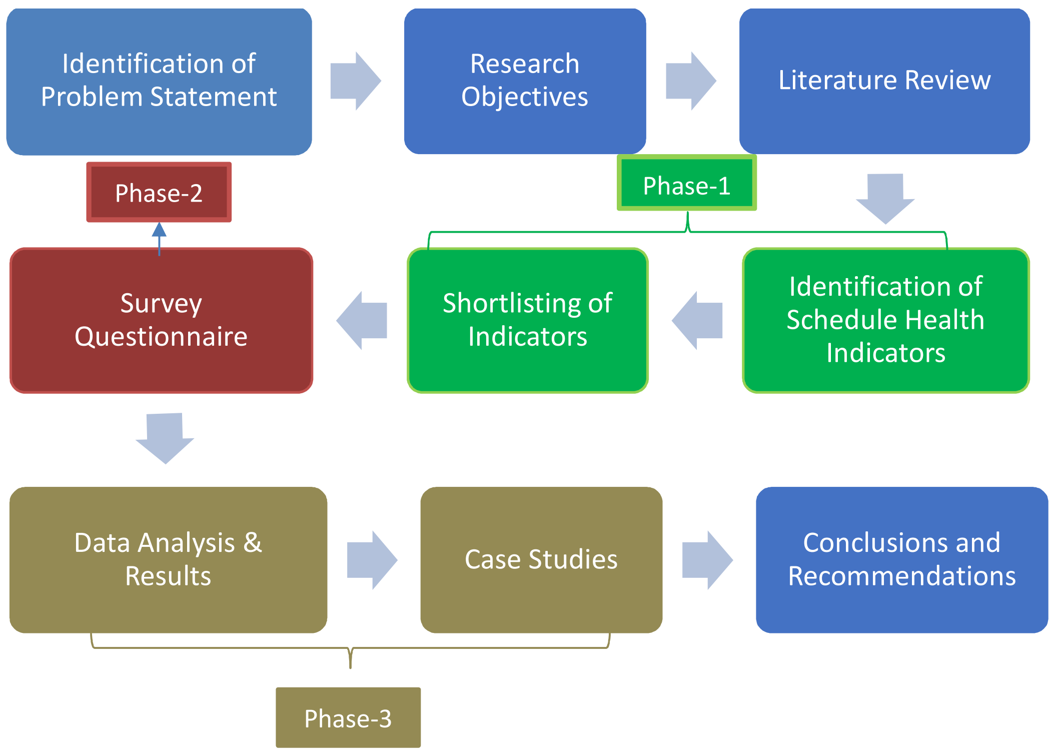

Figure 3.1: Methodology of Research

Chapter 4

DATA ANALYSIS AND RESULTS

4.1 INTRODUCTION

This chapter displays the data collected through questionnaires for quantitative analysis. The questionnaire survey was carried out to get input from construction professionals for threshold value assignment to each criterion and then assigning importance to each criterion to form schedule health assessment criteria. Questionnaire was developed after an extensive literature review. In literature review 30 schedule health indicators were identified. Questionnaire was prepared using Google Forms and was floated to different people working in different areas of Pakistan using social network and emails. Most of the respondents had field experience of more than 5 years. Sample survey questionnaire is attached at Appendix-B.

Results for this research are based on the above-mentioned survey. The online survey was open for a period of 4 months. A total of 118 responses were received.

4.2 CHARACTERISTICS OF RESPONDENTS

4.2.1 LOCATION OF RESPONDENTS

Major portion 45% of the respondents were from Punjab. This indicates that most of the construction in on-going in the province of Punjab. 24% of respondents were based in Islamabad, whereas 20% of the respondents were based in Sindh. Combinedly 11% respondents were based in Balochistan, Khyber Pakhtunkhwa and Gilgit Baltistan as shown in Figure 4.1.

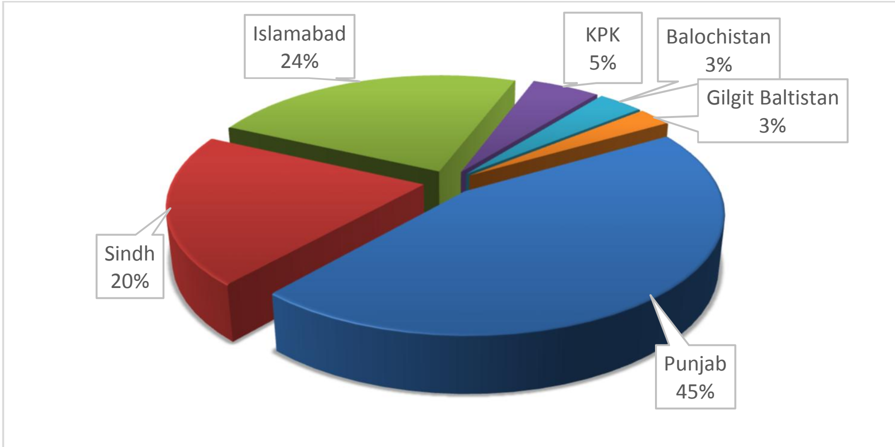

Figure 4.1: Representation of location of respondents

4.2.2 ACADEMIC QUALIFICATION OF RESPONDENTS

75% of the respondents had minimum education till graduation level, indicating that the respondents are well qualified and may have better understanding of the topic. 24% of the respondents had an academic qualification of Post-graduation or higher. Only one percent of respondents had academic qualification lower than graduation. Same is depicted in Figure 4.2.

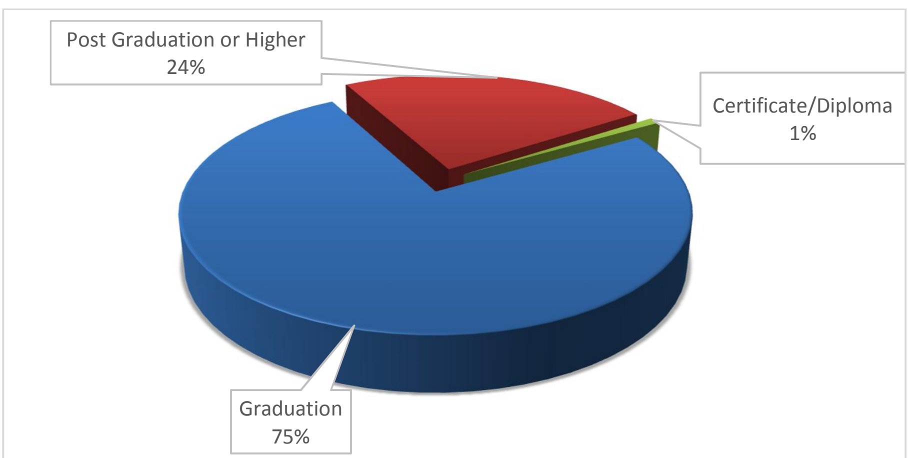

Figure 4.2: Representation of academic qualification of respondents

4.2.3 EXPERIENCE OF RESPONDENTS

39% of the respondents had work experience falling within the range of 6-10 years. 36% had an experience within the range of 0-5 years and 25% respondents had experience of more than 10 years. The data coincides with the fact the concept of planning and particularly scheduling is relatively new in the construction industry of Pakistan. Young engineers are more aware regarding the scheduling software and their use. Percentage of respondents with respect to experience is indicated in Figure 4.3.

