PRACTICE OF CONSTRUCTION SCHEDULING AND ITS IMPACT ON DELAY CLAIM ANALYSIS

MSC THESIS

BY

SADAT AHMED ABDELA

HAWASSA UNIVERSITY, ETHIOPIA

OCTOBER 2022

A THESIS SUBMITTED TO

HAWASSA UNIVERSITY

FACULTY OF CIVIL ENGINEERING & BUILT ENVIRONMENT

INSTITUTE OF TECHNOLOGY

GRADUATE STUDIES, HAWASSA UNIVERSITY

HAWASSA, ETHIOPIA

IN PARTILAL FULFILLMENT OF THE

REQUIREMENTS FOR THE

DEGREE OF

MASTERS OF SCIENCE IN CONSTRUCTION TECHNOLOGY & MANAGEMENT

OCTOBER 2022

ADVISORS' APPROVAL SHEET

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled "Practice of Construction Scheduling in Ethiopia and its Impact on Delay Claim Analysis" submitted in partial fulfilment of the requirements for the degree of Masters of Science in Construction Technology & Management, the Graduate Program of the Department of Construction Technology & Management, and has been carried out by Sadat Ahmed Abdela, GP/CoTMW/0021/13 ID. No., under our supervision.

Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Desalegn Girma (Ph.D.)	________________	________________
Name of major advisor	Signature	Date
Dejene Adugna (MSc.)	________________	________________
Name of Co-advisor	Signature	Date

Examiner's APPROVAL SHEET

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY EXAMINERS' APPROVAL SHEET

We, the undersigned, members of the Board of Examiners of the final open defense by Sadat Ahmed Abdela have read and evaluated his thesis entitled "Practice of Construction Scheduling in Ethiopia and its Impact on Delay Claim Analysis", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfilment of the requirements for the Masters of Science in Construction Technology & Management.

______________________	______________	______________
Name of major advisor	Signature	Date
______________________	______________	______________
Name of Internal Examiner	Signature	Date
______________________	______________	______________
Name of Chairperson	Signature	Date
______________________	______________	______________
Name of External examiner	Signature	Date
______________________	______________	______________
SGS Approval	Signature	Date

Table of Contents

Dedication

I dedicate this thesis to Merdia Hussein, my Mother and my Confidant, an extraordinary mom who sacrificed her childhood and adulthood to send her children to school. It is always my prayer to meet you in paradise, Mom.

Acknowledgement

I would like to thank my advisor Dr. Desalegn Girma Mengistu who did check and guided me through every detail of this thesis work. My second thank goes to my Co-advisor Mr. Dejene Adugna for his positive actions to my efforts.

It is a pleasure to express my sincere thanks to my brother Juhar Ahmed Abdella (PhD. Candidate) who has always been by my side through my study and my life. I can’t express my feelings of how you have been with me, by such a single statement. God bless you.

I finally would like to thank Engr. Demelash Worku and Mr. Addis Getahun who helped me a lot in the data collection process of this work.

Abbreviations

AACE	American Association of Cost Engineers
AVE	Average Explained Variance
CI	Construction Industry
CPM	Critical Path Method
DBB	Design Bid Build
DCA	Delay Claim Analysis
FIDIC	International Federation of Consulting Engineers
FPPA	Federal Public Procurement Authority
MS	Microsoft Office
MSP	Microsoft Office Project
PMBOK	Project Management Book of Knowledge
PMI	Project Management Institute
RBS	Resource Breakdown Structure
SCC	Special Conditions of Contract
SCL	Society of Construction Law
SPSS V-26	SPSS VERSION 26
WBS	Work Breakdown Structure

List of Tables

List of Figures

Abstract

Construction schedules should sufficiently and accurately provide the necessary information to measure effect of a delay event on: succeeding activities, project duration and project cost. However, it was concluded that programs being submitted by contractors in the Ethiopian context don't assist to analyze delays. Performance of delay claims analysis in Ethiopian context is usually very low in terms of accuracy because analysis is little based on reliable and sufficient schedule information. The objective of this thesis was to evaluate practice and challenges of construction scheduling in view of delay analysis in Ethiopia, the impact on delay claim analysis and propose a scheduling framework to improve performance of DCA. In collecting data, survey questionnaire was delivered to purposively selected construction professionals and 155 complete responses were collected. The data was checked for construct validity, content validity and reliability. Mean scores of factors were calculated and one sample T-tests were performed to evaluate relative significance. Multiple regression analysis was conducted to predict impact of the scheduling practice factors and documentation of as-built records on performance of delay claim analysis. Results of the study showed that the construction scheduling practice in Ethiopia is below satisfactory in providing accurate and sufficient information for delay analysis in all dimensions studied. Low Responsiveness of Contractors' Top management to Schedules (1), Lack of Technical knowledge and skill of Scheduling (2), Absence of National Scheduling Standards (3) and Task of iteration in a resource constrained environment (4) were identified challenge factors of construction scheduling in Ethiopia. Task of iteration in a resource constrained environment was found the most challenging factor. Reliability of Schedule (1), Accuracy and Timely Communication of Update Schedules (2), Documentation of Old Schedules and the Schedule basis (3) and Conciseness of Schedule (4) were identified as scheduling practice factors impacting delay claim analysis. Results of regression analysis showed that Documentation of as built records has the most prediction of the impact on delay analysis performance whereas Conciseness of Schedule has the least prediction. The regression model was significant with $F (5,149) = 20.145$, $P < 0.001$. A case study that confirmed results of the quantitative analysis was also conducted. Finally, a scheduling framework to improve performance of delay claim analysis was developed. The developed framework indicates roles of stakeholders in mitigating the impacting factors. The findings of this study are helpful to improve performance of DCA and the scheduling practice because it revealed the status of the practice, identified challenges to be tackled and provided a framework guide for improvement.

Key Words: Scheduling Practice, Delay (Claim) Analysis, Critical Path Method

CHAPTER ONE: INTRODUCTION

1.1. Background of the Study

Delay is among the major performance shortfalls of construction projects (Magdy et al., 2019), which has resulted in delay claim analysis to be among the major activities of contract administration practice. Claims as result of delay can be claim for extension of completion date or claim for prolongation cost. Construction predominantly uses the critical path method (CPM) of scheduling. As early as possible in the project, the contractor should submit and the contract administrator should accept a programme (using commercially available planning software) showing the manner and sequence in which the contractor plans to carry out the works (USCL, 2017). The use of critical path method schedule is often the focus of contract claims due to project time impacts and delays to the contract completion (PMI, 2016). They are invaluable tools for analysing the effects of delays on progress project completion date (Braimah, 2014). The non-CPM based techniques, particularly bar charts, are of limited help in proving the impact of delays because of their inability to show the true effects of delays on project completion (Wickwire & Groff, 2004, as cited in Parry, 2015).

CPM scheduling can be comprehensively described as iterative and interrelated sequence of defining activities, preparing work breakdown structure, developing activity logic, assigning activity resource, estimating activity duration, identifying the critical path, documenting the schedule basis, performing schedule constructability review and schedule risk analysis. A schedule that is prepared by the contractor, usually before the start of the project, and used for performance comparison is called baseline schedule. When the schedule involves sub schedules as for many subcontractors or stakeholders it is called master schedule and in many situations, the master schedule is not the creation of one party (the general contractor or the project management consultant, (PMC) (Mubarak, 2015).

Pickavance (2005, as cited in Braimah, 2014), the resolution of delay claims involves the claimant or the defendant identifying and quantifying the effects of one or more occurrences that caused delay to progress that resulted in delay to one or more completion dates, prolongation of contractor’s and/or subcontractor’s time-related costs, delay to progress that caused loss and/or expense to be suffered by contractors or subcontractors and reduction in productivity (or disruption) that caused loss and/or expense to be suffered by contractors and/or subcontractors. Dealing with each of these scenarios or a combination of them involves the claimant assessing how the delays experienced by various project activities affect others and the project completion date, and then determining how much of the overall project delay is attributable to any party involved (Braimah, 2014).

Literature on study of impact of scheduling practice on delay claim analysis is little done and no effort has been done to rank the impact factors. Developing a robust construction project schedule is one of the major factors towards construction projects’ success (Derbe et al., 2020). Evidence from literature suggests that the reliability of various delay analysis techniques in ensuring successful claims resolution are often undermined by the nature and quality of the underlying programme used (Braimah, 2014).

Subaie (1987, as cited in Shash & Ahcom, 2006)) found that planning and scheduling mistakes also can be a reason for claim. He determined an importance index of 64% that inefficient planning and scheduling causes claims. So, there is a need to improve planning and scheduling trends because risk factors associated with non-excusable delays have been triggered due to lack of proper planning and scheduling in execution of works (Abdela et al., 2014).

Braimah (2014) adds complex software packages such as MS Project pose difficulties when employed for most delay analysis techniques, except for simpler ones, manpower loading graphs are not commonly developed as part of the main deliverables during pre-construction stage planning in UK to accurately reflect planned resource usage on site. The purpose of this study is to evaluate practice & challenges of construction scheduling in Ethiopia, its impact on delay claim analysis, and develop a scheduling framework to improve performance of the delay claim analysis.

1.2. Statement of the Problem

Construction projects rarely, if ever, proceed as planned (Mubarak, 2015). Delay claims especially time extension claims almost always occur in the Ethiopian context, though the way they are managed and the scale of the analysis differ in different organizations. Thus delay claims are inevitable that we should have the necessary information to analyze them better. Construction schedules have been the basic reference documents to determine cost and duration consequences of a delay event. However, programs being submitted by contractors in the Ethiopian context don't assist to analyze delays (Nigussie, 2015). Schedules are usually not true representative of projects that reflect impacts of changes. Performance of delay claims analysis in Ethiopia usually results to inaccurate conclusion because analysis is little based on reliable and sufficient schedule information such as the critical path, resources allocated and schedule update information. Most consulting organizations in Addis Ababa took the contractors request date as a baseline and some of them approve time claim based on the contractor's claimed date; they usually approve time claim for bad weather as a bonus with no justification of how much the weather affected the work (Tesfaye, 2016). Failure to update work programs, Failure to define project deliverables, Failure of the contract to show defined project deliverables, Failure to use appropriate method of programming, Failure to use realistic work breakdown structures, Failure to use realistic project link are problems in the scheduling practice of Ethiopian federal road construction projects (Nigussie, 2015). This thesis is aimed at evaluating the construction scheduling practice in view of delivering for DCA, identify challenges, evaluate its impact on delay claim analysis and develop a scheduling framework to improve performance of delay claim analysis.

1.3. Research Objectives

1.3.1. General Objectives

General objective of this study is to evaluate practice of construction scheduling in Ethiopian context and its impact on delay claim analysis.

1.3.2. Specific Objectives

1. To assess practice of construction scheduling in Ethiopian context in view of delivering for delay claim analysis.
2. To identify challenges of construction scheduling in Ethiopian context.
3. To evaluate impact of construction scheduling practice on delay claim analysis.
4. To develop construction scheduling framework to improve performance of the delay claim analysis.

1.4. Research Questions

This study aims to address the following research questions:

1. How is the construction scheduling and updating practiced in Ethiopian context?
2. What are the challenges of practice of construction scheduling in Ethiopian context?
3. What scheduling factors affect performance of delay claim analysis?
4. What mechanism has to be adopted to improve scheduling and schedule management practice to improve delay claim analysis?

1.5. Research Hypothesis

A descriptive study is hypotheses producing rather than hypothesis testing; thus descriptive research designs use observation or survey data; they have specific aims and research questions, rather than hypotheses (Siedlecki, 2020). Many hypotheses will be produced in the course of data analysis of this study. However, the two hypothesis aimed to be investigated in the study are described below with their null hypothesis, H_0:

1. H_0: Construction schedules in the Ethiopian context are delivering the required information for delay claim analysis.

2. H_0: Reliability of construction schedules have the least impact on performance of delay claim analysis.

1.6. Significance of the Study

The findings of this study are helpful in improving the scheduling practice because it revealed the status of the practice and identified challenges to be tackled for improvement. It also identified scheduling practice impacts of delay claim analysis for improvement of the delay analysis performance. It finally developed construction scheduling framework of scheduling guide with respect to improving delay claim analysis.

A basic construction schedule deliverables and scheduling requirements from perspective of better delay claim analysis can be derived in the industry, which can serve as one guide for preparing a construction scheduling manual/standard at national/sector or company level. This in turn promotes uniform practice of schedule development, schedule control & communication. Schedule requirement on bidding phase of construction projects can also be made specific and uniform based on results of this study. Finally results of this study will contribute indirectly in promoting scheduling skills as a result of the discussions made and the scheduling frame work developed in this study.

1.7. Scope and Limitation of the Study

The study addresses the scheduling practice, challenges and its impact on delay claim analysis in Ethiopian context. Construction industry is highly characterized by professional turnover (Ayele, 2020), this is considered as benefit to this study to get reflection from the different perspective to generalize the practice at industry level. To ensure this, mainly, highly experienced professionals were considered in the data collection. The study is limited to scheduling starting right after award of contract to project completion. Planning at pre-tender stage of construction projects which is done by clients or government bodies in case of public projects is not covered in this work. It also doesn't cover efficiency of a contractor in schedule performance during execution and detail of different delay claim analysis techniques.

CHAPTER TWO: LITERATURE REVIEW

2.1. Schedule Development

Construction predominantly uses the critical path method (CPM) for its scheduling practice. Its use is often the focus of contract claims due to project time impacts and delays to the contract completion (PMI, 2016).

Developing schedule is the process of analyzing activity sequences, durations, resource requirements, and schedule constraints to create the integrated schedule model, which generates the project schedule (PMI, 2016). The American Association of Cost engineers (AACE International) describes scheduling as a process of identification of activities, developing activity logic, identifying the critical path, analyzing S-curves, documenting the schedule basis and performing schedule constructability review. AACE recommends that schedulers and other project team members develop and use S-curves to plan, monitor, analyze, forecast and control project progress. The role of the scheduler, given that the project has been defined is to breakdown the project into work activities, determine the activities' durations, determine logical relationships, draw the logic network, and perform the CPM calculation (Mubarak, 2015). Mubarak puts additional supplementary step of reviewing and analyzing the schedule for missing, wrong, overlapping and looping relationships.

CPM scheduling can therefore comprehensively be described as iterative and interrelated sequence of defining activities, preparing work break down structure, developing activity logic, assigning activity resource, estimating activity duration, identifying the critical path, documenting the schedule basis, performing schedule constructability review and schedule risk analysis.

2.1.1. Defining Activity

AACE international Practice describes activity definition as conversion of scope definition to specific activities and tasks required to complete a program or a project. It recommends team meeting and/or workshop forums involving key project members to identify activities for the project schedule and for contractor schedules, owner representative attend the planning sessions when appropriate. Activity definition is breaking the project deliverables into manageable work packages (WBS), and defining what should be delivered to achieve the project objectives (PMI, 2016). The level of detail when breaking down should be appropriate for the particular project and capable of producing project reports at different levels per stakeholder requirements. It shouldn't also be broken down into too small components leading to an unmanageable level of detail (PMI, 2016). The task of activity definition in DBB projects is usually performed by the client and the consultant before invitation of the works to bidding.

2.1.2. Activity Sequencing

The task of activity sequencing identifies and documents logical relationships, determining predecessors and successors among project activities and should reflect the construction strategy. Relationships, such as finish to start, should also be determined with leads or lags, where required. Proper sequencing is necessary and requires the participation of experienced construction personnel and individuals proficient in the use of scheduling software. In construction, most sequencing is displayed using commercially available scheduling software (PMI, 2016). Better planning results from the involvement of key team members facilitated by the project planner (AACE, 2020).

2.1.3. Allocating Activity Resources

A feasible construction schedule should explicitly and systematically incorporate an organization's capacity to complete a project. This can be done by realizing specific resource requirements versus resource availabilities and capabilities for each construction activity on the schedule (Carone, 2017). A contractor estimates the resources needed to complete each activity. Activity resources and supplementation for peak levels is a source of contention in construction, especially with at-risk contracts. Resource breakdown structures (RBS) and resource calendars are often established for key resources such as tower cranes, excavators, backhoes, equipment operators, and specialized construction crews (PMI, 2016). Estimating activity resources is closely linked with project cost estimating. Performing a schedule delay analysis without considering resource allocations may increase the owner's or contractor's risk of assuming delay responsibility which is not his or her fault (Lee, 2006).

The dominant challenging task in construction scheduling is resource allocation in a resource constrained environment as it can drive cost, sequence, and duration of activities (Tsegaye, 2019). Scheduling techniques often generate schedules that cause undesirable fluctuations in resource utilization levels and unintended peak resource demands that exceed availability limits (Harris, 1978, as cited in Heon Jun & El-Rayes, 2011).

Heon Jun & El-Rayes (2011) added that these undesirable resource fluctuations and peak resource demands are inefficient and costly to implement on site, as they (1) require additional cost to hire additional resources; (2) require the hiring and releasing of workers on a short-term basis; (3) create difficulties in attracting and keeping top-quality workers if stable employment is not guaranteed; (4) produce disruption in the learning curve effects; and (5) require contractors to maintain an unproductive level of workforce on site that keeps some workers idle during low demand periods. This should be mitigated by resource smoothing which is moving activities within their float to minimize the fluctuations.