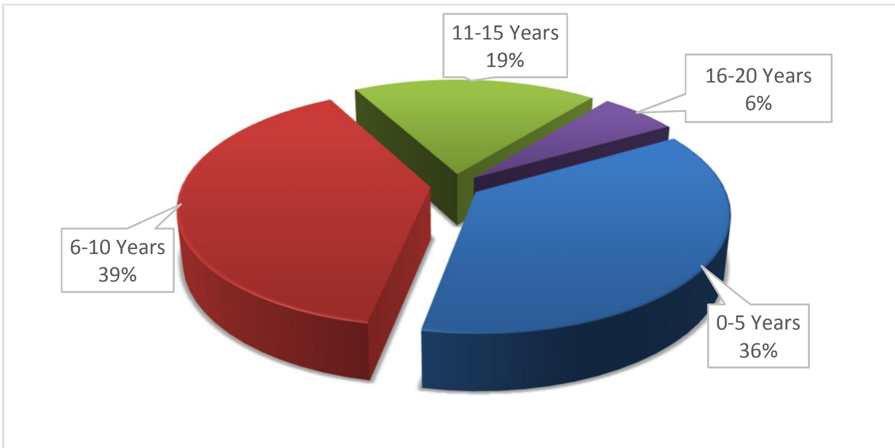

Figure 4.3: Representation of job experience of respondents

4.2.4 RESPONDENT STAKEHOLDER ORGANIZATION

42% of respondents were Client, whereas respondents from Consultant and Contractor were 15% and 39% respectively. Major participation of clients in providing opinion for the formulation of the criteria will help in developing sound criteria with strong focus on scheduling mechanics. The percentage of respondents falling in various categories in respect of stakeholder organization is presented in Figure 4.4.

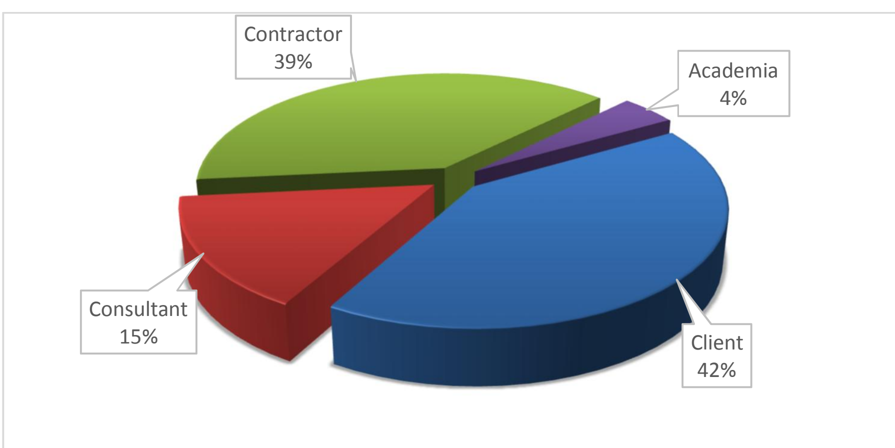

Figure 4.4: Representation of respondent's stakeholder organization

4.2.5 RESPONDENT WORK SECTOR

51% of respondents belong to private sector. The responses received covers the opinion of construction professionals from all sectors. Percentage of respondents from each work sector is shown in Figure 4.5.

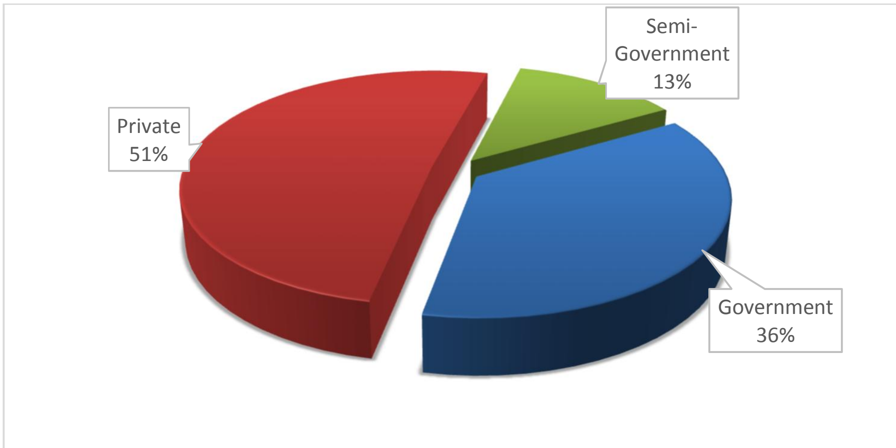

Figure 4.5: Representation of respondent's work sector

4.2.6 NATURE OF EXPERIENCE OF RESPONDENT

72% of the respondents stated that their substantial experience is related to buildings. 9% respondents indicated that they have experience related to roads. 3% respondents belonged to real estate whereas 8% respondents had multi-sector experience. Remaining 8% respondents have been categorized into others portion, which includes respondents having experience of academia, dams, bridges, etc. Percentage of respondents with respect to the nature of their experience is indicated in Figure 4.6.

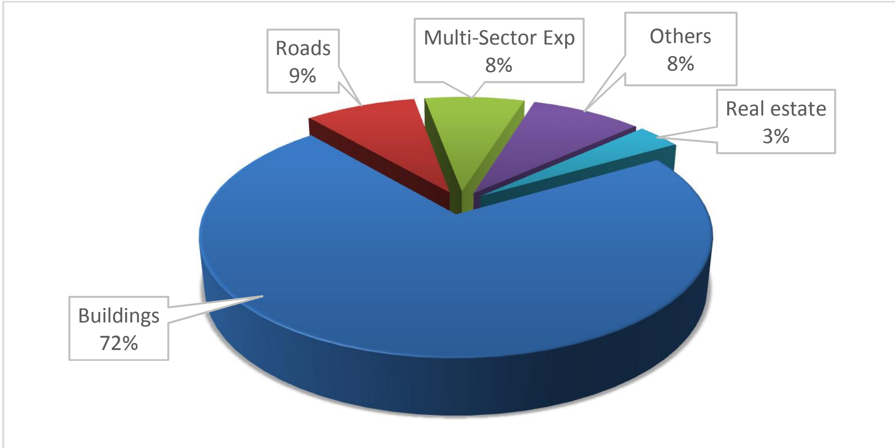

Figure 4.6: Representation of respondent's experience nature

4.2.7 RESPONDENT AWARENESS OF THE TOPIC

67% of the respondents stated that they have intermediate (practical application) level of knowledge regarding the research topic, indicating the major number of respondents have at least prepared work schedules for implementation during construction. Percentage of respondents with respect to their knowledge regarding the research is indicated in Figure 4.7.