2.1.4. Activity Duration Estimation

According to Mubarak (2015) durations are based on previous experiences, with adjustments made for the crew size and the number, current job conditions, such as weather conditions, design complexity, soil type, and so forth. The durations of some activities are totally subjective and left to the project manager and the technical team, such as the mechanical or electrical repair team, to "guesstimate." Estimates of durations, even when they have a scientific basis, are always future predictions—and Murphy's Law exists! (Mubarak, 2015). It means anything that can go wrong will go wrong that there is high possibility of wrong estimation of the activity duration. Durations are in days, weeks, hours or even in minutes when getting plant maintenance project back online is critical (PMI, 2016). The duration of an activity is determined by the following equation and iterated until optimum criteria of resource allocation is obtained (Tsegaye, 2019).

$$Di = \frac{Qi}{Nij \cdot Puj}$$

Where,

Di is duration for activity *i*

Qi is quantity of activity *i*

Nij is a number of unit crew *j* for activity *i*

Puj is productivity of unit crew *j*.

The critical path method of scheduling assumes there are unlimited resources for project execution. In practice, resources are limited and scheduling without considering resource constraints gives unreliable schedule (Kastor & Sirakoulis, 2009). Resources such as manpower and construction materials can be in limited supply that the optimum resource allocation between resource dependent activities should be made so that the completion date is minimized. Kastor & Sirakoulis (2009) concluded project duration depends on the software or the method used that project managers should not rely on the first result they get but try other rules or even software if possible.

2.1.5. Identification of the Critical Path

The critical path is defined as the longest logical path through the CPM network and consists of those activities that determine the shortest time for project completion (AACE, 2010). A delay to the start or completion of any activity in this critical path results in a delay to project completion. According to AACE practice, multiple critical paths may occur due to different paths having exactly the same overall duration and constrained milestones (perhaps reflecting contractual requirements) may cause different paths to be critical at the same time.

2.1.6. Documenting the Schedule Basis

Describing the various elements of information in the schedule basis document will provide a better understanding of the project schedule. Documenting the basis of the cost estimate (BOE) is a generally accepted practice which is frequently used as a reference related to change management as the project moves forward (AACE). According to AACE practice some of the essential schedule basis document elements are: project description, schedule integration process, execution strategy, key project dates, planning basis, cost basis, critical path, path of execution, issues and concerns, risks and opportunities, assumptions, exclusions, and baseline changes.

2.1.7. Performing Schedule Constructability Review

AACE practice describes the primary objective of scheduling constructability review is to determine if the project schedule is accurate, logical and achievable. It is intended to disclose problems in the reasonableness of work sequence, completion of construction planning, coordination and interface among the various craft trades and engineering disciplines, adequacy of lead time for material and equipment procurement, site work restrictions and adequacy of site access (AACE, 2009b). It has been recommended that the schedule constructability review process should be implemented in "vertical slices" for each discipline or major feature of work.

2.2. Schedule Control – Monitoring Changes & Updating the Schedule

Schedule control involves monitoring effects of progress, delays and changes and updating the schedule (Keane & Caletka, 2015). Schedules with status applied to them are called updated schedules (AACE, 2021). Here status could be completed activities, in-progress activities, and changes in the logic, cost, and resources required and allocated. Schedule updating is just one part of the project control process and must reflect actual work. It involves incorporating approved changes into the baseline schedule for fair and realistic periodic comparison with actual performance (Mubarak, 2015).

According to Mubarak (2015) schedules should be updated monthly, biweekly, weekly, or according to another time interval with any new information that was not known for the previous update and relates to the schedule.

2.3. Scheduling with Software Packages

Schedulers deal with many activities every day, a small mistake in processing schedule data can affect the entire project schedule that schedulers should try to process schedule data not manually but systematically, or automatically, if possible (Nam, 2016). The simplest software for scheduling support is MS Excel which helps process data in unlimited ways and manually hatch bar charts of activity plans. However, excel doesn't enable linking activities to each other, resources to activities and automatic update of the schedule is also not possible.

A good schedule is a valid, dynamic model of the project (Ambriz & Landa, 2015). CPM scheduling, software packages such as MS project and Primavera are known to be better in order to make schedules reactive to changes such as new network relations, new constraints imposed and new durations. However, the problem with CPM scheduling software is that new algorithms tend to turn CPM scheduling software into 'black boxes' where the user does not understand the process being employed (Winter, 2006).

Another potential danger of automated updating with software is the assumption that everything that was supposed to have happened, between the last and current updates, has happened on the planned dates and within the planned budget and resources (Mubarak, 2015). Common sense and CPM rules require that activities with remaining duration scheduled in the past must be 'moved' into the future. CPM software don't do this for activities scheduled in the past but with remaining duration unless instructed by the user at the outset and through the schedule update time.

Another disadvantage of computer-based programmes is they provide the tool and opportunity to go into more and more detail until the originally planned intent is lost in a mire of information overload that the emphasis should be on clarity, so that the sequence, duration and timing of the major events are observed, and the critical path is obvious to all who use the document (Hall, 2020).

2.4. Challenges of Construction Scheduling and Schedule Control

One challenge in task of construction scheduling and its management has been that most standard forms of contract contain inadequate requirements for generating an accepted programme and/or keeping it up to date that parties should reach a clear agreement on the type of programming software, construction method statement, time of draft programme submission, mechanisms of approval, updating and documenting (USCL, 2017). Another challenge is the unavailability of a scheduling manual and standards for uniform estimation of resources and activity durations makes the scheduling very prone to wrong estimations based on individual subjectivity. Activities are usually in thousand numbers having complex logical relationships which also compete for resource, a multi-disciplinary environment in which it is crucial to explore interdependencies, manage the uncertainty of the information exchange (Li et al., 2006), the scheduling job by itself involves tasks of estimation during resource assigning and duration estimation which can reduce accuracy, and the task of iteration for the final optimum schedule in a resource constrained environment.

Involvement of key stakeholders in tasks of periodic update, communication and documentation of schedule is also practically challenging. Lack of commitment from the contractor and from the consultant to act on time, contractors submit program that they do not implement, no attention is given to schedule to its preparation and timely submission than its formality purpose (Nigussie, 2015). Top managements of contractors impose unrealistic task of schedule crushing during schedule updating and their low responsiveness to developed schedules is also a potential challenge in the scheduling practice. Moreover, there is a lack of knowledge of, and understanding about, the significance of applications of project planning and scheduling theory in construction projects (H. A. AlNasseri, 2015). Finally, project Schedule Management in construction involves complex challenges mainly due to the magnitude of stakeholders involved such as the owner, prime contractor, subcontractors, vendors, material suppliers, end users, regulatory agencies (PMI, 2016).

2.5. Factors Affecting Schedule Performance

Schedule performance is the level of implementation of the schedule which is accomplishment of activities with respect to scheduled time period and costs. Different studies have been conducted on performance of schedule in different categories of the construction in different parts of the world.

Project schedule reliability, choice of scheduling methods, complexity of projects, probable existence of schedule risks and risk prediction capability, project finance and extent of project team collaboration are challenges to meet a construction project schedule (Derbe et al., 2020). Lack of experience of the construction manager, inadequate planning/scheduling, and influence on people’s land alongside the road construction project (expropriation for the construction of the project) have more significant impacts than frequent changes in the design (which was listed as the most frequent cause of delay) in developing countries (Rivera et al., 2020). Owners’ competence can significantly contribute to schedule performance of Ethiopian public construction projects whereas ‘conflict among project participants’, ‘poor human resource management’ and ‘project manager’s ignorance and lack of knowledge’ are detrimental to schedule performance of Ethiopian public construction projects (Sinesilassie et al., 2017).

Inadequate schedule is found to be the most critical risk, which constitutes a long-term problem causing delay in any construction projects in India (Muneeswaran et al., 2020). Site management, coordination among various parties, design changes by owner during construction, availability of laborers on site, availability of material, and avail- ability of staff to manage projects were the six most critical factors that affect schedule performance of public housing projects in Singapore (Hwang et al., 2013).

Lack of owner's abilities and strategies to manage hi-tech oriented mega project; frequent changes of routes triggered by conflicts between public agencies and growing public resistance from environmental concerns; the inappropriate project delivery system; a lack of proper scheduling tool tailored for a linear mega project; and redesign and change orders of main structures and tunnels for high-speed railway, which is fundamentally different from the traditional railway construction were main causes of delay for Korea Train express (KTX) project (Senghong, 2009).

Inadequate details and inadequate design, Difficulties in obtaining licenses and permits from authorities, Deficient of planning, activity, material, labor and equipment management, Shortage of skilled laborers, Delays in preparation of technical documentation by project designers while construction is in progress, Neglect of critical activities, Frequent change orders during construction, Deficient coordination among participants, Low productivity, Difficulty and delay in the drafting and submitting of requests for institutional opinions and authorizations are major causes for delay of construction projects in Ghana (Wahdan et al., 2013).

Providing management reserve (such as providing an allowable buffer time) helps to manage prominent risks and uncertainties while increased emphasis on planning effort by practitioners contributes to develop reliable construction project schedule (Derbe et al., 2020).

2.6. Delay Claim Analysis

2.6.1. Delay Claim Analysis Techniques

Understanding the types of delay claim analysis and the required input for the respective techniques is important for effectiveness of the practice. According to Keane & Caletka (2015), all of the commonly applied forensic delay analysis techniques generally conform to one of the following primary categories called Impacted as-planned, Collapsed as-built, As-planned versus as-built and Time impact analysis. Many in the industry also list 'windows analysis' as a technique, but the term 'windows' simply refers to the period of time being analyzed. When key milestones are relied on, the same approach is sometimes referred to as 'watershed' analysis (Keane & Caletka, 2015). Parry (2015), after reviewing delay analysis classifications of different researchers and comparing it with the AACE Recommended Practice (2007) and the USCL Protocol (2002) supported this listing as a comprehensive list of the common methods available. In addition to these techniques, USCL (2017) puts another technique called Retrospective Longest Path Analysis.

2.6.2. Choice of Delay Claim Analysis Technique

There is little agreement as to which delay analysis technique is most ‘accurate’ (Keane & Caletka, 2015). (AACE (2011) recommended practice states that uniqueness of each claim and the need to consider multiple variables makes it impossible to recommend one method that is the “best” technique, or to rank the techniques in order of preference. The selection of the proper analysis method depends upon a variety of factors including information available, time of analysis, capabilities of the methodology, and time, funds and effort allocated to the analysis (Arditi & Pattanakitchamroon, 2006). Conditions of contract is the basis reference in choosing which technique to use for delay claim analysis. However, the Ethiopian general conditions of contract in the standard bidding document by the federal public procurement authority (FPPA-2011) doesn’t have such article provision for delay claim analysis.

In terms of construction programme usage, the techniques differ from each other based on three elements: the type of programming format required, the sort of programme used as the analysis baseline reference and the mode of application employed (Braimah, 2014). The mode of application of the techniques methodologies varies based on three different modes of operations: direct analysis, subtractive simulation and additive simulation. On programme format requirements, the techniques are grouped under CPM-based techniques and non-CPM-based techniques. This study is restricted to delay claim analysis supplemented by CPM scheduling.

Faris (2015) concludes delay claim analysis of Ethiopian road authority projects is mostly performed by comparing work program of the contractor with the Impacted for the accepted or conceded causes of delay and sometimes with the As-Built, by observing the site condition and documents, then the difference were judged based on supporting evidences of cause for delay and personal/subjective judgment of the engineer or the dispute review expert. Most of the construction consulting organizations surveyed in Addis Ababa approve time claim for bad weather as a bonus that no justification is provided on how much the weather affected the work and also they don't consider concurrent delays (Tesfaye, 2016).

Though, selection of a suitable analysis method depends heavily on the availability of scheduling data, the familiarity of the analyst with the capabilities of the software used in the project, clear specifications in the contract concerning the treatment of concurrent delays and the ownership of float (Arditi & Pattanakitchamroon, 2006), there is low level application of techniques and software packages in Ethiopian construction projects planning and time control (Zewdu, 2016).

2.6.3. Impact of As-built Records and Scheduling Practice on Delay Claim Analysis

The lack of auditable transparent delay claim analysis processes has resulted in the term 'delay analysis' being equivalent to a 'dark art' to many in the industry (Keane & Caletka, 2015). Most claims fail, not because the legal principle is incorrect, or because there are no grounds for the claim, but because there are insufficient records to support the alleged costs claimed or the impact of the event on the programme (Hall, 2020). Delay analysis techniques make use of delay events to evaluate impacts of them, by adding to and subtracting from as-planned and as-built schedules, the impacts once as a whole sum or one by one in a step, to the whole project duration or to a specific period of the project duration called the window.

Along with the baseline schedule, the as-built schedule, more specifically the as-built schedule data, is one of the most important source data for most types of forensic schedule analysis methods (AACE, 2011). Delay events are as built records if documented. Update schedules through the project duration are basic as built records. Contractor's programme submission, including any updates and covering documents issued with them are one of the most important pieces of evidence (Hall, 2020). Records are needed not only to formulate delay claims but also to defend.

2.6.3.1. Contemporary Records

Records should be prepared contemporaneously, and not created long after the event and this requirement, in terms of primary evidence, was noted by Acting Judge Sanders, in the 1987 edition of the FIDIC Red Book who held contemporary records as original or primary documents or copies there of produced or prepared at the time giving rise to the claim whether by or for the contractor or the employer (Hall, 2020). Documents prepared at the time were given much more evidentiary weight than statements prepared long after the event.

Hall (2020) lists some of the important records as: Related correspondence – notices, submissions, exchanges of opinions, instructions received, drawings issued, regular updates of the programme, records of resources employed (staff and labour) and where they were working/what they were doing, material costs or expenses incurred; invoices, receipts and delivery tickets, plant and equipment used, including any specialist plant deployed, mobilization costs or the time taken to divert to the location, recorded standing time or production lost on the original work due to the event, diaries and notebooks, surveys, diagrams, photographs, sketches, minutes of meetings and internal memos.

2.6.4. Impact of Scheduling Practice on Delay Claim Analysis

The most relevant document when considering an extension of time claim is probably the programme (SMEC, 2020). Along with the baseline schedule, the as-built schedule, more specifically the as-built schedule data, is one of the most important source data for most types of forensic schedule analysis methods (AACE, 2011). The most recent Updated Programme (or, if there is none, the Accepted Programme) should be the primary tool used to guide the analyst in assessing an extension of time application (USCL, 2017). Scheduling practice can be in general practices of: Requirement of schedule deliverables with regard to what a schedule should constitute, involvement of stakeholders during baseline schedule development, schedule updating and communication practice during the whole project duration and practice regarding minimum scheduling software requirements if any. However, most standard forms of contract contain inadequate requirements for generating an accepted programme and/or keeping it up to date that parties should reach a clear agreement on the type of programming software, construction method statement, time of draft programme submission, mechanisms of approval, updating and documenting (USCL, 2017).

The FIDIC Red book (2017) states the contractor shall submit an initial programme for the execution of the Works to the Engineer within 28 days after receiving the Notice Commencement of Works. This programme shall be prepared using programming software stated in the Specification (if not stated, the programming software acceptable to the Engineer). The Contractor shall also submit a revised programme which accurately reflects the actual progress of the Works, whenever any programme ceases to reflect actual progress or is otherwise inconsistent with the Contractor's obligations.

The Ethiopian standard general conditions of contract article 41(1) (FPPA, 2011) states, the Contractor shall within the time stated in the special conditions of contract provide the Engineer with a program of implementation of the tasks, broken down by activity and by month and should include the order in which the Contractor proposes to carry out the works, the time limits within which submission and approval of the drawings are required, an organization chart containing the names, qualifications and curricula vitae of the staff responsible for thes, general description of the method including the sequence of works, plan for the setting out and organization of the Site, and such further details and information as the Engineer may reasonably require.

Requirement of a schedule deliverables that affect accuracy of delay claim analysis are but not limited to timely submission of schedule, clearly shown critical path, reasonableness of float placing & amount, reasonableness of activity logic, appropriate level of activity breakdown, reliable resource loading, reasonable placing of constraints, major milestones such as material supply and plant erection shown and schedule basis included. Mubarak (2015) listed scheduling mistakes related to delay claim analysis as: baseline schedules that don't show logic, baseline schedule with dates rather than logic, overuse of constraints, erasing footprints/previous schedule updates, unrealistic baseline schedules, schedules with logic errors, skipping periodic updates, lack of proper documentation, lack of reasonable time contingency and no allocation of the "pacing" or limited resource.

Involvement of stakeholders during baseline schedule development helps mutual understanding of the schedule basis and the construction methodology that delay claim analysts from the consultant and owner side can quickly understand and review the claim.

Active client involvement is quite important as it would facilitate quick programme approval/acceptance before construction, a necessary requirement for early delay claims settlement, which otherwise are often left unresolved long after the delaying events with the potential of generating into expensive disputes (Braimah, 2014).

Schedule updating is loading the data date status of the project such as progress and any change to the schedule structure because of unaccomplished plan, to the previous schedule. This should be accompanied by communication with key stakeholders in need such as owner, consultant and suppliers so as to inform the changes. Article 41(4) of the Ethiopian standard condition of contract states, if the Contractor does not submit an updated Program within a period stated in the special conditions of the contract, the Engineer may withhold an amount stated in the SCC from the next payment certificate and continue to withhold this amount until the next payment after the date on which the overdue Program has been submitted.

The practice regarding minimum scheduling software requirements is important for purposes of scheduling with the critical path method, systematic updating, linked resource loading, and creating suitable communication platform. This is because delay claim analysis involves schedule simulation tasks which is unreliable without having a CPM schedule reacting to change in the system.

CPM schedule shows the construction logic, identifies the critical activities, helps determine the effects of change orders or delays, allows management to set priorities, adapts to any project-simple or complex, is easy to follow visually, allows analysis of different methods or sequences of construction, is useful for court cases—proving responsible party for delays and creates teamwork during project duration (Newitt, 2009).

Minimum software requirements can be set by conditions of contract. The latest Ethiopian general conditions of contract (2011), issued by the federal public procurement authority (FPPA) doesn't have a provision for minimum scheduling software requirement. However, public employers can insert such provisions in the specific conditions of contract during preparing the agreement documents.