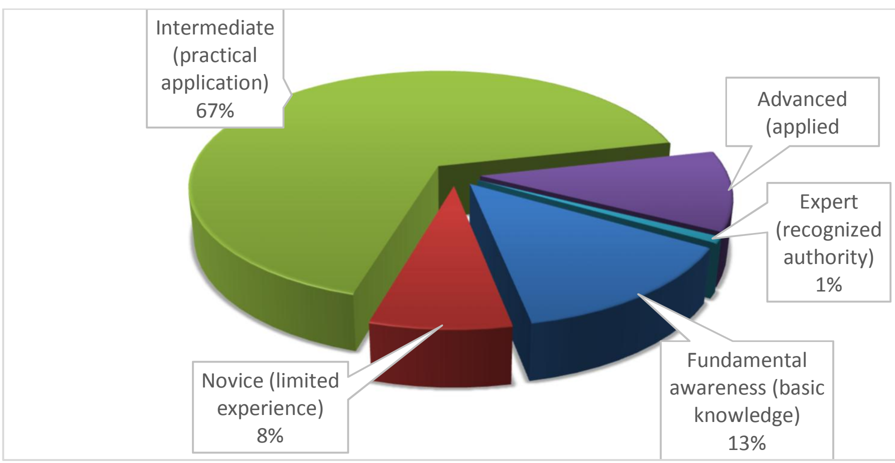

Figure 4.7: Representation of respondent's awareness of topic

4.2.8 SOFTWARE USED IN ORGANIZATION

Major percentage, 62% of the respondents stated that they Primavera software is used in their organization. Primavera software contains all tools and functions required for the scheduling. 25% respondents use MS Project while 12% use MS Excel. Same is indicated in Figure 4.8.

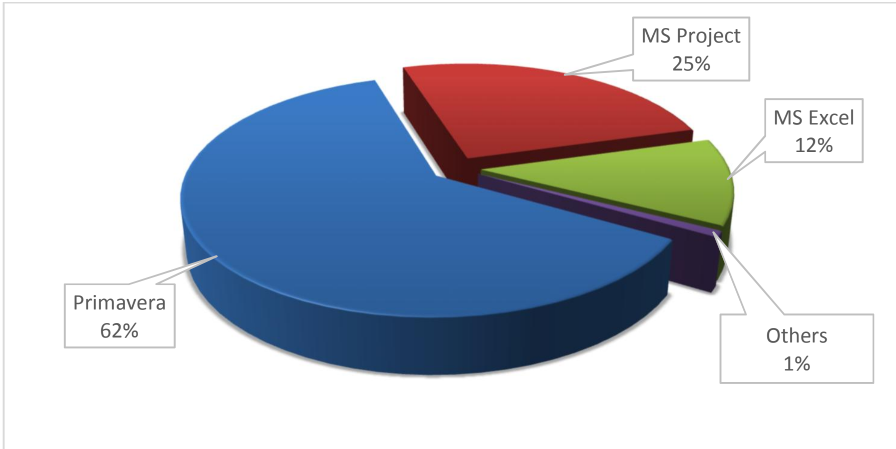

Figure 4.8: Representation of type of software used in respondent's organization

4.3 STATISTICAL ANALYSIS

To statistically validate the collected data, various tests were conducted. MS-Excel and SPSS-16 were used to analyze the data.

4.3.1 RELATIVE IMPORTANCE INDEX AND BENCHMARKING

Relative importance index and Benchmarking factor out of 100 were calculated using excel. The results of these tests for each criterion are presented in Table 4.1.

Table 4.1: Results of Statistical Analysis using MS Excel

Sr. No.	Criteria	Average Score	Rank	Relative Importance Index	Benchmarking factor out of 100
1	Activity duration reasonable	4.39	2	0.88	4.91
2	Excessive total float	2.99	14	0.60	3.35
3	Number of Constraints	2.47	21	0.49	2.76
4	Number of Lags / lag durations	2.35	23	0.47	2.63
5	Resource loading	2.80	15	0.56	3.13
6	Realistic network logic	4.45	1	0.89	4.98

7	Project calendar identification and verification	2.29	24	0.46	2.56
8	Activity coding structure	1.98	30	0.40	2.22
9	Milestones	3.25	10	0.65	3.63
10	Total scope as defined by WBS	4.04	3	0.81	4.52
11	Critical path & critical activities	3.98	4	0.80	4.46
12	Negative float	2.28	25	0.46	2.55
13	Resource levelling and conflicts	2.69	17	0.54	3.01
14	Open ended activities	3.29	9	0.66	3.68
15	Participation of major subcontractors	3.75	7	0.75	4.20
16	Project duration	3.83	5	0.77	4.29
17	Submission date	2.18	28	0.44	2.44
18	Responsibility assignment	2.69	17	0.54	3.01
19	Special / Submittal / Submittal review / Procurement activities included	2.80	15	0.56	3.13
20	Weather sensitive activities	2.10	29	0.42	2.35
21	Relationship ratio	3.05	13	0.61	3.41
22	Critical path test	3.79	6	0.76	4.24
23	Critical path length index (CPLI)	3.07	12	0.61	3.43
24	Schedule criticality rate	3.14	11	0.63	3.51
25	Near criticality rate	2.57	20	0.51	2.87
26	Critical activity duration	3.73	8	0.75	4.17
27	Number of Leads	2.46	22	0.49	2.75
28	Project cost ratio range	2.58	19	0.52	2.88

29	Total amount of working hours/day	2.19	27	0.44	2.45
30	Project effort ratio	2.22	26	0.44	2.48

4.3.2 TEST FOR RELIABILITY

Cronbach's Coefficient Alpha method was used to measure the internal consistency (reliability) of data. This method is commonly used when questions are asked on the Likert scale. According to Hair et al. (2006), the data is reliable if Cronbach's Alpha value is more than 0.6. Whereas according to Li (2007), if Cronbach's Coefficient Alpha value is greater than 0.7, the dataset can be considered reliable for study. Further, if the value is greater than 0.9, the data is highly consistent for use. The value of Cronbach's Alpha came out to be 0.878, therefore the data is reliable.

4.3.3 TEST FOR NORMALITY

To check the normality of data, Shapiro-Wilk test was carried out. This test was conducted to evaluate whether the collected data was normally distributed or not, i.e. the data was parametric or non-parametric. As per the results of normality test, the data is not normally distributed and non- parametric test is needed to further analysis. Table 4.2 indicates that the significance value is less than 0.05, therefore, the data is non-parametric and non-parametric test is required to be performed for further analysis.