2.7. Construction Scheduling Guidelines and Framework

A construction scheduling framework is a guide for preparing a schedule fulfilling minimum requirements. It can be helpful as a schedule requirement guide both at country level at company level. It can also be a basis to prepare standard practice of construction scheduling so as to enable uniform practice and accurate delay claim analysis. An easier work flow in: the schedule preparation, approval and conflict resolution with regard to delay claims can be achieved with the help of scheduling framework.

2.8. Summary of Literature Review

Many studies have been conducted on schedule performance, scheduling techniques, schedule optimization, scheduling software packages and optimum resource allocation especially since the invention of the CPM scheduling. However, relating the scheduling practice to delay claim analysis, its impact on delay claim analysis is little done and no effort has been made to predict the impact. Braimah (2014) suggested that the reliability of various delay analysis techniques in ensuring successful claims resolution are often undermined by the nature and quality of the underlying programme used. Regardless of the method selected for DCA analysis, all available sources of planning and schedule data created during the project, including but not limited to, various versions of baselines, updates and as-builts, should be examined and considered, even if they are not directly used for the analysis (AACE, 2011). Moosavi & Moselhi (2012) introduced a composite index of fitness for purpose of schedule, supported by software application, based on forty-eight criteria for development of baseline building construction schedule. Mubarak (2015) listed scheduling mistakes related to delay claim analysis as: baseline schedules that don't show logic, baseline schedule with dates rather than logic, overuse of constraints, erasing footprints/previous schedule updates, unrealistic baseline schedules, schedules with logic errors, skipping periodic updates, lack of proper documentation, lack of reasonable time contingency and no allocation of the "pacing" or limited resource. It is also a known fact that schedules are among the primary reference documents when assessing delay related claims. It is therefor, an important insight to study the scheduling practice in terms of schedule deliverables, schedule updating, involvement of key stakeholders, schedule communication & documentation, and evaluate its impact on delay claim analysis.

2.9. Conceptual Framework of the Study

It is demonstrated in the literature review that schedule deliverables such as timely submission of schedule, clearly shown critical path, reasonableness of float placing & amount, reasonableness of activity logic, appropriate level of activity breakdown, reliable resource loading, reasonable placing of constraints, major milestones such as material supply and plant erection shown and schedule basis included, affect accuracy and timeliness of delay claim analysis. Further documentation of as-built records also affects delay claim analysis.

Based on this understanding, the conceptual framework of the study is provided in a table showing practice of construction scheduling categorized into three subgroups as: Institutional planning arrangement of client, consultant & contractor organizations, Process of developing baseline schedule and Schedule control-monitoring changes & updating schedule. Practice of developing base line schedule is shown with its recommended good practices in terms of schedule deliverables and involvement of key stakeholders whereas the practice of schedule control has activities of updating, communicating the update schedules and documenting it.

As far as delay claim analysis is concerned contemporary as-built records are invaluable that even best schedules must be supplemented with as built records for delay claim analysis to be made. Practice of recording and documenting as built records as a contemporary is also shown in the framework table. Table 1 shows causal relationship across the columns from left to right end column (delay claim analysis). The framework is also shown with a framework Figure 1a and framework Figure 1b on following pages.

<table>
<tr>
<td rowspan="4">Practice of Construction Scheduling

How is the scheduling practice in Ethiopian context?</td>
<td colspan="3">Good Institutional Planning Arrangement of Client, Consultant & Contractor Firms</td>
<td rowspan="5">• Reliable & Informative As planned Schedules

• Reliable As built Records

• Reliable & Informative As built Schedules

• Reliable & Informative As planned but for Schedules

• Reliable & Informative As planned Impacted Schedules

How is the impact of the scheduling practice on delay claim analysis?</td>
<td rowspan="5">Improved Delay Claim Analysis in terms of Timeliness and Accuracy</td>
</tr>
<tr>
<td rowspan="2">Developing Baseline Schedule</td>
<td>Pre-determined Schedule Deliverables and Specifications</td>
<td>• Activity Schedule
• Critical Path shown
• Resource Loaded Schedule
• Schedule of Major Supplies & Plant Erection
• Pre Specified Software Type Used
• Reliable Estimations of Activity Duration & Resource , Reliable Logic
• Reasonable Use of Float and Constraints
• Simple Summary Schedule (conciseness)
• Assumptions & Considerations Documented
• Non-Working days Shown
• Timely Submission</td>
</tr>
<tr>
<td colspan="2">Involvement of key stakeholders</td>
</tr>
<tr>
<td>Schedule Control-Monitoring Changes & Updating Schedule</td>
<td colspan="2">• Updating as Contractual Responsibility
• Documentation of Previous/Old Schedule
• Updates Communicated to Key Stakeholders
• Risks of Software-based Automatic Updating Mitigated
• Timely Response of Client and Consultant
• Feedbacks from client incorporated</td>
</tr>
<tr>
<td colspan="4">Contemporary As-built Records Recorded & Documented</td>
</tr>
</table>

Table 1: Conceptual Framework of the Study (Causal relationship from left to Right)

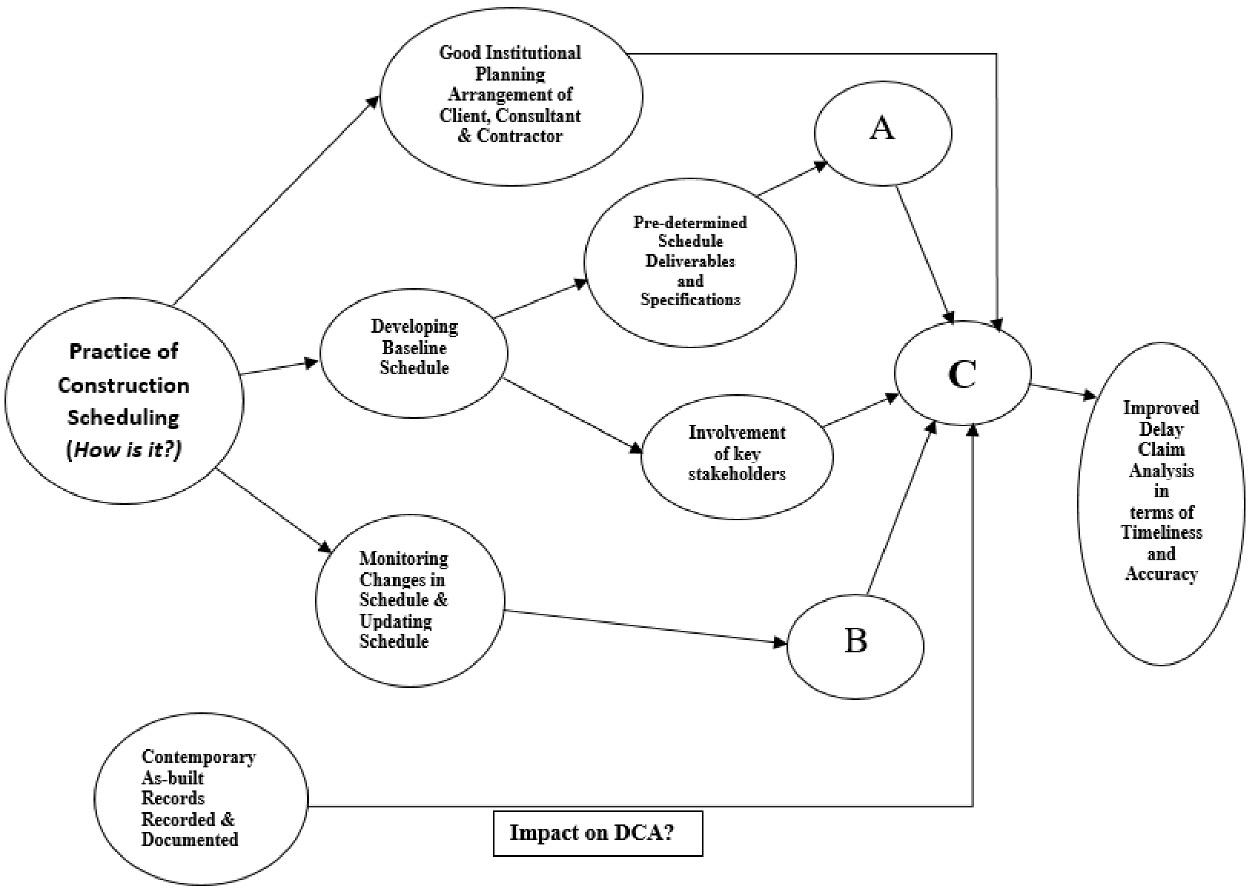


Figure 1a: Conceptual Framework of the Study

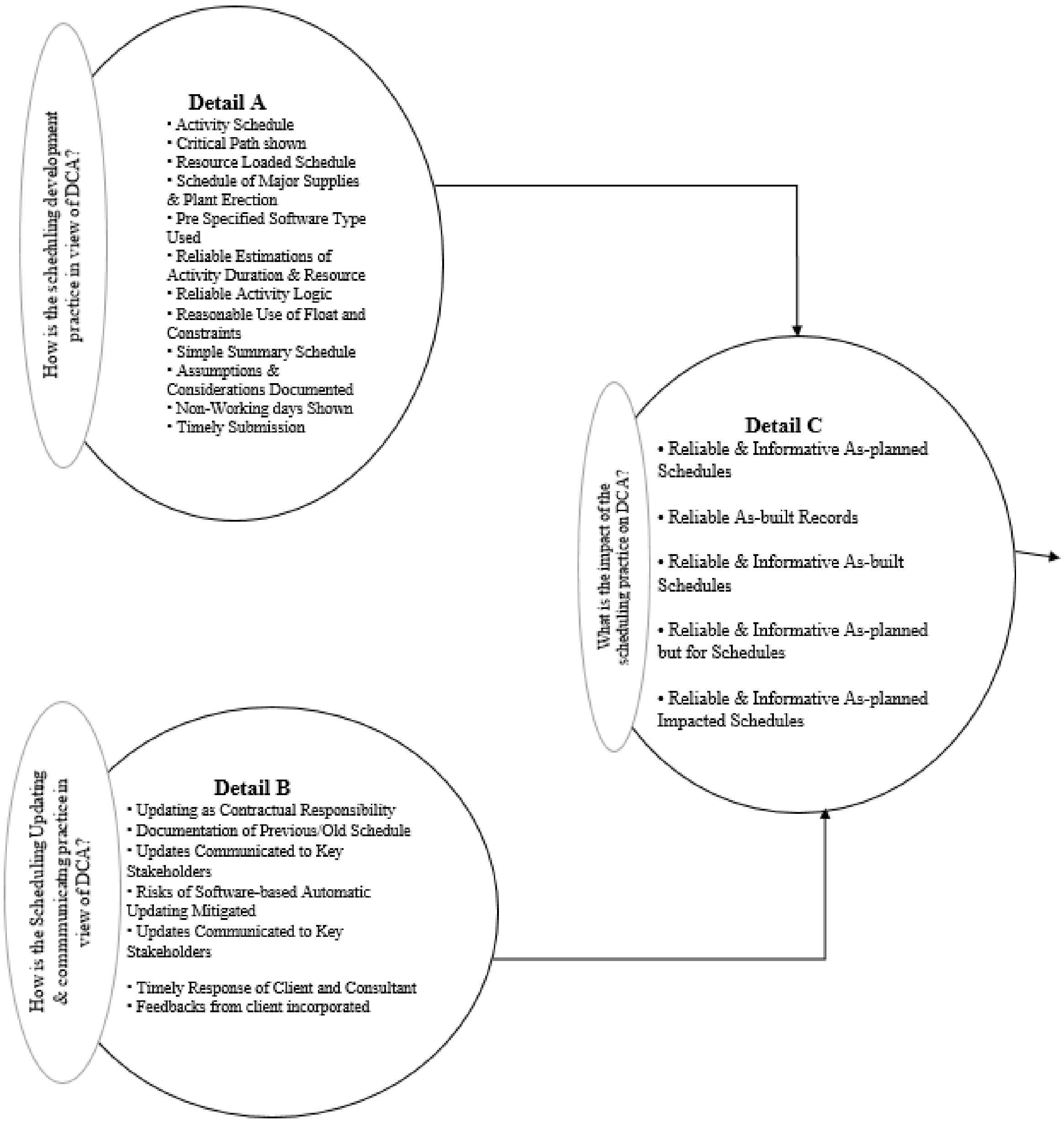


Figure 1b: Conceptual Framework (Details)

CHAPTER THREE: MATERIALS AND METHODS

3.1. The Research Approach

This study is a descriptive research type with objective of studying the practice, challenges and impact of the construction scheduling on delay claim analysis Ethiopian context. The approach implemented is quantitative research approach which was collecting and analyzing sample survey data from selected construction professionals. Additionally, case study on selected construction organizations was performed to cross check reliability of survey data collected and test internal validity of the measurement. Tests of normality and reliability for each data group were performed to evaluate internal consistency and reported in this chapter. Skewness and kurtosis values were also determined. Coefficients of Cronbach's Alpha were also determined to measure internal consistency of the data.

3.2. Population and Sampling Technique

This thesis aimed majorly to achieve its general objective through assessing perception of the professional in the industry. Hence, the primary population of this study is construction professionals working with client, contractor and consultant organizations. The ideal sampling technique of a population is random sampling. However, the population of this study is very large and of unknown size that random sampling is impossible. Therefore, nonprobability sampling method called purposive sampling was used to select respondents with relevant work experience and exposure to topic of the study. Eighty two percent of the respondents have work experience of above 6 years. Purposive sampling technique is the deliberate choice of an informant based on knowledge or experience the informant possesses (Rai & Thapa, 2015). The questionnaire stayed on air for 55 calendar days and 155 complete responses were collected.

3.3. Sample Size

Size of the population and standard deviation of the population from previous works are not available for sample size calculation. Therefore, Cochran's formula was used. Given ordinal categorical data, 20% or 80% proportion and for a medium precision of 7% and 95% confidence level the sample size can be calculated by the Cochran's formula. The construction industry of Ethiopia appears homogeneous consisting native professionals, similar technology and similar competitiveness of personnel in its pool of human resource across the country that a less conservative value for proportion (P) of 0.2 or 0.8 relative to the mean value of the categorical scales, can be reasonable. Results of previous studies on scheduling and schedule performance (such as Nigussie (2015), Tesfaye (2016), Sinesilassie et al., (2017), Omer (2016) and Rivera et al., (2020)) also suggest homogeneity in that they state similar challenges and problems.

$$\text{Sample size } (n) = \frac{z^2\,pq}{e^2} = \frac{1.96^2 x 0.2 x 0.8}{(0.07)^2} = 125.44 \sim \mathbf{126}$$

Where $q = 1-p$

The boundary between 'large number' and 'small number' statistics is at n = 32, although the size adopted in practice is often n = 30 (Fellows & Liu, 2015), sample size of this study is large with n = 126 >>30.

Based on the above reasoning and the 155 responses collected for the study, the homogeneity level of the construction industry in terms of the scheduling practice was compared against the assumed 0.2/0.8 proportion. The proportion of responses for list of the scheduling practice which are at a scale score of good and above are compared against proportion of scale score of below good. Accordingly, the mean of responses given by all respondents on a specific scheduling practice variable came to be in the range of 2.3-2.9 which is below scale of good (3). Therefore, there is a solid indication of the homogeneity characteristics in the scheduling practice that proportions such as 0.1/0.9 (giving sample size below 126 respondents) would also be reliable. In this study 155 responses were gained. If we revise the sample size for proportion of 0.1/0.9, even for a better precision of 5% the Cochran's formula gives 138 respondents which is yet less than 155 respondents gained. The study is therefore, externally valid.

$$\text{Sample size } (n) = \frac{z^2 pq}{e^2} = \frac{1.96^2 x 0.1 x 0.9}{(0.05)^2} = 138.29 \sim < 155$$

3.4. Data Collection Methods

3.4.1. Questionnaire Survey

A 5 point Likert scale, structured and close ended questionnaire survey were used to collect professionals' perception (expert's view) data through Google form. Regarding structure of the Questionnaire, it had five sections as described below:

Section 1: Consisted general information on the research aim and objectives, the Professional Ethics Notification and general questions regarding work experience and work environment of the respondent. Section 2: Consisted of questions regarding practice of construction scheduling as described in the conceptual framework. Section 3: Consisted of questions regarding scheduling practice factors impacting delay claim analysis. Section 4: Consisted of questions regarding performance of delay claim analysis in Ethiopian context. Section 5: Consisted of questions regarding challenges in construction scheduling practice also as described in the conceptual framework and problem statement.

A 5 point Likert scale of categories Poor, Fair, Good, Very Good and Excellent were used for questionnaire part on practice of scheduling. For challenges of scheduling categories were: Not a challenge at all, Slightly a Challenge, Moderately a challenge, Highly a challenge and Extremely a Challenge. No Impact, Low Impact, Moderate Impact, High Impact and Very High Impact categories were used for questionnaire part on impact of scheduling practice on delay claim analysis section. The questionnaire stayed on air for 55 days and 155 complete responses were collected.

3.4.2. Pilot Survey

Pilot survey was conducted on 12 respondents. Based on responses from pilot survey, the questionnaire was improved for clarity, inclusiveness and freedom to respond. Unclear questions due to sentence construction and technicality of terms used were improved. Three questions regarding scheduling practice of consulting organizations and two questions on challenges of scheduling practice were added. Some multiple-choice questions were made to enable respondents give multiple answers. Profile of the respondents is shown in appendix II.