Table 4.2: Results of Normality Test

Sr. No.	Parameter	Statistic	df	Significance
1	Maximum activity duration allowed in work schedule	0.744	118	0.000
2	Maximum allowable total float for at-least 95% of activities	0.454	118	0.000
3	Maximum range of constraints on percentage number of activities	0.651	118	0.000

4	Maximum lag duration for at-least 95% of activities	0.657	118	0.000
5	Maximum range of lag on relationships against total relationships	0.697	118	0.000
6	Minimum percentage range of milestones against total activities	0.731	118	0.000
7	Percentage range of critical activities against total activities	0.738	118	0.000
8	Maximum allowable percentage range of activities to have negative float against total activities	0.623	118	0.000
9	Maximum allowable percentage range of open-ended activities against total activities	0.664	118	0.000
10	Range of relationship ratio	0.850	118	0.000
11	Range for schedule criticality rate	0.467	118	0.000
12	Defining near critical activities	0.469	118	0.000
13	Range for near criticality rate	0.502	118	0.000
14	Maximum duration of critical activity allowed in work schedule	0.728	118	0.000
15	Maximum range of no. of leads on relationships against total relationships	0.667	118	0.000
16	Range of project cost ratio	0.623	118	0.000
17	Range of project effort ratio	0.633	118	0.000
18	Activity duration reasonable	0.689	118	0.000
19	Excessive total float	0.766	118	0.000
20	Number of Constraints	0.777	118	0.000
21	Number of Lags / lag durations	0.736	118	0.000
22	Resource loading	0.791	118	0.000
23	Realistic network logic	0.641	118	0.000
24	Project calendar identification and verification	0.793	118	0.000
25	Activity coding structure	0.740	118	0.000
26	Milestones	0.740	118	0.000
27	Total scope as defined by WBS	0.758	118	0.000

28	Critical path & critical activities	0.780	118	0.000
29	Negative float	0.831	118	0.000
30	Resource levelling and conflicts	0.836	118	0.000
31	Open ended activities	0.794	118	0.000
32	Participation of major subcontractors	0.769	118	0.000
33	Project duration	0.780	118	0.000
34	Submission date	0.742	118	0.000
35	Responsibility assignment	0.826	118	0.000
36	Special / Submittal / Submittal review / Procurement activities included	0.801	118	0.000
37	Weather sensitive activities	0.753	118	0.000
38	Relationship ratio	0.708	118	0.000
39	Critical path test	0.705	118	0.000
40	Critical path length index (CPLI)	0.764	118	0.000
41	Schedule criticality rate	0.757	118	0.000
42	Near criticality rate	0.814	118	0.000
43	Critical activity duration	0.764	118	0.000
44	Number of Leads	0.745	118	0.000
45	Project cost ratio range	0.796	118	0.000
46	Total amount of working hours/day	0.793	118	0.000
47	Project effort ratio	0.789	118	0.000

4.3.4 KRUSKAL WALLIS TEST

The data that was collected for this questionnaire-based research was not able to be validated by the normality test. Accordingly, Kruskal-Wallis test was used for further analysis to check the variations in the perceptions of the stakeholders i.e. Client, Consultant, Contractor and Academia. All the stakeholders will have same perception if the significance value is above 0.05 and vice versa. Table 4.3 depicts the results of the Kruskal Wallis test.

Table 4.3: Results of Kruskal Wallis Test

Sr. No.	Parameter	Significance
1	Maximum activity duration allowed in work schedule	0.104

2	Maximum allowable total float for at-least 95% of activities	0.842
3	Maximum range of constraints on percentage number of activities	0.043
4	Maximum lag duration for at-least 95% of activities	0.435
5	Maximum range of lag on relationships against total relationships	0.292
6	Minimum percentage range of milestones against total activities	0.275
7	Percentage range of critical activities against total activities	0.852
8	Maximum allowable percentage range of activities to have negative float against total activities	0.401
9	Maximum allowable percentage range of open-ended activities against total activities	0.103
10	Range of relationship ratio	0.229
11	Range for schedule criticality rate	0.005
12	Defining near critical activities	0.486
13	Range for near criticality rate	0.478
14	Maximum duration of critical activity allowed in work schedule	0.767
15	Maximum range of no. of leads on relationships against total relationships	0.003
16	Range of project cost ratio	0.135
17	Range of project effort ratio	0.014
18	Activity duration reasonable	0.501
19	Excessive total float	0.479
20	Number of Constraints	0.437
21	Number of Lags / lag durations	0.562
22	Resource loading	0.821
23	Realistic network logic	0.235
24	Project calendar identification and verification	0.395
25	Activity coding structure	0.363
26	Milestones	0.338
27	Total scope as defined by WBS	0.071
28	Critical path & critical activities	0.745
29	Negative float	0.220
30	Resource levelling and conflicts	0.691

31	Open ended activities	0.484
32	Participation of major subcontractors	0.230
33	Project duration	0.283
34	Submission date	0.643
35	Responsibility assignment	0.665
36	Special / Submittal / Submittal review / Procurement activities included	0.896
37	Weather sensitive activities	0.150
38	Relationship ratio	0.857
39	Critical path test	0.485
40	Critical path length index (CPLI)	0.963
41	Schedule criticality rate	0.335
42	Near criticality rate	0.712
43	Critical activity duration	0.004
44	Number of Leads	0.110
45	Project cost ratio range	0.618
46	Total amount of working hours/day	0.193
47	Project effort ratio	0.145

For most of the factors, the stakeholder's perception was same but for the following five factors, difference in perception was observed.

i. Maximum range of constraints on percentage number of activities

ii. Range for schedule criticality rate

iii. Maximum range of no. of leads on relationships against total relationships

iv. Range of project effort ratio

v. Critical activity duration

4.4 CASE STUDIES

To demonstrate the use of the developed criteria, schedules of two actual building construction projects were analyzed. The two work schedules were also assessed by the DCMA 14-Point method and the results were compared.

4.4.1 ANALYSIS OF WORK SCHEDULES

The two actual projects are residential and institutional buildings constructed in Rawalpindi and Islamabad respectively. The work schedules of both the projects were prepared using Primavera software. Soft files of work schedules were acquired for analysis. The major features of these projects are summarized in Table 4.4.

Table 4.4: Features of case study projects

Sr. No.	Description	Project A	Project B
1	Building Nature	Residential	Institutional
2	Covered Area	103,125 Sq.ft	62,000 Sq.ft
3	Floors	10	4
4	Planned Duration	640 Days	380 Days
5	Actual Duration	806 Days	817 Days
6	Planned Cost	240.04 Million	345.04 Million
7	Actual Cost	260.52 Million	348.00 Million

These work schedules were reviewed to know whether they fulfil the criteria or not. After the completion of assessment for compliance to each criterion, the total benchmark score was calculated for each of the two work schedules. The condition of fulfillment of each criterion gives score equal to benchmarking factor value out of 100. If the criterion is not fulfilled, zero score was given. The score of each criterion was then totaled to acquire total score for the fitness of the schedule. Schedule of project B obtained the higher benchmark score of 66.06

out of 100 compared to the schedule of project A which obtained a score of 62.71 out of 100. There were common deficiencies in work schedules of both the projects. As a result, the schedules were unable to satisfy the criteria pertinent to total float, resource loading, milestones, resource leveling and conflicts, participation of major subcontractors in schedule preparation, responsibility assignment, weather sensitive activities and project effort computations. Table 4.5 shows compliance or non-compliance of work schedules of both projects to each criterion.

Table 4.5: Evaluation of projects under formulated criteria

Criteria	**Fulfilment of Criteria (Yes/No)**		**Score for each criterion**	
	Project A	**Project B**	**Project A**	**Project B**
Activity duration reasonable	Yes	Yes	4.91	4.91
Excessive total float	No	No	0	0
Number of Constraints	Yes	No	2.75	0
Number of Lags / lag durations	Yes	No	2.63	0
Resource loading	No	No	0	0
Realistic network logic	Yes	Yes	4.98	4.98
Project calendar identification and verification	Yes	Yes	2.56	2.56
Activity coding structure	Yes	Yes	2.22	2.22
Milestones	No	No	0	0
Total scope as defined by WBS	Yes	Yes	4.52	4.52
Critical path & critical activities	Yes	Yes	4.46	4.46
Negative float	Yes	Yes	2.55	2.55
Resource levelling and conflicts	No	No	0	0
Open ended activities	No	Yes	0	3.68

Participation of major subcontractors	No	No	0	0
Project duration	Yes	Yes	4.29	4.29
Submission date	No	Yes	0	2.44
Responsibility assignment	No	No	0	0
Special / Submittal / Submittal review / Procurement activities included	No	Yes	0	3.13
Weather sensitive activities	No	No	0	0
Relationship ratio	Yes	No	3.41	0
Critical path test	Yes	Yes	4.24	4.24
Critical path length index (CPLI)	Yes	Yes	3.41	3.41
Schedule criticality rate	Yes	Yes	3.53	3.53
Near criticality rate	Yes	Yes	2.85	2.85
Critical activity duration	Yes	Yes	4.2	4.2
Number of Leads	Yes	Yes	2.75	2.75
Project cost ratio range	No	Yes	0	2.89
Total amount of working hours/day	Yes	Yes	2.45	2.45
Project effort ratio	No	No	0	0
		Total Score =	62.71	66.06

The actual schedules were also analyzed using the DCMA 14-Point Assessment. Work schedules of project A passed seven tests, whereas the work schedule of project B passed six tests. Both the project's work schedules fulfilled criteria for logic, leads, hard constraints, negative float, invalid dates, critical path test and critical path length index (CPLI). However, the work schedule of project A also passed the test high duration. Criteria for missed tasks and baseline execution index (BEI) were not applicable as these criteria are applicable to monitoring and control phase. It is pertinent to mention here that as no weight is assigned to each criterion by DCMA, therefore, relative importance is taken same for each individual criterion. The results of assessments are summarized in Table 4.6.

Table 4.6: Evaluation of project under DCMA 14-Points

Criteria	**Fulfilment of Criteria (Yes/No)**		**Score for each criterion**	
	Project A	**Project B**	**Project A**	**Project B**
Logic	Yes	Yes	1	1
Leads	Yes	Yes	1	1
Lags	No	No	0	0
Relationship types	No	No	0	0
Hard Constraints	Yes	Yes	1	1
High Float	No	No	0	0
Negative Float	Yes	Yes	1	1
High Duration	Yes	No	1	0
Invalid Dates	Yes	Yes	1	1
Resources	No	No	0	0
Missed Tasks (Not applicable as the criteria is applicable to monitoring phase)	-	-	-	-
Critical Path Test	Yes	Yes	1	1
Critical Path Length Index (CPLI)	Yes	Yes	1	1
Baseline Execution Index (BEI) (Not applicable as the criteria is applicable to monitoring phase)	-	-	-	-

Total Score =	8	7

4.4.2 DISCUSSION ON CASE STUDIES RESULTS

Both schedules had nearly same set of deficiencies. Their benchmarking scores were considerably less than the perfect score of 100. The benching score calculated for schedule B was relatively higher than that for schedule A, indicating that Schedule B was developed better than schedule B. While reviewing both schedules using the DCMA 14-Point method, it was observed that similar deficiencies were present in both the schedules, however, work schedule of project A passed one more test than that of work schedule for project B.

DCMA does not give weight to individual criterion, therefore, relative importance index (RII) is assumed to be same for every criterion. In addition to this DCMA only has fourteen criterions to judge the health of the schedule and two of them were not applicable in this research is indicated earlier. Therefore, with thirty detailed criterions to judge the health of schedule with the proposed criteria in this research, one can safely say that work schedule of project B is better developed. It should be noted that a lot of improvement needs to be done in work schedules to achieve a perfect or near perfect score.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

In this chapter, conclusion is drawn in-line with the results presented in Chapter 5.

5.1 CONCLUSIONS

A Schedule Health Assessment method has been proposed with the aim of improving the quality of a construction schedule and scheduling process. Schedule health indicators were identified through pertinent literature. Well-defined criteria were established for the purpose of schedule assessment. The fitness of the scheduling process and of schedule itself can be measured through the criteria consisting of 30 assessment check points. The criteria were established based on the feedback received for construction professionals through survey questionnaire. First, the respondents assigned threshold values forming each criterion. These criterions were then assigned relative importance. Formulated criteria are appended at Appendix-A.

The Schedule Health Assessment method introduces checklists of detailed requirements which can be used as a guide to scheduling process itself. In fact, the method has also the aim of being a pro-active method for master and detailed construction scheduling i.e. it can be used as a guide in the schedule development process by project planners and for quality assessment for controlling purposes by project supervisors. It is believed that the proposed method has also the effect of increasing project control in the execution phase, as quality audit of the schedule maintenance process can have the effect of enhancing the monitoring and controlling process. Relative weights of the Indicators have been formulated using the opinion of construction industry professionals. The proposed method was tested on work schedules of two actual projects. The result of the Schedule Health Assessment procedure indicated low health level of the schedules. This means that further improvement of the evaluated schedule was possible, as to increase its fitness. Both the projects faced schedule overrun and poor planning and scheduling are one of the important contributing factors. It is still needed to make project scheduling an effective production plan and not only a documentation requirement. As schedule health assessment is performed through checklists, it is also believed that the developed method is suitable for the majority of owners, consultants and contractors of SMEs construction projects, where resource shortage for project planning and scheduling can lead to the development of low-quality schedules. The formulated criteria will assist clients and consultants in schedule assessment and evaluation in order to make appropriate decisions regarding the submitted schedules. In addition, a composite index i.e. benchmarking of schedule was presented for the evaluation of the overall level of fitness of schedules considering the relative level of importance of each schedule assessment criterion.

In opposition to the legal connotation of existing Schedule Health Assessment methods, which mainly aim at performing schedule quality assessment for contract management purposes, the proposed method has been developed also to be used as a guide for the scheduling process. The proposed method has a strong connotation in the construction sector, or it is construction oriented, while indeed most of existing standards are not.