3.4.3. Content Validity of the Study

Content validity of a measuring instrument is an internal validity study that reveals the extent to which each item in the measuring instrument serves the purpose. It is evaluation by more than one referee for obtaining expert opinions on relevance of the survey questions (the measuring instrument this case) in addressing the study topic. Evaluation by more than one referee is a method of obtaining expert opinions (Sürücü & Maslakçı, 2020). Experts score these statements as "Appropriate", "Appropriate But Should Be Corrected" and "Subtracted". A value of CVR> 0 which means "Appropriate" is desired, otherwise measuring instrument should be subtracted for CVR=<0.

$$CVR = \frac{N_e - 1}{N/2}, \quad \text{(Lawshe, 1975)}$$

Where, CVR = Content Validity Ratio

N= Total number of experts evaluating items in the measuring instrument.

N_e = Number of experts evaluating the relevant item as appropriate.

Content validity test was conducted with the pilot survey and content validity ratio of much greater than zero (0.75) was obtained. Only two respondents responded for more contents to be added. One respondent responded contents in challenges of construction scheduling section are not sufficient that two questions were added according to recommendations. Three questions on scheduling practice were also added based on another respondent’s comments.

3.4.4. Strategy of Selecting a Respondent

Construction industry is highly characterized by professional turnover (Ayele, 2020) that it is not suitable to categorize a construction professional as professional of building, road or water works construction. In fact, the turnover is an opportunity that a construction professional is highly likely to give information regarding scheduling in different categories of the industry. This study addressed the general construction categories of road, building and water works. Many construction organizations such as general contractors and consultants also work on different categories of the construction. Moreover, the scheduling in the different categories of the construction in Ethiopia is usually similar except the difference in the type of work items that scheduling techniques such as line of balance are not common. Above all, what is important from perspective of providing information for the study is one's opinion from his/her exposure through his/her years of experience, not the category of construction organization s/he is working at the time of the study.

Finally, exposure of a professional to scheduling and delay claim analysis which is influenced by work experience in the industry, is very important for reliable response. Therefore, a longer work experience of the respondent was highly preferred in this study. Respondents were actively working in the construction at the time of the study, 82% of them had work experience of above six years. The survey questionnaire was delivered to 413 construction professionals from the building, water works, infra structure sectors that were actively working in the industry at the time of the study. The questionnaire was on air for 55 days while at least three periodic reminder messages were sent to the respondents. One hundred fifty-five complete responses gained of which 104 responded they are experts in either scheduling or contract administration tasks. Summary of the respondents’ profile is provided in Table 2 below.

Table 2: Summary of Main Survey Respondents' Profile

Education Level		Work Experience (Years)	Number of respondents (N)	Current Working Position	Current Working Construction Sector	Organization Category
MSc.	45	Above 16	12	Top Managements, Directors	Building, Water Works & Infrastructure	78 respondents from contractor organization
		10-15	33	Project Managers, Resident Engineers, Coordinators	Building, Water Works & Infrastructure	
		10-15	13	Project Managers, Resident Engineers, Coordinators	Building, Water Works & Infrastructure	
		6-9	69	Contract Admins, Construction Engineers, Project Engineers	Building, Water Works & Infrastructure	

Education Level		Work Experience (Years)	Number of respondents (N)	Current Working Position	Current Working Construction Sector	Organization Category
BSc.	110	3-5	19	Office Engineers, Site Engineers,	Building, Water Works & Infrastructure	42 from consulting organization 35 from Client organization
		0-2	9	Junior Office Engineers	Building, Water Works & Infrastructure	

3.5. Data Analysis Techniques

The main data analysis techniques used in this study are factor analysis and multiple regression analysis. In addition, mean score was used with one sample T-test to identify significance of the variables and the impacting factors. Before conducting the regression analysis, the variables used to evaluate the scheduling practice need to be reduced to manageable number; hence a factor analysis was adopted. Factor analysis has two primary purposes: to reduce a large number of variables to a smaller, manageable set of data, and to study the underlying structure of the variables (Fellows & Liu, 2015). MS Excel 2016 and SPSS V-26 data analysis software package were used for all the analyses in this study.

Adequacy of sample size for factor analysis should be checked before running factor analysis. Test of Kaiser-Meyer-Olkin (KMO) evaluates the adequacy of the sample size. Minimum suggested standards for KMO is 0.5 (Hair et al., 2010; Field, 2013). KMO value of 0.924 ($P<0.001$) was obtained in this study that shows the sample size is adequate for factor analysis. Bartlett's test shows whether the correlation matrix is significantly different from an identity matrix. Bartlett's Test of Sphericity has to be significant to get the data to be suitable for analysis. Significance of the null hypothesis should be less than the commonly accepted boundary of 0.05 for the factor analysis to be worthwhile. The significance value in this case was less than 0.001 which means the chance of the null hypothesis to be true is less than 0.1%. Data analysis of the factors is then conducted by T-test and regression analysis. T-test is basically used to compare mean values and detect the difference between them. This means it can also be used to compare mean value of a variable with another hypothetical value of interest to evaluate whether there is significant difference between them or not. After identifying the factor components of the scheduling practice through factor analysis and one additional variable, documentation of as-built records were considered as independent variables for the regression analysis. Multiple regression was conducted with the continuous type data after factor analysis. MS Excel 2016 and SPSS V-26 data analysis software were used for analysis through the study.

3.6. Validity and Reliability

Effective construction research requires proper application of social science research methods and, in social science research, no single method of data collection is ideal (Abowitz & Toole, 2010). The trustworthiness (reliability and validity) of the data to make decisions is the foundation of a good research; otherwise a good decision cannot be made (Mohajan, 2017). Validity in quantitative research refers to the extent to which a test measures what it is supposed to measure, it is the extent to which differences found with a measuring instrument reflect true differences among those being tested (Kothari, 2004). Reliability is the extent to which measurements are repeatable – when different persons perform the measurements, on different occasions, under different conditions, with supposedly alternative instruments which measure the same thing (Drost, 2004).

3.6.1. Testing Validity

Researchers should consider four types of validity : statistical conclusion validity, internal validity, construct validity, and external validity (Drost, 2004). Major threats to statistical conclusion validity are low statistical power, violation of assumptions, reliability of measures, reliability of treatment, random irrelevancies in the experimental setting, and random heterogeneity of respondents. Creswell & Pallant (2005; 2011, as cited in Mohajan, 2017) categorize validity into content validity, face validity, construct validity and criterion related validity.

Internal validity indicates whether the results of the study are legitimate because of the way the groups were selected, data were recorded or analyses were performed and the researcher can describe appropriate strategies, such as triangulation, prolonged contact, member checks, saturation, reflexivity, and peer review (Mohajan, 2017). The same author describes strategies to increase external validity by achieving representation of the population such as: random selection, using heterogeneous groups, using non-reactive measures, and using precise description to allow for study replication across different populations, settings, etc.

Tests of construct validity and content validity were performed in this study. Content validity is the extent to which a measurement addresses the concept under study. This aspect of the validity was addressed in section 3.4.3 in which expert opinion method was implemented to calculate content validity ratio of the study. Tests of construct validity are performed with the factor analysis and results reported in chapter four. Tests of Kaiser-Meyer-Olkin Measure of Sampling Adequacy and Bartlett's Test of Sphericity were also conducted for data groups of this study as summarized in Table 3 below.

Table 3: Summary of KMO and Bartlett's Test of Sphericity Results

Data Group	KMO and Bartlett's Test		
Construction Scheduling Practice	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.905
	Bartlett's Test of Sphericity	Approx. Chi-Square	1543.622
		df	210
		Sig.	.000
Challenges of Construction Scheduling	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.700
	Bartlett's Test of Sphericity	Approx. Chi-Square	295.950
		df	45
		Sig.	.000
Construction Scheduling Factors Impacting Delay (Claim) Analysis	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.924
	Bartlett's Test of Sphericity	Approx. Chi-Square	1901.654
		df	210
		Sig.	.000

3.6.2. Testing Reliability

Sürücü & Maslakçı (2020) identified that use of the wrong scale is the primary reason for low reliability coefficient that researchers should prefer to use scales whose validity and reliability have already been tested. Using likert scale data for this study is appropriate as the respondent ranks his perception on level of either the scheduling practice, the challenge or the impact level. The authors also recommended increasing sample size is the best way to increase the Cronbach's alpha coefficient of reliability; increasing the number of expressions in the measuring instrument also increases this coefficient. Sample size (155) of this study is large this aspect. Though more expensive than the single method approach, combining quantitative and qualitative approaches in research design and data collection, improves the validity and reliability of the resulting data and strengthens causal inferences (Abowitz & Toole, 2010). A case study on reliability of schedule and impact of the scheduling practice on delay claim analysis was conducted in this study. Typical methods to test reliability in behavioral research are: test-retest reliability, alternative forms, split-halves, inter-rater reliability, and internal consistency to estimate stability over time, equivalence, and internal consistency respectively (Drost, 2004). Split-half reliability compares two halves of a data to provide similar analysis results suggesting that the test has internal reliability. The most common internal consistency reliability measure is Cronbach's alpha (α), which is usually interpreted as the mean of all possible split-half coefficients (Mohajan, 2017). In this study, Cronbach's alpha method was applied to determine coefficient of internal consistency (0.725-0.943), $P<0.001$.

Sürücü & Maslakçı (2020), state a Cronbach's alpha value of 0.6 to 0.7 is acceptable and a greater value up to 0.9 is favorable, 0.95 and above indicates some expressions found in the measuring instruments are the same and do not have any distinctive features meaning there are more expressions in the measuring instrument than necessary. Too low (0.40 and below) Cronbach's alpha value indicates either vast majority of the participants in the sample group answered the statements in the measuring instrument without reading or gave random answers or the researcher used a formative scale where the direction of relationship is from the observed variables to the latent variables (Sürücü & Maslakçı, 2020). Because items expressions determine the latent variable and show the reasons, not the effects, of the latent variable (Aksay & Ünal, 2016; as cited in Sürücü & Maslakçı, 2020). In case study research, because only a small number of cases are studied, but the studies are in-depth, the purpose is to secure theoretical validity (as for experiments), rather than the (more common) statistical validity required of surveys (Fellows & Liu, 2015).

Tests of reliability for each data group of the study were conducted in SPSS V-26 software, to measure internal consistency. Coefficient of Cronbach's Alpha were determined for each data group. A very good Cronbach's alpha coefficients of 0.725-0.943 were obtained that 72.5% to 94.3% of the response scores were reliable in terms of consistency. Results of reliability tests is summarized in Table 4.

Table 4: Summary of Reliability Statistics

Variable Group	**Coefficient of Cronbach's Alpha**	**Number of Items**
Practice of Scheduling	0.924	21
Awareness on responsibility of Updating Schedule	0.790	3
Challenges of Scheduling	0.725	10
Impact of scheduling practice on delay claim analysis	0.943*/0.928	24*/21
Performance of Delay claim Analysis	0.786	4

* Calculated in combination with the dependent variable

3.7. Tests of Normality

Blanca et al. (2013) conclude that real data are often not normally distributed. They evidenced that Micceri (1989, as cited in Blanca et al., 2013) analyzed the distributional characteristics of over 400 large-sample achievement and psychometric measures and found several classes of contamination in addition to asymmetry and tail weight. The authors added several other researchers have also found a variety of non-normal distributions in social and health sciences data, with different shapes and degrees of skewness and kurtosis.

The whole data for this study has a total of sixty quantitative data variables: twenty-one on practice of scheduling, three on awareness regarding responsibility of schedule updating, twenty one on scheduling practice factors impacting DCA, ten on challenges of scheduling, and five on performance of delay claim analysis. Skewness and kurtosis measures are one of the most widely used measures for assessing normality. Zero skewness value indicates a symmetrical shape, positive values means the curve is skewed to the right and negative values suggest skewing to the left (Blanca et al., 2013). A small deviation from normal distribution with very small skewness and kurtosis values of 0.015 to 0.555 for practice of scheduling and impact variables whereas it extended up to 0.700 for challenges and performance of delay claim analysis. Absolute values of both skewness and kurtosis less than 1.0 tend to be categorized as slight non-normality, values between 1.0 and about 2.3 are regarded as moderate non-normality, and values beyond 2.3 correspond to severe non-normality (Lei & Lomax, 2005, as cited in Blanca et al., 2013). Zero value of kurtosis means that the data show the same kurtosis as a normal distribution.

CHAPTER FOUR: RESULTS AND DISCUSSION

Results of mean response scores of variables and/or factors as appropriate and one sample T-tests to evaluate the relative significance of mean values are discussed in this chapter. Results of Factor analysis and multiple regression to predict impact of the scheduling practice on performance of delay claim analysis were also discussed.

4.1. Practice of Construction Scheduling in Ethiopia

The sample size collected was 155 complete responses giving size to variable ratio of 7.38 which is far greater than 5. Spearman's correlation coefficient of up to 0.582 significant to 0.01 were obtained between variables. The principal component analysis and the varimax orthogonal rotation were employed. Kaiser-Meyer-Olkin Measure of Sampling Adequacy of 0.905 was obtained. The null hypothesis for Bartlett's Test of Sphericity was rejected that the correlation matrix was significantly different ($P<0.001$) from unit matrix. Eigen value of at least 1.00 was used to retain factors. Four factors were extracted out of the twenty one variables and 64% of the variance was explained by the factors. Average explained variances (AVE) of factors ranging from 0.391 to 0.622 were obtained for the construct validity. The result is summarized in Table 5.

One sample T-test was performed to evaluate the significance of the scheduling practice dimensions. The T-test is conducted against good scheduling practice of scale 3 based on numbering given to the Likert scale responses. Mengistu & Mahesh (2022;

2020) used one sample T-test to evaluate the relative significance of mean scores of ordinal data on manpower development factors and challenge factors in the construction industry of Ethiopian City. In this study, the null hypothesis was rejected (P<0.001) for all the scheduling practice dimensions. The alternative hypothesis was accepted. The difference of the mean values from value of 3 is different from zero; the practice is significantly below satisfactory in terms of providing information for delay claim.

Weighted average of the response scores of variables were also calculated to evaluate the level of the scheduling practice. Weighted average scores of 2.38 to 2.91 were found. One sample T-test at 95% confidence level was performed to evaluate if each of the mean is significantly different from an assumed population parameter values or not. The null hypothesis in case of assumed value of 3 was rejected (P<0.05) for most of the variables except for two variables: schedules for submission being simple and summarized (P=0.195), timely submission of a baseline schedule (P=0.082). Another one sample T-test against fair practice scale level of 2 also resulted in rejection of the null hypothesis except for one variable: 'Communicating assumptions and considerations of a schedule /schedule basis/ (P=0.328). Communicating the schedule basis (assumptions and considerations of a schedule) to consultants and clients (P=0.328) is the least practiced parameter.

Finally, as far as delay claim analysis is concerned, mean value for the practice of documenting as built records' was found to be not significantly different (P=0.251) from assumed scale value of 3. However, it was found to be significantly different from a lower scale level of 2 ($P<0.001$). This practice was found to be satisfactory in terms of giving sufficient information for delay claim analysis. Summary of the analysis results is shown in Table 5.

Table 5: Summary of Analysis Results (Scheduling Practice)

Dimension of Scheduling Practice	**Variables**	**Component**					**Significance (One sample T-test, Test Value=3**
		1	**2**	**3**	**4**	**5**	
Accurate and timely update of Schedule (Mean =2.58)	On time transfer of update schedules.	.713					0.000
	Documentation of previous/old schedules.	.646					
	Timely submission of update schedules.	.624					
	Mitigation risks from software based automatic schedule updating.	.612					
	Smoothing of resources assigned to activities.	.514					
Showing the critical path clearly and resource loading (Mean= 2.69)	Showing the critical path of a schedule clearly.		.732				0.000
	Organizational structure of the planning and scheduling team in organizations.		.725				
	Resource loading on schedules.		.708				
	Timely submission of a baseline schedule.		.523				
	Documentation of Schedule basis.			.831			
	Communicating the schedule basis.			.803			

Dimension of Scheduling Practice	Variables	Component					Significance (One sample T-test, Test Value=3
		1	2	3	4	5	
Documenting and communicating the schedule basis (Mean= 2.56)	Schedules for submission being simple and summarized.			.580			0.000
Reasonableness of activity logic and Slack time (Mean =2.69)	Reliability of schedules in terms of Activity Logic.				.640		0.000
	Using the appropriate type of software package for scheduling.				.600		
	Use of reasonable amount of Slack time.				.502		
Involvement of parties in Task of Scheduling (Mean =2.61)	Involvement of consultant organizations during the baseline schedule preparation.					.810	0.000
	Involvement of client organizations during the baseline schedule.					.766	
Percentage of Explained Variance		15.59	15.19	13.09	10.27	9.57	
Percentage of Cumulative Explained Variance						**63.71**	

Forty seven to sixty one percent of respondents in this study agreed that during baseline schedule approval, consultants in Ethiopia check whether: The schedule time frame is within the project duration, sequence of work activities in the schedule is reliable and the critical path is shown clearly. Only 17%-40% of the respondents agreed the consultants check whether: The schedule is resource loaded, dates of major supplies & plant erection are shown, amount of float time/Slack time used is reasonable, number of constraints used are reasonable and the right type of software package is used for developing the schedule. The responses suggest the practice of checking for the above requirements during updating is much smaller than during the baseline schedule submission. Below 42% agreed during updating, consultants check for the above schedule requirements except for the schedule time frame being within the project duration (71%) and whether the critical path is shown clearly (46%). Checking for the amounts of slack time and constraints is the least practiced according to the responses.

The responses also suggested that consultants in Ethiopia just write notification letters about a contractor that doesn't update a schedule or doesn’t update on time. The practice that the consulting Engineer continues to withhold an amount of money stated in the special conditions of contract from the next payments until the update program is submitted (FPPA, 2011), seems very low and seventy three percent of the respondents agreed on that.

4.1.1. Accurate and Timely Update of Schedules

Update schedules should be accurate in terms of showing work progress, changes to activity logic and changes to resource allocation. According to the Ethiopian standard bidding document (2011), an update of the program shall be a program showing the actual progress achieved on each activity and the effect of the progress achieved on the timing of the remaining work, including any changes to the sequence of the activities. Schedule updating is one part of the project control process and must reflect actual work and involves incorporating approved changes into the baseline schedule for fair and realistic periodic comparison with actual performance (Mubarak, 2015). The Contractor shall submit a revised programme which accurately reflects the actual progress of the Works, otherwise the initial programme and each revised programme shall be submitted with relevant supporting information and documents (FIDIC, 2017).

Timely update refers to a period stated in the special conditions of the contract (FPPA, 2011), or a time when it is believed necessary to update schedule as agreed by parties with any new information that was not known for the previous update and relates to the schedule (Mubarak, 2015). If the schedule is updated and submitted on the time needed, it serves as a contemporary records for a delay event occurred up to the next schedule update. Contemporary records are those prepared or generated at the same time, or immediately after, the event or circumstance giving rise to claim (FIDIC, 2017).

4.1.2. Showing the Critical path clearly and Resource Loading

The critical path is defined as the longest logical path through the CPM network and consists of those activities that determine the shortest time for project completion (AACE, 2010). A delay to the start or completion of any activity in this critical path results in a delay to project completion. The use of critical path method schedule is often the focus of contract claims due to project time impacts and delays to the contract completion (PMI, 2016). Because a delay event is considered to affect the project completion date if it affected the critical path. The loss and/or expense flowing from an employer delay cannot usually be distinguished from that flowing from contractor delay without the following: an as-planned programme showing how the contractor reasonably intended to carry out the work and the as-planned critical path; an as-built programme demonstrating the work and sequence actually carried out and the as-built critical path (USCL, 2017). It is therefore, important to clearly show the critical path schedule on a separate sheet when submitting schedule. Construction projects usually have hundreds of activities that software packages are needed for CPM scheduling. The software package for use can be chosen based on agreement between parties.

4.1.3. Documenting and Communicating the Schedule Basis

Describing the various elements of information in the schedule basis document will provide a better understanding of the project schedule. Documenting the basis of the cost estimate (BOE) is a generally accepted practice which is frequently used as a reference related to change management as the project moves forward (AACE, 2009). According to the AACE practice some of the essential schedule basis document elements are: project description, schedule integration process, execution strategy, key project dates, planning basis, cost basis, critical path, path of execution, issues and concerns, risks and opportunities, assumptions, exclusions, and baseline changes/reconciliation. The schedule basis is described as schedule dictionary in PMBOK guide, 2016 in which it was explained to provide information such, but not limited to, production rates, level of accuracy, exclusions, and assumptions.

4.1.4. Reasonableness of Activity Logic and Amount of Slack time

One of the key differences between construction activity scheduling and solving routing and logistical sequencing problems is that a series of well-defined constraints remains within the construction sequencing process; once this sequencing is established, the order in which the various trades should work through a space are also relatively fixed (Shamp, 2017). Identification of logical relationships is task of activity sequencing in which predecessors and successors among project activities are determined. The sequence should reflect the construction strategy in a logical manner, determining predecessors and successors (PMI, 2016). Relationships, such as finish to start, should also be determined with leads or lags, where required. Proper sequencing requires the participation of experienced construction personnel and individuals proficient in the use of scheduling software. Software packages don't detect unreliable inputs that the scheduler should feed them with reasonable inputs of logic and floats.

4.1.5. Involvement of Parties in Task of Scheduling

Schedule preparation should be accompanied by communication with key stakeholders in need, such as owner consultant and suppliers so as to easily communicate changes later. Strong involvement of project stakeholders, as well as identification of interrelationships between project tasks prior to executing the project, are important for effectively managing and controlling project schedules (H. A. AlNasseri, 2015). Active client involvement is quite important as it would facilitate quick programme approval/acceptance before construction, a necessary requirement for early delay claims settlement, which otherwise are often left unresolved long after the delaying events with the potential of generating into expensive disputes (Braimah, 2014). They (clients) should be competent in addressing their needs and interests on the basis of real needs behind the project idea (H. A. AlNasseri, 2015).

4.2. Challenges of Construction Scheduling

One hundred fifty five responses resulted in size to variable ratio of 15.5. Spearman's correlation coefficient of up to 0.4 significant to 0.01 were obtained between variables. The principal component analysis and the varimax orthogonal rotation were employed. Kaiser-Meyer-Olkin Measure of Sampling Adequacy of 0.700 was obtained. The null hypothesis for Bartlett's Test of Sphericity was rejected that the correlation matrix was significantly different ($P<0.001$) from unit matrix. Eigen value of at least 1.00 was used to retain factors. Four factors were extracted out of the ten variables and 65% of the variance was explained by the factors. Average explained variances (AVE) of factors ranging from 0.498 to 0.682 were obtained for the construct validity.

Weighted average of the response scores of the factors were calculated to evaluate the level of the challenges. Weighted average scores of 3.79, 3.70, 3.40 and 3.85 were obtained. One sample T-test was conducted against assumed population mean of 4 to evaluate how significantly the mean scores differ from each other. The null hypothesis was rejected for Factor-1, Factor-2 & Factor-3 that there was a significant difference ($P<0.001$) between mean of the factors and high challenge scale level of the practice. For Factor-4 there was no evidence to reject the null hypothesis ($P=0.056$) that we failed to reject it. The alternative hypothesis that the difference of the mean values is different from zero was accepted for the other three factors. The mean values of these factors were significantly different from the assumed mean of 4 ($P<0.001$). The T-test was also conducted against mean value of 3 and the difference for all the factors was significant ($P<0.001$).

Low responsiveness of contractors' top management (Factor-1), Lack of technical knowledge and skill of scheduling (Factor-2), Absence of National Scheduling Standards (Factor-3) were moderately challenging factors of construction scheduling with similar significance. Factor-4 which was 'task of iteration in a resource constrained environment' found to be the most challenging in Ethiopian construction scheduling. The results are summarized in Table 6.

Table 6: Summary of Analysis Results (Challenges of Scheduling)

Challenge Factor	Variables	Component				Significance (One Sample T-test, Test Value=4)
		1	2	3	4	
Low Responsiveness of Contractors' Top management (Mean=3.79)	Top management of contractor imposes unrealistic task of schedule crushing during schedule updating.	.811				0.000
	Low responsiveness of contractor's top management to developed schedules.	.733				
	The practically difficult joint involvement of key stakeholders in task of periodic update of a schedule.	.632				
Lack of Technical knowledge and skill of Scheduling (Mean=3.70)	Lack of knowledge and understanding on theories of project planning and scheduling Techniques.		.739			0.000
	A challenge to the accuracy of a schedule arising from task of estimation of activity duration.		.739			
	Large number of construction work's activities (in thousands) of construction projects having a complex logical relationships which also compete for resource.		.635			
	Main parties consider the purpose of a schedule a formality purpose.		.484			

Challenge Factor	Variables	Component				Significance (One Sample T-test, Test Value=4)
		1	2	3	4	
Absence of National Scheduling Standards (Mean=3.40)	Construction specifications don't specify sufficient schedule requirements.			.816		0.000
	Absence of national scheduling standards			.776		
Task of iteration in a resource constrained environment (Mean=3.85)	Optimum schedule output requires many iterations in a resource constrained environment.				.826	0.056
Percentage of Explained Variance		19.89	18.67	14.63	12.29	
Percentage of Cumulative Explained Variance					**65.48**	

4.2.1. Low Responsiveness of Contractors' Top management

Lack of commitment from the contractor and from the consultant to act on time, contractors submitting program that they do not implement, giving no attention to schedule to its preparation and timely submission than its formality purpose (Nigussie, 2015). Contractor's top managements usually don't respond to their schedules by not allowing financial requirements, material supplies and manpower accordingly. They also tend to respond late that floats are consumed or the project's critical path is affected. Nigussie (2015) added that programs submitted are not realistic or they are already delayed. Top managements also impose task of unrealistic schedule crushing on the scheduling staff for submission purposes despite they know they are not implementing at least some part of that schedule. According to the Red Book FIDIC (2017) the Engineer shall Review the initial programme and each revised programme submitted by the contractor and may give a notice to the contractor stating the extent to which it does not comply with the contract or ceases to reflect actual progress or is otherwise inconsistent with the Contractor's obligations. Consultants should not approve such unrealistic programs. They should implement penalty terms like withholding an amount stated in the SCC from the next payment certificate (FPPA, 2011). Eighty eight percent of respondents in this study agreed that strict implementation of penalties on a party responsible for a delay can influence to improve the scheduling practice of construction organizations. The low responsiveness of contractors' top managements can also possibly be improved with implementation of penalties in case of identified delay responsibility.

4.2.2. Lack of Technical Knowledge & Skill of Scheduling

It was found in this study that the scheduler's lack of technical knowledge & skill of scheduling is another challenge of the construction scheduling. There is a lack of knowledge of, and understanding about, the significance of applications of project planning and scheduling theory in construction projects (AlNasseri, 2015). It is unusual to show plant & equipment supply dates as a milestone. Large respondent number in the questionnaire survey (51%) responded the type of software package used for scheduling is Microsoft excel which means that it is not suitable for showing milestones, automatic updating of schedule, calculating of the completion date. It can also be that the scheduler is not concerned about these requirements because s/he doesn't has the knowhow and importance of those scheduling concepts. This study leaves investigation of this dimension for future research. It is also unusual to show the critical path schedules on separate sheet while submitting schedules. The practice of demonstrating the critical path was found below good and unsatisfactory in terms of giving the necessary information for delay claim analysis.

4.2.3. Absence of National Scheduling Standards

Construction scheduling and its management has been a challenging task because most standard forms of contract contain inadequate requirements for generating an Accepted Programme and/or keeping it up to date that parties should reach a clear agreement on the type of programming software, construction method statement, time of draft programme submission, mechanisms of approval, updating and documenting (The UK Society of Construction Law delay and disruption protocol, 2017). Absence of national scheduling standards in Ethiopia was found to be another challenge of construction scheduling. National scheduling standard for uniform scheduling practice which can serve as a manual, guide or a minimum scheduling requirement by which schedules can be checked against and approved for acceptance is important. In the absence of such documents, there is also no way that construction owners can set minimum requirements of a schedule while preparing contract agreements at the outset. Culture of using the PMBOK guide is also rare that absence of such national scheduling standard documents brings a challenge to the construction scheduling. A project team needs to prepare schedule related standards or criteria at project level that will be shared with counterparts at departments, field site offices, and subcontractors (Nam, 2016), despite this is not an implemented practice in Ethiopia.

4.2.4. Task of Iteration in a Resource Constrained Environment

The task of iteration in a resource constrained environment was found to be the most challenging factor in the Ethiopian construction scheduling. The critical path method of scheduling assumes there are unlimited resources for project execution. In practice, resources are limited and scheduling without considering resource constraints gives unreliable schedule (Kastor & Sirakoulis, 2009). Resources such as manpower and construction materials can be in limited supply that the optimum resource allocation between resource dependent activities should be made so that the completion date is minimized. This is also related to the technical skill and the type of software package used for scheduling. Software packages allowing automatic processing of data such as MS project and primavera are better for this purpose. In Ethiopia, MS excel is largely used for scheduling that the task of resource optimization can be difficult. There is a high probability that unreliable schedules are prepared. Large number of respondents

(77%) responded iteration in a resource constrained environment as high and moderate challenge to scheduling. The T-test also showed the challenge as the most significant.

4.3. Scheduling Practice Factors Impacting Delay Claim Analysis

Factor analysis was possible with sample size of 155 and size to variable ratio of 7.38. Spearman's correlation coefficient of 0.3 – 0.6 significant to 0.01 were obtained between variables except one variable which is 'incorporation of client's feedback to update schedules'. Kaiser-Meyer-Olkin Measure of Sampling Adequacy of 0.924 was obtained. The principal component analysis and the oblique promax rotation were employed. The oblique promax rotation method was used due to the assumption that there is correlation between the factors. It gave better results with regard to average explained variances of the factors which were an indication of acceptable construct validity. The null hypothesis for Bartlett's Test of Sphericity was rejected that the correlation matrix is significantly different ($P<0.001$) from unit matrix. Eigen value of at least 1.00 was used to retain factors. Four factors were extracted out of the twenty-one variables and 64% of the variance was explained by the factors. Average explained variances (AVE) of 0.428, 0.492, 0.509 & 0.616 were obtained for the factors.

Weighted average of the response scores of the factors were calculated to evaluate the level of the impact. Weighted average scores of 3.38, 3.53, 3.61 and 3.63 were obtained. One sample T-test was conducted against assumed population mean of 4 to evaluate how significantly the mean scores differ from each other. The null hypothesis was rejected for all the variables that there is significant difference ($P<0.001$) between mean of the factors and high impact level (4) of the practice. The alternative hypothesis that the difference in means is different from zero was accepted. The means of all the factors were significantly different ($P<0.001$) from the assumed mean of 4.

The T-test was repeated for assumed value of 3 and the same result obtained. The null hypothesis was rejected. Summary of the analysis results are shown in Table 7.

Table 7: Summary of Analysis Results (Scheduling Practice Factors Impacting DCA)

Impact Factor	Variables	Component				Significance (One Sample T-test, Test Value=4)
		1	2	3	4	
Reliability of schedule (Mean=3.38)	Smoothing of resources assigned to activities of schedules.	.765				0.000
	Resource loading on schedules.	.725				
	Accuracy in estimating activity duration.	.686				
	Reliability of schedules in terms of constructability /Activity Logic	.681				
	Organizational structure of the planning and scheduling team in construction organizations.	.622				
	Using the appropriate type of software for scheduling.	.612				
	Showing dates of Major Supplies & Plant Erection in schedules.	.592				
	Showing the critical path of a schedule clearly.	.517				
Accuracy and Timely	Involvement of client organizations during the baseline schedule preparation.		.858			
	Transferring update schedules to client timely.		.847			
	Mitigation of software based automatic schedule updating risks.		.789			

Impact Factor	Variables	Component				Significance (One Sample T-test, Test Value=4)
		1	2	3	4	
Communication of Update Schedules (Mean=3.53)	Involvement of consultant organizations during the baseline schedule preparation.		.622			0.000
	Timely submission of update schedules.					
	Incorporating feedback of client to update schedules.					
Documentation of Old schedules and Schedule basis (Mean=3.61)	Communicating the schedule basis.			.800		0.000
	Documentation of assumptions and considerations of a schedule (Schedule Basis)			.798		
	Timely submission of a baseline schedule.			.617		
	Documentation of previous/old schedules.			.615		
Conciseness of Schedule (Mean=3.63)	Use of reasonable number of constraints.				.809	0.000
	Submission schedules being simple and summarized (simplicity & conciseness).				.689	
	Using reasonable amount of float time/Slack time.				.589	
Percentage of Explained Variance		21.58	16.98	14.64	10.74	
Percentage of Cumulative Explained Variance		**63.93**				

4.3.1. Reliability of Schedule

Reliability of the schedule is important for effectiveness of the delay claim analysis, and it is evaluated through constructability, activity duration and resource related information. Resource loaded to a schedule is highly related to cost claims due to a delay. Cost claims arising from reduced productivity are determined from manpower and equipment allocated for the activity affected by the delay. Schedules with reliable resource loading, reliable activity sequence and reliable activity duration provide the correct information for the delay analysis. Resource breakdown structures (RBS) and resource calendars are often established for key resources such as tower cranes, excavators, backhoes, equipment operators, and specialized construction crews (PMI, 2016). All the necessary resources should be included when loading resources. They shouldn't also be over allocated above the requirement for the specific activity that cost claims be higher than the correct amount. The critical path scheduling software packages, however don't support resource levelling that construction organizations need to devise their own resource scheduling mechanism such as separate resource schedule. Such resource schedules are usually called resource calenders.

Resources should be loaded in such a way that it is practically possible to deploy them despite constraints available. Constraints can be availability limit of the resource itself or space constraints. Resource loading should be accompanied by resource smoothing and resource levelling to account for constraints. Studies such as Abeyasinghe et al. (2001), Kim (2020), Christodoulou et al. (2009), Biruk & Jaśkowski (2017), Tomczak & Jaskowski (2020) and Kastor & Sirakoulis (2009) have been conducted on different techniques of scheduling in a resource constraint.

Understanding those different techniques would be helpful for better resource scheduling especially techniques of resource levelling and resource smoothing.

Constructability is very important in schedules that effect of delay of preceding activity can correctly be attributed to the succeeding one during delay analysis. It is the activity sequence in the schedule showing interdependence that it should be logical and acceptable. In Skanska Construction UK Ltd v Egger (Barony) Ltd (2004) EWHC 1748 (TCC) for example, the baseline programme used in the analysis was held to be of no evidential value as it contained a fundamental error (Parry, 2015), otherwise it would lead to wrong conclusions of the analysis.

Activity durations should also be convincing to the level that is practiced in the industry with the specific manpower and machinery. Contractors should not make durations be very long so as to make a longer critical path. Durations are estimations and should be based on previous experiences, with adjustments made for the crew size and the number, current job conditions, such as weather conditions, design complexity, soil type, and so forth (Mubarak, 2015). Ambriz & Landa, (2015) also suggest progress reporting periods and the 1%-10% rule can additionally be considered in determining duration and level of activity details. Optimum activity durations are also a result of iterations because of iterated resource allocations in a resource constraint.

Consultant and client organizations should be involved at the outset to check for inappropriately long activity durations, overestimated activity resources and illogical activity sequencing so that the information provided during delay occurrence will be fair.