One of the important finding is that the 12% of respondents stated that MS Excel is used in their organization for scheduling, which is of great concern as MS Excel is not a specialized tool for scheduling and lacks major functions required for scheduling. Further, the schedule prepared using Primavera lacks some the important components of a good schedule which includes Resource loading and leveling.

5.2 RECOMMENDATIONS

Recommendations for efficacious implementation of best planning and scheduling in construction industry of Pakistan for coping with an important problem which is schedule overrun so that the projects can be delivered better and performance of construction industry can be increased are presented below:

i. Further research needs to be carried out while considering the development of criteria of schedule evaluation for high-rise buildings.
ii. Efforts need to be focused on making schedule evaluation software.
iii. Governmental support is very much necessary which would motivate the stakeholder of the construction industry to adopt best scheduling practices.
iv. Research and development in planning and scheduling should be promoted.
v. Academic-Industry gap needs to be eliminated.
vi. Seminars and trainings should be conducted on awareness and to educate the stakeholders on importance of planning and scheduling.
vii. Schedule health assessment criteria should be included in bidding documents and made part of the contract for effective implementation to reduce schedule overruns.
viii. Pakistan Engineering Council (PEC) should play a vital role in its implementation and include the schedule health assessment criteria in standardized bidding documents already available at PEC website.
ix. Use of modern techniques and tools should be appreciated. PEC being the governing body can play its role in acquiring licensing of planning and scheduling software. Universities should acquire licensing of latest planning and scheduling software and their training should be provided to students.
x. Pakistan Engineering Council (PEC) can also arrange CPD courses regarding the importance of planning and scheduling and best scheduling practices.

REFERENCES

Al-Momani, A. H. (2000). Construction delay: a quantitative analysis. *International Journal of Project Management, 18*(1), 51-59.

Assaf, S. A., & Al-Hejji, S. (2006). Causes of delay in large construction projects. *International Journal of Project Management, 24*(4), 349-357.

Bragadin, M. A., & Kahkonen, K. (2016). Schedule health assessment of construction projects. *Construction management and economics, 34*(12), 875-897.

Bubshait, A. A., & Cunningham, M. J. (1998). Determining schedule impact: working practice. *Practice Periodical on Structural Design and Construction, 3*(4), 176-179.

Chan, D. W., & Kumaraswamy, M. M. (1997). A comparative study of causes of time overruns in Hong Kong construction projects. *International Journal of Project Management, 15*(1), 55-63.

Cole, L. J. R. (1991). Construction scheduling: Principles, practices and six case studies. *Journal of construction engineering and management, 117*.

DCMA. (2012). Earned value management system (EVMS), Program analysis pamphlet (PAP).

De La Garza, J. M., & Ibbs, C. W. (1990). Knowledge-elicitation study in construction scheduling domain. *Journal of computing in civil engineering, 4*(2), 135-153.

Dillman, D. A. (2000). Mail and Internet Surveys: The Tailored Design Method. *New York: Wiley*.

Dzeng, R.-J., & Lee, H.-Y. (2004). Critiquing contractors' scheduling by integrating rule-based and case-based reasoning. *Automation in construction, 13*(5), 665-678.

Dzeng, R., Tserng, H., et al. (2005). Automating schedule review for expressway construction. *Journal of construction engineering and management, 131*(1), 127-136.

Echeverry, D., Ibbs, C. W., et al. (1991). Sequencing knowledge for construction scheduling. *Journal of construction engineering and management, 117*(1), 118-130.

Endut, I. R., Akintoye, A., et al. (2009). Cost and time overruns of projects in Malaysia. *retrieved on August, 21*, 243-252.

Faridi, A. S., & El-Sayegh, S. M. (2006). Significant factors causing delay in the UAE construction industry. *Construction management and economics, 24*(11), 1167-1176.

Farzad Moosavi, S., & Moselhi, O. (2014). Review of detailed schedules in building construction. *Journal of legal affairs and dispute resolution in engineering and construction, 6*(3), 05014001.

Fellows, R. F., & Liu, A. M. (2015). *Research methods for construction*: John Wiley & Sons.

Finance Division, G. o. P. (2018). Pakistan Economic Survey.

Galloway, P. D. (2006). Survey of the construction industry relative to the use of CPM scheduling for construction projects. *Journal of construction engineering and management, 132*(7), 697-711.

GAO, U. S. (2009). Cost Estimating and Assessment Guide.

GAO, U. S. (2012). GAO Schedule Assessment Guide. *Applied Research and Methods*.

Griffith, A. F. (2006). Scheduling practices and project success. *Cost Engineering, 48*(9), 24.

Gunduz, M., Nielsen, Y., et al. (2012). Quantification of delay factors using the relative importance index method for construction projects in Turkey. *Journal of management in engineering, 29*(2), 133-139.

Hair, J. F., Black, W. C., et al. (2006). Multivariate data analysis (Vol. 6): Upper Saddle River, NJ: Pearson Prentice Hall.

Hancher, D. E. (2003). Construction Planning and Scheduling: CRC press: USA.

Haseeb, M., Lu, X., et al. (2011). Causes and effects of delays in large construction projects of Pakistan. *Kuwait chapter of arabian journal of business and management review, 33*(832), 1-25.

Iyer, K., & Jha, K. (2006). Critical factors affecting schedule performance: Evidence from Indian construction projects. *Journal of construction engineering and management, 132*(8), 871-881.

Kaming, P. F., Olomolaiye, P. O., et al. (1997). Factors influencing construction time and cost overruns on high-rise projects in Indonesia. *Construction Management & Economics, 15*(1), 83-94.

Kenley, R. (2014). Productivity improvement in the construction process. *Construction Management & Economics*.

Khan, R. A. (2008). *Role of construction sector in economic growth: Empirical evidence from Pakistan economy.* Paper presented at the Proceedings of the First International Conference on Construction in Developing Countries (ICCIDC), Karachi, Pakistan.

Kog, Y., Chua, D., et al. (1999). Key determinants for construction schedule performance. *International Journal of Project Management, 17*(6), 351-359.

Le-Hoai, L., Dai Lee, Y., et al. (2008). Delay and cost overruns in Vietnam large construction projects: A comparison with other selected countries. *KSCE journal of civil engineering, 12*(6), 367-377.

Leu, S.-S., & Yang, C.-H. (1999). GA-based multicriteria optimal model for construction scheduling. *Journal of construction engineering and management, 125*(6), 420-427.

Li, C. (2007). The Proficient SPSS Statistical Analysis in Practice and Application, CHWA.

Mohamed, A. N. (2001). Knowledge based approach for productivity adjusted construction schedule. *Expert systems with applications, 21*(2), 87-97.

Moosavi, S. F., & Moselhi, O. (2012). *Schedule assessment and evaluation.* Paper presented at the Construction Research Congress 2012: Construction Challenges in a Flat World.

NDIA. (2012). Planning and scheduling excellence guide

Oladinrin, T., Ogunsemi, D., et al. (2012). Role of construction sector in economic growth: Empirical evidence from Nigeria. *FUTY Journal of the Environment, 7*(1), 50-60.

PMI. (2017). Practice Standard for Scheduling.

Sambasivan, M., & Soon, Y. W. (2007). Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management, 25*(5), 517-526.

Saunders, M., Lewis, P., et al. (2009). *Research methods for business students*: Pearson education.

Song, L., Mohamed, Y., et al. (2009). Early contractor involvement in design and its impact on construction schedule performance. *Journal of management in engineering, 25*(1), 12-20.

Zwikael, O., & Globerson, S. (2004). Evaluating the quality of project planning: a model and field results. *International Journal of Production Research, 42*(8), 1545-1556.

APPENDIX-A: FORMULATED CRITERIA

The work schedule assessment criteria have been established after incorporating detailed feedback of construction professionals working at various location throughout Pakistan. The criteria focus on semi high-rise building construction projects; however, it may be used as guideline for evaluation of work schedules for high-rise building construction projects. Other sectors of construction industry may formulate their own criteria in-line with the process detailed in chapter 3.

The criterion consists of 30 checks which are detailed below:

1. Activity duration **(RII = 0.88)**

Description: Duration of no activity should be greater than 28 Days

2. Excessive total float **(RII = 0.60)**

Description: For 95% of the activities the total float should not exceed 14 Days

3. Number of Constraints **(RII = 0.49)**

Description: Constraints should not be on more 5% of the activities

4. Number of Lags / lag durations **(RII = 0.47)**

Description: Lags should not be assigned to more than 20% of the activities and for 95% of the activities the lag duration should not exceed 14 Days.

5. Resource loading **(RII = 0.56)**

Description: Work schedule should be resource loaded

6. Realistic network logic **(RII = 0.89)**

Description: The relationships assigned to the activities should be logical as per the sequence of activities.

7. Project calendar identification and verification **(RII = 0.46)**

Description: Project calendar should be established with assignment of work and non-work days.

8. Activity coding structure (RII = 0.40)

Description: An activity coding structure should be maintained

9. Milestones (RII = 0.65)

Description: No. of milestones should range from 6% to 10% of the total activities

10. Total scope as defined by WBS (RII = 0.81)

Description: Work Break Down Structure should define complete scope of work

11. Critical path & critical activities (RII = 0.80)

Description: No. of critical activities should range from 16% to 20% of the total activities

12. Negative float (RII = 0.46)

Description: No negative float should be present on the baseline schedule

13. Resource levelling and conflicts (RII = 0.54)

Description: Resource leveling and conflict of resource analysis should be carried out

14. Open ended activities (RII = 0.66)

Description: No open-ended activities should be present in the work schedule

15. Participation of major subcontractors (RII = 0.75)

Description: Participation of major subcontractors in developing the work schedule should be ensured

16. Project duration (RII = 0.77)

Description: Project duration computation check must be carried out

17. Submission date (RII = 0.44)

Description: The schedule should be submitted prior to the submission deadline as per contract

18. Responsibility assignment (RII = 0.54)

Description: Responsibility assignment should be ensured in work schedule

19. Special /Submittal /Submittal review /Procurement activities included (RII = 0.56)

Description: Special / Submittal / Submittal review / Procurement activities should be included in the work schedule

20. Weather sensitive activities **(RII = 0.42)**

Description: Weather sensitive activities should be identified & indicated, and accordingly necessary time allowance should be added in the work schedule

21. Relationship ratio **(RII = 0.61)**

Description: Ratio of no. of relationships to no. of activities should range from 1.31 to 1.4

22. Critical path test **(RII = 0.76)**

Description: Critical path test should be carried out in the work schedule

23. Critical path length index (CPLI) **(RII = 0.61)**

Description: Computation of Critical path length index (CPLI) is necessary for progress monitoring (CPLI = (Critical Path Length +/- Total Float) / Critical Path Length)

24. Schedule criticality rate **(RII = 0.63)**

Description: Schedule criticality rate should be in range of 0% to 25%

25. Near criticality rate **(RII = 0.51)**

Description: Near criticality activities are activities with less than 5 days float and schedule near criticality rate should be in range from 0% to 20%

26. Critical activity duration **(RII = 0.75)**

Description: Duration of no critical activity should be greater than 14 Days

27. Number of Leads **(RII = 0.49)**

Description: No. of Leads on relationships should not be greater than 5% of the activities

28. Project cost ratio range **(RII = 0.52)**

Description: Project cost ratio range should be between 0.21 - 0.4

29. Total amount of working hours/day **(RII = 0.44)**

Description: Total amount of working hours/day should be assigned

30. Project effort ratio **(RII = 0.44)**

Description: Project effort ratio range should be between 0.21 - 0.4

APPENDIX-B: SURVEY QUESTIONNAIRE

Department of Construction Engineering and Management, National Institute of Transportation (NIT), School of Civil and Environmental Engineering (SCEE), National University of Sciences and Technology (NUST), Islamabad, Pakistan.

SCHEDULE HEALTH ASSESSMENT CRITERIA FOR SEMI HIGH-RISE BUILDING CONSTRUCTION PROJECTS IN PAKISTAN

Dear Respondent,

This data collection is being carried out as part of MS research as titled above. The research is aimed at formulation of schedule health assessment criteria for semi high-rise building construction projects in Pakistan. The formulation of criteria has also the purpose of assisting the project planners to produce and maintain good quality schedules starting from the project initiation until its completion. The evaluation carried out using criteria will help to detect deficiencies of project schedules and other critical issues having importance with respect to schedule maintenance. This research will improve planning and scheduling practices of building construction projects in Pakistan.

Your contribution towards this research is highly appreciated. Please be assured that the data provided shall be used for study purposes only and will be treated in strict confidence.

Thanking you for your cooperation and assistance in advance.

Regards,

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Date:

Thesis Supervisor and HOD:

Dr. Muhammad Jamaluddin Thaheem
Department of Construction Engineering and Management
NIT, National University of Sciences and Technology (NUST),
Islamabad

QUESTIONNAIRE

Research Topic: **Schedule health assessment criteria for semi high-rise building construction projects in Pakistan**

Respondent Profile

Name (Optional):		
Contact No (Optional):		
Email address (Optional):		
Name of organization/ company/ firm:		
Location of your job/work:		
Please encircle the most appropriate category/option for each question below		
Highest academic qualification:	a) Primary c) Certificate/Diploma e) Post-graduation or Higher	b) Secondary d) Graduation
Experience:	a) 0-5 Years c) 11-15 Years e) 20+ Years	b) 6-10 Years d) 16-20 Years
You belong to which stake holder organization:	a) Client c) Contractor	b) Consultant d) Academia
You work for sector:	a) Government c) Semi-Government	b) Private
Position/appointment:	a) Manager c) Inspector e) Owner	b) Field Engineer d) Supervisor
Nature of experience:	a) Buildings c) Bridges e) Real estate	b) Roads d) Dams f) Design