4.3.2. Accuracy and Timely Communication of Schedules

This scheduling factor includes correct update of schedules by solving risks arising from shortcomings of scheduling software packages. For example, a scheduler in MS Project should assign start no earlier constraint for un-started activities when updating. However, constraints in the middle of a schedule will prevent the scheduler to see by how much the project end date is missed overall because those constraints prevent tasks from floating past them (Ambriz & Landa, 2015). Schedulers should know what is going on within scheduling software packages that the packages will not come out with wrong output. Schedule validation protocols described in the AACE (2007) recommended practice of forensic schedule analysis, can be very helpful towards attaining accuracy. Those protocols related to schedule updating are: Ensuring that the data date is set at notice-to-proceed (or earlier) with no progress data for any schedule activity that occurred after the data date, Ensuring that there is at least one continuous critical path, Ensuring that all activities have at least one predecessor, except for the start milestone, and one successor, except for the finish milestone, Ensuring that the full scope of the project/contract is represented in the schedule, Ensuring that the calendars used for schedule calculations reflect actual working day constraints and restrictions actually existing at the time when the baseline schedule was prepared.

Delays can sometimes occur during short periods after the start of construction projects in absence of submitted/approved baseline schedules. Timely submittal and approval of baseline schedules is very important in such cases of delay analysis. They should be communicated. Communication in the sense that it should be with proof of receipt, given or made when delivered in person to an authorized representative of the Party to whom the communication is addressed, or when sent to such Party at the address specified in the SCC (FPPA, 2011). Baseline schedules should be submitted before the start of the work. Commencement date of a construction project execution is as fixed by public body or agreed by the parties according to article 71 of FPPA 2011. For international contracts, it is between fourteen and forty two days after the Contractor receives the letter of acceptance unless otherwise stated in the particular conditions (FIDIC, 2017).

Update schedules should also be reviewed by consulting organizations, approved and formally communicated to clients earlier. They should not be transferred later to the client at time of delay claim requests. According to FPPA, 2011, the Engineer shall return schedule documents to the contractor with his approval or any relevant remarks within ten days of receipt, except where the Engineer, within those ten days, notifies the contractor of his wish for a meeting. Feedback from the client should be considered at the same time if there are any. A prospect of schedule communication in the next few years is that modern scheduling software packages provide a web based data storage system that instant communication is possible. However training, technological facility and implementation towards those systems is needed.

4.3.3. Documentation of Old schedules and the Schedule Basis

FIDIC conditions of contract (2017) states unless otherwise proposed by the Contractor and agreed by the Engineer, Contractor shall include records of: occupations and actual working hours of each class of Contractor's Personnel, the type and actual working hours of each of the Contractor's Equipment, the types of Temporary Works used, the types of Plant installed in the Permanent Works; and the quantities and types of Materials used in each progress report, the for each work activity shown in the Programme, at each work location and for each day of work.

When updating schedules, both the old schedules and the update should be documented. Documentation is part of keeping as-built records which later will be referred during delay analysis. Delay analysis requires utilization of the schedule under use at the time of the delay event. Such records are called contemporary records. Contemporary records are records prepared or generated at the same time, or immediately after, the event or circumstance giving rise to the claim (FIDIC Red book, 2017). In case delay events are back in the former schedule, those schedules will be needed. Further, any conflicts in logic or resource or other information can be referred to the preceding schedule.

The schedule basis will be a communication tool as to make understand & convince parties reviewing the schedule, approving the schedule and analyzing for delay consequences. The schedule basis shows the scheduler's assumptions, risks and constraints consisting of project description, schedule integration process, execution strategy, key project dates, planning basis, cost basis, critical path, path of execution, issues and concerns, risks and opportunities, assumptions, exclusions, and baseline changes. Documenting and explaining the software settings used for the baseline schedule development is also important for schedule delay analysis purpose (AACE, 2007). The schedule basis further substantiates the confidence and degree of completeness of the project schedule in order to support change management, reconciliation, and analysis (AACE, 2009a).

4.3.4. Conciseness of Schedule

Schedules need the right level of detail unless the schedule model is as complex as the reality itself; however many organizations create schedules that are so complex it takes weeks to understand them (Ambriz & Landa, 2015). The WBS used in scheduling should fully address the entire project scope and contract requirements (PMI, 2016). The guide also states that schedule activities broken down into too small components can lead to an unmanageable level of detail. Schedules should also be concise and clear to the level that details are neither omitted nor overly described to the extent that the information overload causes difficulty to get main information. This especially happens when using software packages. Computer-based programmes provide the tool and opportunity to go into more and more detail until the originally planned intent is lost in a mire of information overload; the emphasis should be on clarity, so that the sequence, duration and timing of the major events are observed, and the critical path is obvious to all who use the document (Hall, 2020).

Based on its detail, Nam (2016) classifies schedule into three levels: Level 3 Schedule – A master schedule used by schedulers and the staff of the departments of a contractor that will be basis for all measurements, analyses, and calculations for the project progress and status. The number of activities depends on the size and characteristics of the project. Level 2 Schedule – Summary schedule of Level 3 schedule used by the staff of the client. The number of activities is approximately 300 to 500. Level 1 Schedule (A milestone summary schedule) – Summary schedule of Level 2 schedule reported to the client's management to help them understand the whole process of the project, graphical elements (photos and symbols) or time-distance diagrams can be used in creating the schedule. The number of activities is approximately 30 to 50. Such hierarchical schedules to address the different stakeholders and their needs for schedule information are also provided in PMBOK guide, 2016.

It should be noted that details should be made to the required extent, guided by outline of important information for the schedule. The scheduling practice dimensions evaluated in section 4.1 of this study can be a guide. Scheduling framework developed in section 4.5 of this work also provides guide to extent of important details of a schedule with regard to delay analysis. Ambriz & Landa (2015) suggest that the rationale behind finding the right level of detail is to create enough checkpoints for monitoring and controlling the progress of the project and to enable estimating and scheduling. Kaka et al. (2008) in their work to propose frame work for WBS of a building construction work, discussed that physical location, type of element, work section, construction aids and construction product are guides to breaking down tasks. The authors added that the level of detail reflects the extent of decomposition and is related to the number of decomposition criteria used across the WBS hierarchy. It is suggested in PMBOK guide (2016), the level of detail should be appropriate for the particular project and capable of producing project reports at different levels per stakeholder requirements.

Some schedule validation protocols provided in AACE (2007) recommended practice for forensic schedule analysis can also be helpful in determining the appropriate conciseness of schedule. Those protocols are: the level of detail is such that no one schedule activity carries a value of more than 0.5% of project contract value per unit of activity duration, and no more 5% of project contract value per schedule activity, splitting activities that contain scope of work performed by more than one subcontractor, and replacing controlling constraints, except for the start milestone and the finish milestone, with logic and/or activities.

4.4. Analysis and Results of Case Study

Cross case analysis was conducted to evaluate the impact of schedules on delay claim analysis and the reliability of schedules in the industry. Three Grade-1 consultant organizations, two client organizations including ERA, and two Grade-1 contractor organizations whose head office is in Addis Ababa were selected. The organizations were selected instead of single claim cases so as to represent the most common practice. The case study mainly included in depth interview with respective experts of the organizations and document evaluations. A total of 247:58 minutes interview was conducted. List of the interview questions are provided in appendix IV and profile of interviewees' is given in Table 8 below.

Interviewee	Duration of Interview (Minutes)	Years of Experience	Level of Education
Senior Resident Engineer	23:06	16	MSc.
Project Manager (Road)	69:31	9	Completed MSc. Courses
Contract Administration Engineer (Consultant)	25:01	8	MSc.
Building Design and Supervision head	26:06	17	MSc.
Senior Contract Administration Engineer	28:42	14	BSc.
Road Works Planning Engineer	12:50	9	BSc.
Senior Resident Engineer	40:14	18	BSc.
Senior Contract Administration Engineer	31:21	13	BSc.
Total Minutes	**247:58**		

Table 8: Profile of Case Study Interviewees

As far as delay claim analysis is concerned, the concept of work register in most Ethiopian construction organizations is not as broad as it is and is usually limited to logs of rainy time and work permit. It is difficult to find registers such as hours of work, number and type of workmen employed on the site, materials supplied, equipment in use and equipment not in working order. The practice of showing dates of major supplies & plant erection is also poor. Contractors complain that the task of frequent schedule revision by itself has been tough because the construction industry is not stable and projects are affected by frequent delays due to cement shortage, fuel shortage and financing difficulty as a result of inflation. Unlike in case of ERA projects, unreliable schedules in terms of resource loading are common. Resource loading and work load of schedules are not given attention. For this, automatic updating would be the solution once the baseline schedule is reasonably prepared and resource loaded. The practice of schedule communication and approval is also very poor in those organizations. Notification of intent of claim is also rarely made in those organizations. Some large consulting organizations have better scheduling and claim evaluation culture in case of ERA projects. It appears that the scheduling and claim management of those organizations is influenced by interest and project performance culture of the client.

Contractors in Ethiopian context request claims for extension of completion date not solely for the purpose of completing projects. The completion date has passed means that the contract has expired and requested payments can’t be paid. Therefore contractors ask for extension of completion date for purpose of validating the contract so that payments can be processed. Even some contractors claim for extension of completion date at time of payment request for the same purpose without prior notification of claim. Clients are usually not in a position to claim for liquidated damage because time extension permissions are usually non-compensable. Clients also don’t want to claim liquidated damage because that may end with termination of the contract when the maximum payable amount is reached. However, the client doesn’t want to bear cost of procuring the work to another contractor with new inflated new project cost time extensions are often allowed for non-compensable while the contractor also doesn’t want to be registered as terminated. The consultant sometimes even reminds the contractor to claim for extension of completion date which is very contrary to the claim notification responsibility of the contractor. In case the contract expires before the contractor requests time extension claims, the three parties make a meeting to negotiate for the project completion date and the contractor promises to complete the project on the agreed time. Delay claims can be claim for extension of completion date or prolongation cost claims. Prolongation cost claims are not common in the Ethiopian context except in projects of Ethiopian Roads administration. However, time extension claim has been common and inevitable in all other project types. The USCL and AACE recommended practices are not much known and used for delay analysis guidance. The accuracy and depth of delay claims analysis was seen to be highly influenced by company practice, knowledge of the analyzing officer and the client's interest. Client's interest is affected by its choice of avoiding termination. Clients avoid termination due to the high level inflation that cost them to procure the work to another contractor. Clients are not entitled to compensation costs of delays for which they have given extension of completion date. Giving permissions for extensions of completion date means either the client has admitted it has delayed the work by its fault of not performing his responsibility or the delays are non-compensable.

The timeliness aspect of delay claims analysis has not been a problem in all organizations other than Ethiopian Roads Administration. In Ethiopian Roads Administration projects, delay claims remain unresolved for at least 2-3 months. It appears that the more accurate the analysis and the more stringent and the delay claim management process, the more time it took to reach agreement. Claim decisions in such environments are not satisfying for the contractor. Prolongation cost claims in Ethiopian Roads Administration are usually referred to dispute review expert. Contractors tend to choose to refer the case to the expert whereas, the client wants decision of the Engineer to be final.

Three major justifications for rejection of prolongation cost claims were identified from the case study interviews. The first justification usually leading to total rejection is when the Engineer asks the contractor to prove supply of resources at time of the delay event, otherwise the delay would be considered concurrent. Whereas, resources such as fuel and cement are difficult to stock in large amount in the current Ethiopian context of supply shortage and inflation. Contractor's financial capacity is also a factor for stocking those materials. The second justification which is usually a cause of partly rejection is concurrent and overlapping delays. Those are delays caused by the contractor and the client at the same time or occurred at different segments of the project work at the same time. The third major justification given by consultant and client for delay claim rejection is low intensity of rain which is commonly taken to be below 5mm. However, time extension for rain shouldn't be allowed for even greater intensity seasonal rain which can be anticipated by experienced contractor. FIDIC (2017) states that the contractor shall be entitled to extension of time if and to the extent that completion is or will be delayed by exceptionally adverse climatic conditions, which shall mean adverse climatic conditions at the site which are unforeseeable having regard to climatic data made available by the Employer before the base date and/or climatic data published in the country for the geographical location of the site. The Ethiopian bidding document by the federal procurement authority also states that time extension should be given for exceptional weather conditions in the federal democratic republic of Ethiopia. ERA is now implementing transfer of risk to the contractor by the special conditions or addendums of the contract agreement that extension of time due to adverse weather condition will not be allowed.

Based on their practice of scheduling and delay claim analysis, this study categorized Ethiopian construction organizations into three categories. Category-1 consists small percentage of the organizations that perform thorough schedule evaluation before approval, stringent debate through delay claims are also common. These organizations have their own manuals and guides on: scheduling, claim management and contract administration. Automatic update of schedules and schedule simulation for purpose of delay analysis are not practiced. Schedules in these organizations are unconcise because they usually consist of large MS Excel workbook for resource allocation and duration calculation. Most Grade-1 contractors and some Grade-1 consultants fall in this category. Category-2 are those characterized by absence of cost claims due to delay, no scheduling or contract management guide, but they address critical path of a schedule and concurrent delays when analyzing delay claims. The practice in these organizations is determined by knowledge and skill of their experts. Notification of intent of claim may not always considered compulsory. These organizations hire experienced contract administration staff at head office level, but schedulers are usually junior Engineers at project level. Schedules in these organizations are unreliable in terms of resource allocation. However, it is difficult to identify the boundary between category-2 and category-3 in percentages. The author of this thesis suggests Grade-3 contractors and Grade-2 consultants mostly fall in this category. Category-3 are those that don't understand concept of critical path, schedules are just formalities, cost claims due to delay are rare, and time extension claims are decided in favor of a contractor just based on daily logs with no assessment. Schedules in this category are not reliable in aspects such as constructability and resource allocation. Concept of claim notification and concurrent delay is very low understood. Most of their claim management officers don't understand the procedure and contractual provisions for a claim management. Contractual provisions such as price adjustment are likely to be used in favor of contractors.

The case study also investigated techniques of delay claim analysis implemented in Ethiopia. Methods of delay analysis employed in Ethiopia are retrospective, observational and mostly the gross mode. In the gross mode, the entire project duration is considered as one whole analysis period without any segmentation as opposed to periodic mode. The as-planned vs as-built/updated observational method to gross period is applied. Modelled analysis techniques are not known in the industry, in which the analyst inserts or extracts activities representing delay events into or from a CPM network and compares the calculated results of the before‟ and „after‟ states (AACE, 2011). Culture of contemporaneous delay analysis is very poor that usually longer duration time claims are usually submitted at end of original completion period. Contemporaneous analysis and early resolution allows appropriate mitigation measures to be considered by the project participants to limit the impact of the delay event. It also provides the Employer and the Contractor with clarity around the contract completion date so that they can understand their risks and obligations and act accordingly (USCL, 2017).

4.5. Impact of the Scheduling Practice on Performance of Delay Analysis

Reliability of schedule (1), Accuracy and Timely communication of update schedules (2), Documentation of old schedules and schedule basis (3) and Conciseness of Schedule (4) were scheduling practice factors impacting delay claim analysis identified and discussed in section 4.3. In this section, impact level of those factors will be predicted by regression analysis. Mean values of the impact factors as calculated based on response scores of scheduling practice variables, were utilized as four independent variables impacting performance of delay claim analysis. These four impact factors and documentation practice of as built records together make a total of five predictor/independent variables. The single dependent variable was performance of delay claim analysis. Mean values of responses of parameters of delay claim analysis performance parameters (accuracy, timeliness, satisfaction) were used as value of the dependent variable. It is to be noted that here, those data are continuous data type convenient for linear regression analysis. Scatter plots between the independent and dependent variables were plotted. A positive linear relationship was observed as indicated in Figure 2.