General Questions

How do you rate your knowledge regarding the subject research topic?	
a) Fundamental awareness (basic knowledge)	b) Novice (limited experience)
c) Intermediate (practical application)	d) Advanced (applied theory)
e) Expert (recognized authority)	
Are you aware of latest computing tools available in market regarding planning and scheduling	
a) Yes	b) No
Which software is used in your organization/ company/ firm for scheduling:	
f) MS-Excel	g) Primavera P6
h) MS-Project	i) Any other (Please specify)

Research Questions (Part – 1)

Please encircle the most appropriate category/option for each question below	
1. In your opinion, what should be the maximum activity duration allowed in work schedule	
Note: Normally semi high-rise building construction project duration varies from one to three years.	
a) 14 Days	b) 21 Days
c) 28 Days	d) 35 Days
e) More than 35 Days (Please specify)	
2. What should be the maximum allowable total float for at least 95% of total activities?	
Note: Total Float is the amount of time that an activity can be delayed from its early start date without delaying the project finish date.	
a) 14 Days	b) 21 Days
c) 28 Days	d) 35 Days
e) Others (Please specify)	
3. What should be the maximum range of constraints on percentage number of activities?	
Note: Constraint is a specific limitation placed upon an activity to regulate the start or finish dates.	
e) Less than or equal to 5%	f) Less than or equal to 10%
g) Less than or equal to 15%	h) Other (Please specify)
4. What should be the maximum lag duration for at least 95% of activities?	
Note: Lag time is the delay between the first and second *activity.*	
a) 7 Days	b) 14 Days

c) 21 Days	d) 28 Days
e) Other (Please specify)	
5. What should be the maximum range of lag on relationships against total relationships? (Computed as total number of lags divided by total number of relationships)	
Note*:* Lag *time* is the delay between the first and second *activity*.	
a) Less than or equal to 10% c) Less than or equal to 30% e) Other (Please specify)	b) Less than or equal to 20% d) Less than or equal to 40%
6. What should be the minimum percentage range of milestones against total activities?	
Note: The milestones include project activities and interim steps needed to implement the project	
a) 0% - 5% c) 11% - 15% e) Other (Please specify)	b) 6% - 10% d) 16% - 20%
7. What should be a percentage range of critical activities against total activities?	
Note: Critical activity is an activity, if delayed, results in the delay of the project	
a) 0% - 5% c) 11% - 15% e) Other (Please specify)	b) 6% - 10% d) 16% - 20%
8. What should be the maximum allowable percentage range of activities to have negative float against total activities?	
Note: Negative float, also known as negative slack, is the amount of time beyond a project's scheduled completion that a task within the project requires.	
a) No negative float c) 2% - 5% e) Other (Please specify)	b) Less than 2% d) 6% - 10%
9. What should be the maximum allowable percentage range of open-ended activities against total activities?	
Note: Activities without predecessor, successor or both. (First and last activity cannot have predecessor and successor relationship respectively)	
a) No open-ended activities c) 2% - 5% e) Other (Please specify)	b) Less than 2% d) 6% - 10%

10. What should be the range of relationship ratio?	
Note: Relationship ratio is the ratio of total number of relationships and total number of activities.	
a) 1 – 1.10	b) 1.11 – 1.20
c) 1.21 – 1.30	d) 1.31 – 1.40
e) 1.41- 1.50	f) Other (Please specify)
11. What should be the range for schedule criticality rate?	
Note: Schedule criticality rate is defined as the ratio of number of critical activities to total number of activities multiplied by 100.	
a) 0% – 25%	b) 26% – 50%
c) 51% – 75%	d) 76% – 100%
12. How a near critical activities should be defined?	
a) Activities with float of less than 5 days	b) Activities with float of less than 10 days
c) Activities with float of less than 15 days	d) Activities with float of less than 20 days
e) Other (Please specify)	
13. What should be the range for near criticality rate?	
Note: Near criticality rate is defined as the ratio of number of near critical activities to total number of activities multiplied by 100.	
a) 0 – 20%	b) 21% – 40%
c) 41% – 60%	d) 61% – 80%
e) 80% – 100%	
14. In your opinion, what should be the maximum duration of critical activity allowed in work schedule?	
Note: Critical activity is an activity, if delayed, results in the delay of the project	
a) 7 Days	b) 14 Days
c) 21 Days	d) 28 Days
e) Other (Please specify)	
15. What should be the maximum range of no. of leads on relationships against total relationships? (Computed as total number of leads divided by total number of relationships)	
Note: *Lead* time is the negative delay between the first and second *activity*	
a) Less than or equal to 5%	b) Less than or equal to 10%

c) Less than or equal to 15%	d) Less than or equal to 20%
e) Other (Please specify)	
16. What should be the range of project cost ratio?	
Note: Project cost ratio is defined as cost associated with critical activities divided by total project cost.	
a) 0 – 0.2	b) 0.21 – 0.40
c) 0.41 – 0.60	d) 0.61 – 0.80
e) 0.81 – 1.0	
17. What should be the range of project effort ratio?	
Note: Project effort ratio is defined as critical path effort (number of labor hours) divided by total project effort	
a) 0 – 0.2	b) 0.21 – 0.40
c) 0.41 – 0.60	d) 0.61 – 0.80
e) 0.81 – 1.0	

Research Questions (Part – 2)

Please encircle one box to indicate the weightage/importance of each schedule health indicator on overall quality of the schedule.

Sr. No.	Schedule health indicators	Very Low	Low	Moderate	High	Very High
1	Reasonable activity duration	1	2	3	4	5
2	Excessive total float	1	2	3	4	5
3	No. of Constraints	1	2	3	4	5
4	No. of Lags / lag durations	1	2	3	4	5
5	Resource loading	1	2	3	4	5
6	Realistic network logic	1	2	3	4	5
7	Project calendar identification and verification	1	2	3	4	5
8	Activity coding structure	1	2	3	4	5
9	Milestones	1	2	3	4	5
10	Total scope as defined by WBS	1	2	3	4	5

11	Critical path & critical activities	1	2	3	4	5
12	Negative float	1	2	3	4	5
13	Resource leveling and conflicts	1	2	3	4	5
14	Open ended activities	1	2	3	4	5
15	Participation of major subcontractors	1	2	3	4	5
16	Project duration	1	2	3	4	5
17	Submission date	1	2	3	4	5
18	Responsibility assignment	1	2	3	4	5
19	Special / Submittal / Submittal review / Procurement activities included	1	2	3	4	5
20	Weather sensitive activities	1	2	3	4	5
21	Relationship ratio	1	2	3	4	5
22	Critical path test	1	2	3	4	5
23	Critical path length index (CPLI)	1	2	3	4	5
24	Schedule criticality rate	1	2	3	4	5
25	Near criticality rate	1	2	3	4	5
26	Critical activity duration	1	2	3	4	5
27	Number of Leads	1	2	3	4	5
28	Project cost ratio	1	2	3	4	5
29	Total amount of working hours/day	1	2	3	4	5
30	Project effort ratio	1	2	3	4	5

Thanks for your cooperation