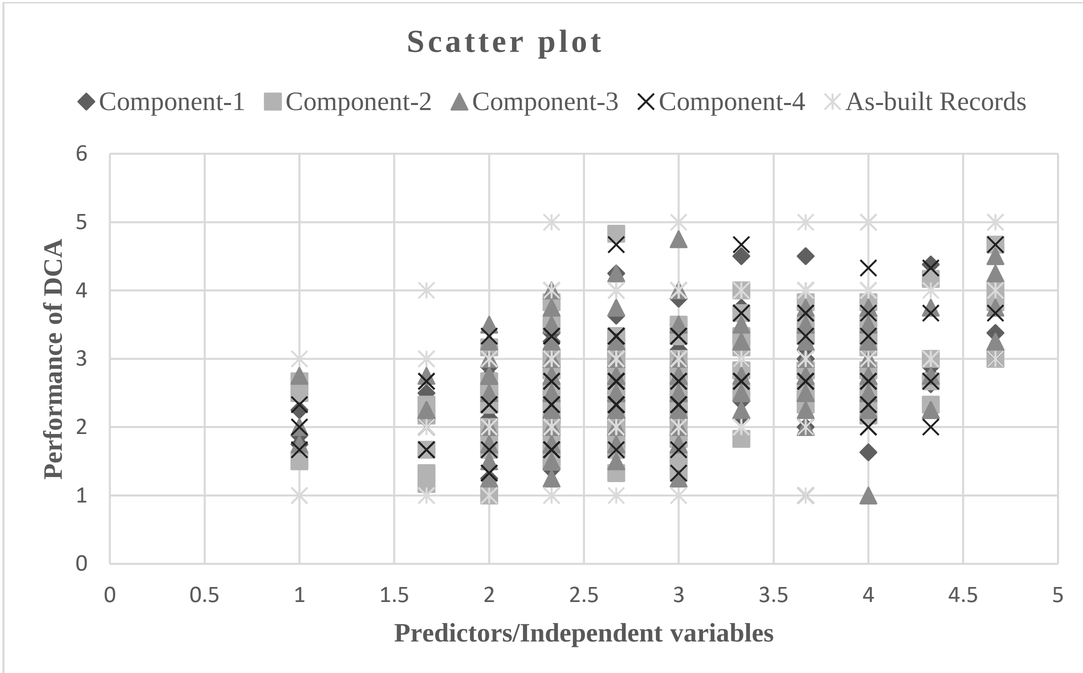


Figure 2: Scatter plot of Dependent Vs Independent Variables

The enter method of entering the independent variable was used in SPSS V-26. The data was fit with the regression model with F (5,149) = 20.145, P < 0.001. The model explained 40.3% of the change in the dependent variable. The fact that it explained a medium variance of 40.3% shows there remain other impact factors such as technical skill and knowledge of the person analyzing the delay, performance of the software package used for the task of delay analysis and professional ethics of the analyzing person. Another factor for performance of a delay analysis can be a statement of the contractual and/or other legal basis of the claim as stated in conditions of contract article 20.2 (4) of the FIDIC Red Book, 2017. Performing regression is a task of predicting a mathematical model for a cause-and-effect relationship between independent and dependent variables. When the relationship is linear the regression is called linear regression and when the independent variables are multiple, it is called multiple linear regression. Regression models, like many other data analysis techniques, are approximations that there are always assumptions to be fulfilled for the model to be valid. Tests of multicollinearity, homoscedasticity and normality of residuals are important assumptions for multiple regression. Multicollinearity is interdependence of explanatory/independent variables. Since the purpose of regression is to model a causal relationship between dependent and independent variables, it is assumed that relationship between multiple independent variables should be small so as not to disturb the regression model. Presence of multicollinearity can cause serious problems with the model approximation and the interpretation (Oke et al., 2019). Variance inflation factor (VIF) and collinearity tolerance (t) values are measures of multicollinearity. Values of these measures are reciprocals of one another. Variance inflation factor (VIF) measures as how much the variance of the coefficient estimate is being inflated by multicollinearity. Tolerance is the amount of variability in one independent variable that is not explained by the other independent variables. Daoud (2018) says tolerance values less than 0.10 (VIF>10) indicate multicollinearity. In this study there was no problem of multicollinearity with collinearity tolerance value of 0.447 to 0.815. This means at least 44.7% to 81.5% of one independent variable is not explained by the other. Homoscedasticity refers to the assumption that the vertical spread of residual data (estimate of the error) across the predicted regression line is constant (i.e., the error has constant variance). Homoscedasticity or constant variance of errors can be assessed by the scatter plot of residuals versus the predicted values; a random spread suggests the variance is constant (Casson & Farmer, 2014). Normality of predictor data is an indication of absence of outliers and non-normality of residual data can be an indicator of potential data cleaning issues (Osborne, 2013). Results from SPSS V-26 showed that residual data of the regression analysis is approximately normally distributed. The frequency distribution curve of the residual data against the normal curve is shown in Figure 3.

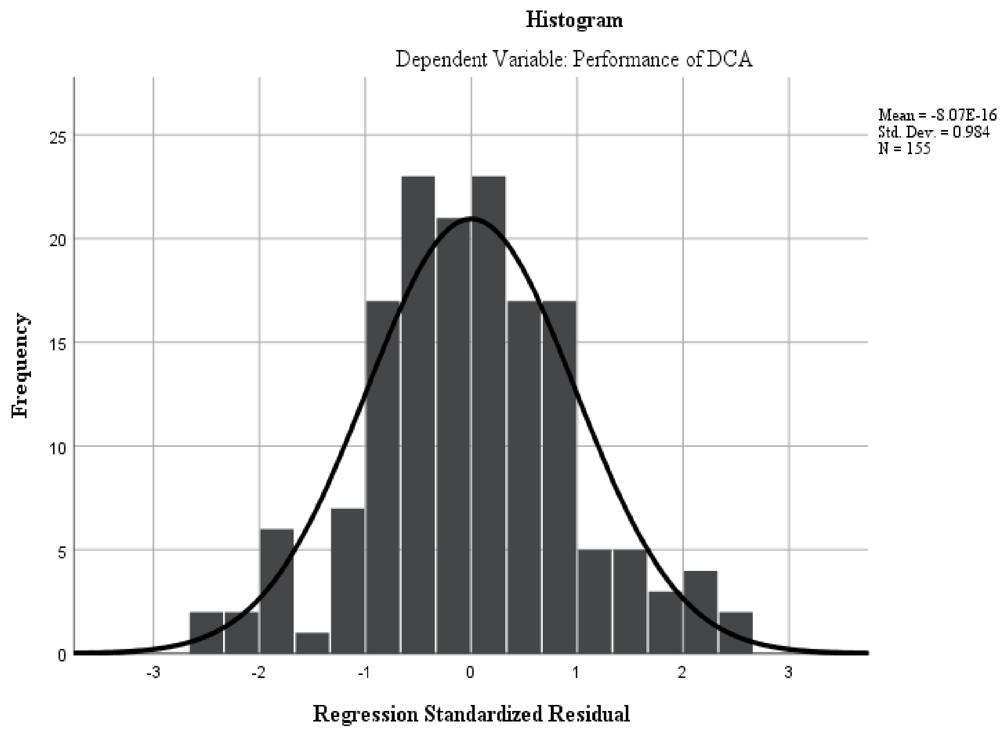


Figure 3: Normality Curve of Residuals

The factor ‘Availability/Documentation of as built records’ has the maximum unique explained variance of 34.8% ($P<0.001$). Impact Factor-1 and impact Factor-2 have unique explained variances of 32.8% and 20.8% significant to 0.05. The unique explained variances by impact Factor-3 and impact Factor-4 were not significant. Impact Factor-4 has the least contribution in terms of unstandardized beta which was only 5.2% of the change in the independent variable. The partial correlations of impact Factor-3 were very small ($r=0.034$) compared to other variables that suppressor effects in the regression model resulted in a negative beta coefficient for impact Factor-3. The partial correlation of component-3 is its correlation with the dependent variable when other independent variables are controlled. Outputs of the regression model, ANOVA and regression coefficients are provided in Tables 9, 10 and 11.

Table 9: Regression Model Summary

Model Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.635	.403	.383	.58288	1.966

Table 10: ANOVA Results

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	34.220	5	6.844	20.145	.000
	Residual	50.622	149	.340		
	Total	84.842	154			

a. Dependent Variable: Performance of Delay Analysis

b. Predictors: (Constant), Availability/documentation of as-built records, Factor-1, Factor-2, Factor-3, Factor-4

Table 11: Regression Coefficients

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	.891	.226		3.936	.000		
	Impact Factor-1	.386	.119	.328	3.230	.002	.389	2.570
	Impact Factor-2	.208	.083	.208	2.508	.013	.584	1.713
	Impact Factor-3	-.190	.104	-.171	-1.834	.069	.459	2.177
	Impact Factor-4	.052	.099	.050	.529	.598	.447	2.240
	Availability/ documentation of as-built records	.265	.053	.348	4.971	.000	.815	1.227
a. Dependent Variable: Performance of Delay Analysis								

It was tried to collect data for performance of delay claim analysis in this study in terms of timeliness, accuracy and satisfaction of stakeholders, despite the latter being influenced by the former two parameters. Because it is obvious that a stakeholder expecting timely and accurate result of a delay claim would be satisfied more. Timeliness of delay claim analysis should be compared to time period provided by standard conditions of contract. The Ethiopian standard conditions of contract (2011) provides a period of 21 calendar days after submission of fully detailed particulars for the Engineer after due consultation with the Public Body and, where appropriate, the Contractor, to grant or reject an extension of time. FIDIC Red Book 2017 however provides a period of 42 days or within such other time limit as may be proposed by the Engineer and agreed by both parties after fully detailed claims are made. The Engineer shall be deemed to have given a determination of rejecting the claim if he does not give the notice of determination within this time limit. Unconcise schedule needs more time and effort to get information out of it. Very much detail with complex networks is difficult to read. It again results in the need of more time for parties to agree on implications of the schedule deliverables. Moreover the complexity leads to higher workload of schedule simulation tasks while analyzing delay. The other factor contributing to longer delay analysis time is failing to document the schedule basis. Without the schedule basis, it will be harder to understand the schedule logic, assumptions and considerations. This in turn leads to risk of giving delay liabilities of a party to another party despite the latter shouldn't be responsible.

Unreliability of resource scheduled, unreliability of the logic, inaccurate and untimely schedule updating and inadequate documentation of previous schedules and the schedule basis can impact accuracy of delay analysis. The effect of resource allocation can either add to or reduce the impact of some delaying event that apportionment of delay responsibility may be inaccurate unless resource allocation practice is considered in the analysis. (Lee, 2006). Manpower loading graphs are not commonly developed as part of the main deliverables during pre-construction stage planning that most programmes are not subjected to resource loading and leveling for them to accurately reflect planned resource usage on site (Braimah, 2014). The other impact parameter affecting accuracy is inaccurately updated schedules because the quality of delay analysis depends on a realistic comparison of actual progress on the construction site and well-made as-planned, updated and as-built schedules (Türkakın et al., 2020).

4.6. Construction Scheduling Improvement Framework: Delay Analysis Perspective

Frameworks can specify guides of what is very important in performing a task. In this study it is used to show what is important to include in construction schedules with perspective of giving sufficient and clear information for delay analysis. Four construction scheduling factors impacting delay claim analysis were identified in section 4.3. Those factors include tasks of: Reliable resource loading on schedules, reliable activity sequencing and acceptable activity duration estimation, Timely submission of baseline schedules, Accuracy of update schedules, Timely Communication of Update schedules, Documentation of old schedules during schedule updating, documenting the Schedule basis and Conciseness of Schedule. A scheduling framework was developed based on these important tasks, theoretical background of the study and framework validation based on evaluation of professionals.

4.6.1. Role of the Contractor

The contractor has the main role in the development of baseline schedule and update schedules. Construction scheduling shouldn't be on a "throw over the wall" basis - schedules shouldn't be developed only or mainly for control purpose, and ignore the "how" aspect; it should not be treated as a linear process and isolated from information and logistics management (Li et al., 2006). (Li et al., 2006). The contractor has the responsibility to prepare such a schedule and submit for approval on time. He also has the responsibility to communicate the approval process and document all schedules throughout a project. The schedule the contractor submits should be reliable and easily readable (concise) with resource loaded to it, the critical path clearly shown. The schedules for delay analysis should show realistic logic (constructability issue) constraints shouldn't be overused (Conciseness), footprints/previous schedule updates should be kept (documentation), periodic updates should be made, reasonable time contingency and resources allocated (resource scheduling) Mubarak (2015).

The Contractor shall within the time stated in the special conditions of contract provide the Engineer with a program of implementation of the tasks, broken down by activity and by month and should include the order in which the Contractor proposes to carry out the works, the time limits within which submission and approval of the drawings are required, an organization chart containing the names, qualifications and curricula vitae of the staff responsible for the Site, general description of the method including the sequence of works, plan for the setting out and organization of the Site, and such further details and information as the Engineer may reasonably require (FPPA, 2011). The standard also states, if the Contractor does not submit an updated Program within a period stated in the special conditions of the contract, the Engineer may withhold an amount stated in the SCC from the next payment certificate and continue to withhold this amount until the next payment after the date on which the overdue Program has been submitted.

The contractor shall submit an initial programme for the execution of the Works to the Engineer within 28 days after receiving the Notice Commencement of Works. This programme shall be prepared using programming software stated in the Specification (if not stated, the programming software acceptable to the Engineer) (FIDIC Red book (2017). The Contractor shall also submit a revised programme which accurately reflects the actual progress of the Works, whenever any programme ceases to reflect actual progress or is otherwise inconsistent with the Contractor's obligations. Contractor should stick to program approved because there should be an agreed reference schedule for delay analysis purpose. No material alteration to the program shall be made without the approval of the Engineer (FPPA, 2011).

4.6.2. Role of the Consultant and the Client

Active client involvement is quite important as it would facilitate quick programme approval/acceptance before construction, a necessary requirement for early delay claims settlement (Braimah, 2014). The consultant and the client have roles of communicating, documenting and evaluating schedules for approval. Clients should be competent and increase their awareness of the consequences of any uncontrolled or poorly planned changes on the effectiveness of planning and scheduling systems (H. A. AlNasseri, 2015). The client sees whether his expectations are met when the preparing the schedule and documents it after approval by the consultant. Expectations of the client can be completion date of the whole work or parts of it as agreed in the contract. The client should mainly reflect his needs on the scheduling during baseline scheduling by discussion with the contractor and the consultant. The consultant communicates with both the contractor and the client to approve the schedule. He should check for technical details in the schedule such as the critical path, resource allocation, activity logic, and conciseness parameters like level of detail, appropriate use of slack time& constraints. The schedule should be knowledge-based and fostering scheduling concepts (H. AlNasseri & Aulin, 2015) that it is descriptive and logical. Finally the consultant documents the schedule. There are also contractual responsibilities of the consultant and client that should performed. The Engineer shall return schedule documents to the Contractor with his approval or any relevant remarks within ten days of receipt, except where the Engineer, within those ten days, notifies then Contractor of his wish for a meeting (FPPA, 2011).

4.6.3. Validation of the Proposed Framework

The framework was first proposed and subjected to evaluation by experts to validate it. Six experts with work experience of above 15 years were involved. Minor corrections to the proposed framework network were made based on comments. All the experts confirmed the framework is helpful to develop a better schedule for delay analysis purpose. Four experts argued that rescheduling of a schedule by contractor after remarks made to it should be called schedule revision. This concept of schedule revision was introduced and the final framework was developed. The proposed framework is shown in appendix I. Figure 4 shows final framework diagram. *Placement position of the stakeholder parties in the framework diagram doesn't represent their involvement level or any other thing relating to their roles in the scheduling.*

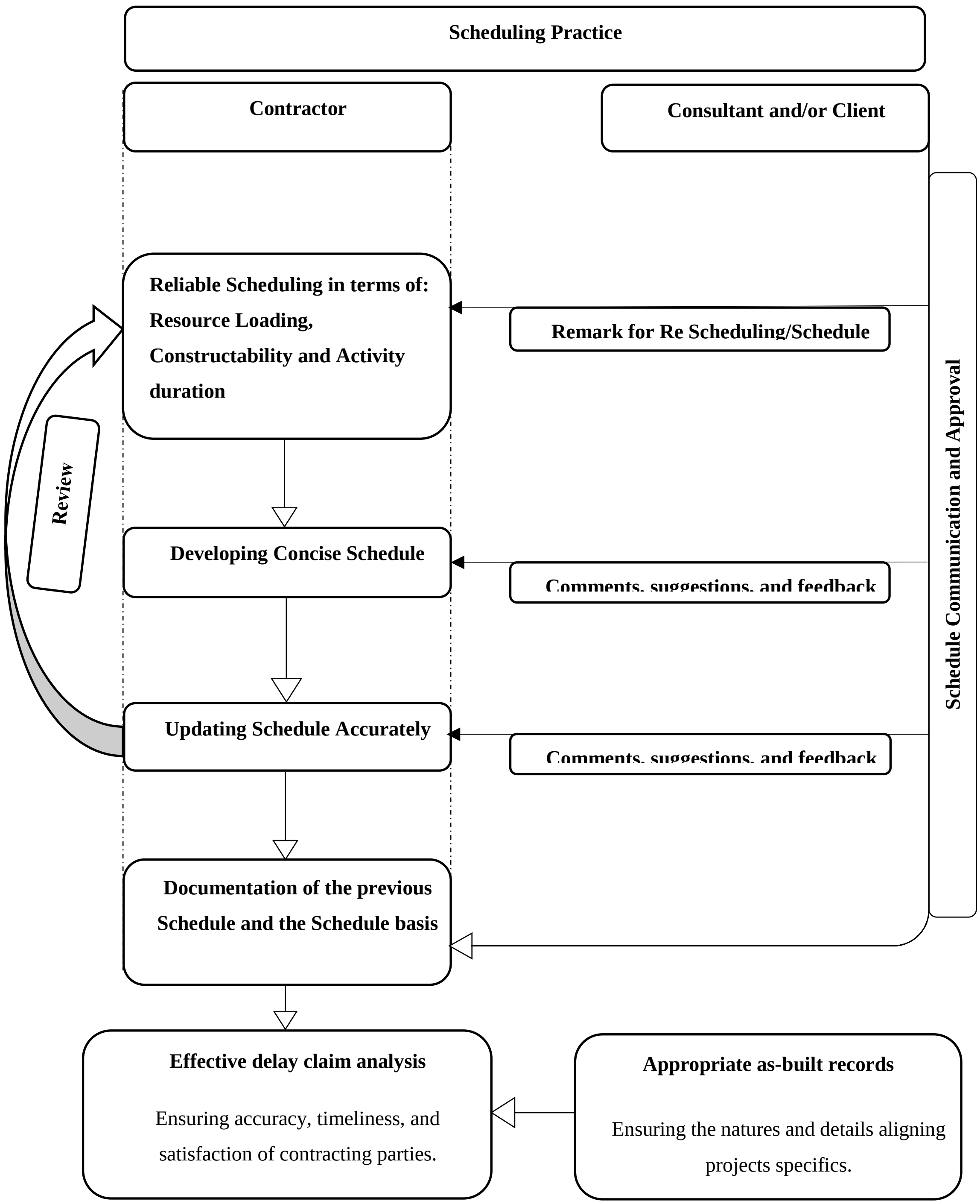


Figure 4: Construction Scheduling Improvement Framework: Delay Analysis Perspective

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

In this chapter findings of the study are summarized, contributions are discussed and recommendations for future research are made.

5.1. Conclusion

The study aimed at evaluating practice of construction scheduling in Ethiopia with respect to giving sufficient and accurate information for delay claim analysis. It also aimed at identifying challenges of construction scheduling and reveal impact of the scheduling practice on delay claim analysis.

One hundred fifty five respondents completely responded the questionnaire. MS Excel and MS Project are the most used software packages of scheduling with greater responses given to MS Excel. This means that at least half of schedules in the Ethiopian construction industry context are not suited for automatic updating and schedule simulation for DCA purpose. It is also responded that the reason for using these software packages is that they are just easy to work with, not contractual requirement. Most of the consultants in the Ethiopian construction industry are aware that updating schedule is a contractual responsibility while only some of the contractors and clients aware. The responses implied that Ethiopian consultants just write notification letters despite withholding an amount of money stated in the special conditions of contract from the next payments until update schedule is submitted. The tasks of scheduling: Schedules for submission being simple and summarized (Conciseness) (1) (P=0.195) and (2) timely submission of a baseline schedule (P=0.082) are performed satisfactorily. However, the tasks: Staffing the planning and scheduling team (1), Showing the critical path of a schedule clearly (2), Resource loading on schedules (3), Showing dates of Major Supplies & Plant Erection in schedules (4), Using the appropriate type of software package based on contractual requirement and enabling CPM technique (5), Reliability of schedules in terms of constructability (6), Accuracy in estimating activity duration (7), Smoothing of resources assigned to activities of schedules (8), Use of reasonable amount of Slack time (9), Use of reasonable number of constraints (10), Documentation of assumptions and considerations of a schedule (11), Communicating assumptions and considerations of a schedule (12), Timely submission of update schedules(13), Involvement of consultant and client organizations during the baseline schedule (14), On time transfer of update schedules to client (15), Documentation of previous/old schedules (16) and Mitigation of software based automatic schedule updating risks (17) have a lower performance.

The scheduling practice was evaluated into five dimensions based on the tasks: Accurate and timely update of Schedule (1), Showing the critical path clearly and Resource loading (2), Documenting and Communicating the Schedule Basis (3), Reasonableness of activity logic and Slack time (4) and Involvement of parties in Task of Scheduling (5). It was found that the construction scheduling practice in Ethiopia is below satisfactory in all dimensions in providing accurate and sufficient information for delay analysis.

Four challenge factors of the construction scheduling were identified: Low Responsiveness of Contractors' Top management to Schedules (1), Lack of Technical knowledge and skill of Scheduling (2), Absence of National Scheduling Standards (3) and Task of iteration in a resource constrained environment (4). Task of iteration in a resource constrained environment was found the most challenging factor.

Four scheduling practice factors impacting performance of delay claim analysis were identified: Reliability of Schedule (1), Accuracy in Updating Schedules and Timely Communication (2), Documentation of Old Schedules and Schedule basis (3) and Conciseness of Schedule (4). Impacts of the scheduling practice factors and documentation of as-built records on performance of delay claim analysis were predicted by regression analysis. Performance of delay analysis was represented by timeliness, accuracy and satisfaction of stakeholders. Documentation of as built records has the most impact on performance of delay analysis and Conciseness of Schedule has the least.

The results from the case study are convergent with results from survey data. The schedules prepared in Ethiopian context are not reliable in terms of resource loading which is an indication of resource availability that the practice is unsatisfactory in terms of delivering information for delay claim analysis. Indeed, it is usually misleading to refer to schedules at category-2 and category-3 organizations for the task of delay claim analysis. Almost all of schedules prepared at category-1 organizations suit to the observational analysis techniques. The relationship between schedules and delay claims analysis is largely not understood. Results of delay claims analysis are often inaccurate but usually timely and satisfying for the parties. Schedules in ERA and some experienced large consulting organizations (Category-1), are exceptionally reliable in terms of resource allocated. Automatic updating of schedules and schedule simulation for purpose of delay claims analysis is not practiced at all categories. There is also no effort in action to improve those practices.

Contractors are expected to submit on time a reliable, easily readable (concise) schedule with resource loaded to it, the critical path clearly shown; communicate for its approval, document it. Consultants and clients have to evaluate the constructability, resource allocation, critical path and conciseness of a schedule, communicate for timely approval and finally document it.

The findings of this study are helpful in improving the scheduling practice because it revealed the status of the practice and identified challenges to be tackled for improvement. It also identified scheduling practice impacts of delay claim analysis for improvement of the delay analysis performance. It finally developed construction scheduling framework of scheduling guide with respect to improving delay claim analysis.

5.2. Recommendation for Future Research

It is revealed in this study that effective resource scheduling is very important for delay analysis and schedule performance. Studies have been done on different techniques of resource scheduling that it is highly beneficial to conduct a review study of those different techniques as a future research. Schedule communication has been identified as very important in this study. To enhance the communication in scheduling a study on BIM technology for schedule communication would also be beneficial. This study also recommends a study towards developing national construction scheduling standard. A research on effect enforcing legal and contractual construction schedule delay liabilities on the scheduling practice in Ethiopia can be a future research. Understanding and use of scheduling software packages in Ethiopian construction industry can also be investigated. Level of schedule details with regard to schedule performance versus delay analysis can also be studied. The study also recommends further research on factors affecting performance of delay analysis such as technical skill and knowledge of the person analyzing the delay, performance of the software package used for the task of delay analysis, professional ethics of the analyzing person and statement of the contractual or legal basis for the claim.

REFERENCES

AACE. (2007). AACE, Forensic schedule analysis. In *International recommended practice No. 29R-03* (Issue 29).

AACE. (2009a). AACE, Documenting the schedule basis. In *AACE International 38R-06* (pp. 0–3).

AACE. (2009b). Schedule constructability review. In *AACE international recommended practice No. 48R-06*.

AACE. (2010). AACE, Identifying the critical path. In *AACE international recommended practice No. 49R-06*.

AACE. (2011). Forensic Schedule Analysis. In *AACE® International Recommended Practice No. 29R-03 FORENSIC* (Issue 29, pp. 1–135).

AACE. (2020). Cost estimate classification system as applied in engineering, procurement, and construction for the process industries revised (sample). In *International Recommended Practice No. 18R-97 Sample*. https://web.aacei.org/docs/default-source/toc/toc_18r-97.pdf

AACE. (2021). AACE, Analyzing s-curves. In *AACE international recommended practice No. 55R-09 sample*.

Abdela, N. M., Teklu, B., Sahilu, G., & Mekuria, G. (2014). *A study on planning and scheduling in federal road projects of Ethiopia: Causes of non-excusable delays: (case studies in selected projects)*. Addis Ababa University.

Abeyasinghe, M. C. L., Greenwood, D. J., & Johansen, D. E. (2001). An efficient method for scheduling construction projects with resource constraints. *International Journal of Project Management*, *19*(1), 29–45. https://doi.org/10.1016/S0263-7863(00)00024-7

Abowitz, D. A., & Toole, T. M. (2010). Mixed Method Research : Fundamental Issues of Design , Validity , and Reliability in Construction Research. *Journal of Construction Engineering and Mangement*. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000026

AlNasseri, H. A. (2015). *Understanding applications of project planning and scheduling in construction projects* [Lund University]. https://lup.lub.lu.se/record/7767241

AlNasseri, H., & Aulin, R. (2015). Assessing understanding of planning and scheduling theory and practice on construction projects. *EMJ - Engineering Management Journal*, *27*(2), 58–72. https://doi.org/10.1080/10429247.2015.1035963

Ambriz, R., & Landa, M. (2015). *Dynamic scheduling with MS project 2013* (1st ed.). J. Ross Publishing and International Institute for Learning, Inc.

Arditi, D., & Pattanakitchamroon, T. (2006). Selecting a delay analysis method in resolving construction claims. *International Journal of Project Management*, *24*(2). https://doi.org/10.1016/j.ijproman.2005.08.005

Ayele, H. Y. (2020). *Causes of professional turnover and its effects on building construction project performance in Hawassa city*.

Biruk, S., & Jaśkowski, P. (2017). Scheduling linear construction projects with resource constraint. *Archives of Civil Engineering*, *LXIII*(1), 3–15. https://doi.org/10.1515/ace-

2017-0001

Blanca, M. J., Arnau, J., López-Montiel, D., Bono, R., & Bendayan, R. (2013). Skewness and kurtosis in real data samples. *Methodology*, *9*(2), 78–84. https://doi.org/10.1027/1614-2241/a000057

Braimah, N. (2014). Understanding construction delay analysis and the role of preconstruction programming. *Journal of Management in Engineering*, *30*(5). https://doi.org/10.1061/(asce)me.1943-5479.0000216

Carone, C. (2017). *The differences between CPM and resource-loaded scheduling and how they applied to the Martinez Tesoro Refinery Flare Header Replacement Project*. California Polytechnic State University.

Casson, R. J., & Farmer, L. D. M. (2014). Understanding and checking the assumptions of linear regression: A primer for medical researchers. *Clinical and Experimental Ophthalmology*, *42*(6), 590–596. https://doi.org/10.1111/ceo.12358

Christodoulou, S., Ellinas, G., & Aslani, P. (2009). Entropy-based scheduling of resource-constrained construction projects. *Automation in Construction*, *18*(7). https://doi.org/10.1016/j.autcon.2009.04.007

Daoud, J. I. (2018). Multicollinearity and Regression Analysis. *Journal of Physics: Conference Series*, *949*(1). https://doi.org/10.1088/1742-6596/949/1/012009

Derbe, G., Li, Y., Wu, D., & Zhao, Q. (2020). Scientometric review of construction project schedule studies: Trends, gaps and potential research areas. In *Journal of Civil Engineering and Management* (Vol. 26, Issue 4).

https://doi.org/10.3846/jcem.2020.12317

Drost, E. A. (2004). Validity and reliability in social science research. *Education Research and Perspectives*, *38*(1), 105–125.

Faris, A. M. (2015). *Delay analysis technique in Ethiopian road construction (a case study on selected road projects implemented by the ethiopian road authorithy)*. Hawassa University.

Fellows, R., & Liu, A. (2015). *Research methods for construction* (4th ed.). John Wiley & Sons, Ltd.

FIDIC. (2017). *FIDIC, Conditions of contract for construction: for building and engineering works designed by the employer*. FIDIC.

FPPA. (2011). *Standard bidding document (SBD) for procurement of non-consultancy services for national competitive biddings (NCB)*. The Ethiopian federal public procurement authority.

Hall, S. C. (2020). *Preparing construction claims* (1st ed.). John Wiley & Sons Ltd.

Heon Jun, D., & El-Rayes, K. (2011a). Multiobjective optimization of resource leveling and allocation during construction scheduling. *Journal of Construction Engineering and Management*, *137*(12), 1080–1088. https://doi.org/10.1061/(asce)co.1943-7862.0000368

Heon Jun, D., & El-Rayes, K. (2011b). Multiobjective Optimization of Resource Leveling and Allocation during Construction Scheduling. *Journal of Construction Engineering and Management*, *137*(12). https://doi.org/10.1061/(asce)co.1943-7862.0000368

Hwang, B. G., Zhao, X., & Ng, S. Y. (2013). Identifying the critical factors affecting schedule performance of public housing projects. *Habitat International*, *38*, 214–221. https://doi.org/10.1016/j.habitatint.2012.06.008

Kaka, A., Ibrahim, Y. M., Kagioglou, M., & Aouad, G. (2008). Framework for a generic work breakdown structure for building projects. *Construction Innovation*, *9*(4), 388–405.

Kastor, A., & Sirakoulis, K. (2009). The effectiveness of resource levelling tools for resource constraint Project scheduling problem. *International Journal of Project Management*, *27*(5), 493–500. https://doi.org/10.1016/j.ijproman.2008.08.006

Keane, P. J., & Caletka, A. F. (2015). Delay analysis in construction. In *Wiley Blackwell* (2nd ed.).

Kim, K. (2020). Generalized resource-constrained critical path method to improve sustainability in construction project scheduling. *Sustainability*, *12*(8918). https://doi.org/10.3390/su12218918

Kothari, C. R. (2004). *Research Methodology* (2nd ed.). New Age International Limited Publishers.

Lawshe, C. H. (1975). A quantitative approach to content validity. *Personnel Psychology*, *28*(4), 563–575. https://doi.org/10.1111/j.1744-6570.1975.tb01393.x

Lee, J. S. (2006). Delay analysis considering productivity. *AACE International Transactions*, *2006*.

Li, B., Austin, S., & Thorpe, T. (2006). Management and planning of a collaborative construction planning process. *Proceedings of International Conference on Asia-European Sustainable Urban Development*,.

Magdy, M., Georgy, M., Osman, H., & Elsaid, M. (2019). Delay Analysis Methodologies Used by Engineering and Construction Firms in Egypt. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *11*(3), 1–11. https://doi.org/10.1061/(asce)la.1943-4170.0000293

Mengistu, D. G., & Mahesh, G. (2020). Challenges in developing the Ethiopian construction industry. *African Journal of Science, Technology, Innovation and Development*, *12*(4), 373–384. https://doi.org/10.1080/20421338.2019.1654252

Mengistu, D. G., & Mahesh, G. (2022). Manpower development framework for Ethiopian construction industry. *International Journal of Construction Management*, *22*(2), 121–132. https://doi.org/10.1080/15623599.2019.1613208

Mohajan, H. K. (2017). Two criteria for good measurements in research : Validity and reliability. *Annals of Spiru Haret University: Economic Series*, *17*(3), 58–82. https://mpra.ub.uni-muenchen.de/83458/

Moosavi, S. F. (2012). *Assessment and evaluation of detailed schedules in building construction*. Concordia University.

Mubarak, S. (2015). *Construction project scheduling and control* (3rd ed.). John Wiley & Sons, Inc.

Muneeswaran, G., Manoharan, P., Awoyera, P. O., & Adesina, A. (2020). A statistical approach to assess the schedule delays and risks in Indian construction industry.

International Journal of Construction Management, *20*(5). https://doi.org/10.1080/15623599.2018.1484991

Nam, J. (2016). *Construction scheduling with primavera P6*. AuthorHouse.

Newitt, J. (2009). *Construction scheduling: principles and practices* (2nd ed.). Pearson Education, Inc.

Nigussie, A. (2015). *Work programming and implementation practice in Ethiopian federal road projects*. Addis Ababa University.

Oke, J. A., Akinkunmi, W. B., & Etebefia, S. O. (2019). Use of Correlation, Tolerance and Variance Inflation Factor for Multicollinearity Test. *Global Scientific Journal*, *7*(5).

Osborne, J. W. (2013). Normality of residuals is a continuous variable, and does seem to influence the trustworthiness of confidence intervals: A response to, and appreciation of, Williams, Grajales, and Kurkiewicz (2013). *Practical Assessment, Research and Evaluation*, *18*(12), 0–9.

Parry, A. (2015). *The improvement of delay analysis in the UK construction industry*. Northumbria univerisy.

PMI. (2016). *PMI, Construction extension to the PMBoK guide*. PMI.

Rai, N., & Thapa, B. (2015). A study on purposive sampling method in research. *Kathmandu:Kathmandu School of Law*, 1–12. http://stattrek.com/survey-research/sampling-methods.aspx?Tutorial=AP,%0Ahttp://www.academia.edu/28087388

Rivera, L., Baguec, H., & Yeom, C. (2020). A study on causes of delay in road construction projects across 25 developing countries. *Infrastructures*, *5*(10), 1–16. https://doi.org/10.3390/infrastructures5100084

Senghong, C. (2009). Analyzing schedule delay of mega project: Lessons learned from korea train express. *IEEE Transactions on Engineering Management*. https://doi.org/10.1109/TEM.2009.2016042

Shamp, P. (2017). *Scheduling strategies for construction project managers toward on time delivery*. Walden University.

Shash, A. A., & Ahcom, J. (2006). Organizational aspects of planning and scheduling subsystem. *Journal of Construction Research*, *7*(1/2), 247–265.

Siedlecki, S. L. (2020). Understanding Descriptive Research Designs and Methods. *Clinical Nurse Specialist*, *34*(1). https://doi.org/10.1097/NUR.0000000000000493

Sinesilassie, E., Tabish, S. Z., & Jha, N. (2017). Critical factors affecting schedule performance: A case of Ethiopian public construction projects -Engineers' perspective. *Engineering, Construction and Architectural Management*, *18*(3), 312–328.

SMEC. (2020). *Claim management: Consultancy service for the technical assistance to build ERA's capacity*.

Sürücü, L., & Maslakçı, A. (2020). Validity and reliability in quantitative research. *Business & Management Studies*, *8*, 2694–2726.

Tesfaye, H. (2016). *Review of time extension delay analysis techniques trend Addis Ababa*.

Tomczak, M., & Jaskowski, P. (2020). Crashing construction project schedules by relocating resources. *IEEE Access, 8*. https://doi.org/10.1109/ACCESS.2020.3044645

Tsegaye, M. (2019). Efficient procedure to scheduling construction projects at the planning phase. *Baltic Journal of Real Estate Economics and Construction Management*, *7*(1), 60–80. https://doi.org/10.2478/bjreecm-2019-0004

Türkakın, O. H., Manisalı, E., & Arditi, D. (2020). Delay analysis in construction projects with no updated work schedules. *Engineering, Construction and Architectural Management*, *27*(10). https://doi.org/10.1108/ECAM-09-2019-0470

USCL. (2017). *The USL delay and disruption protocol* (2nd ed.). the Society of Construction Law.

Wahdan, M. I., Abu, M. S. M., Zuhair, Y., Partnership, F. &, & Farid, A. T. M. (2013). *Study and assessment of the reasons for project delay or stalled from project management view*.

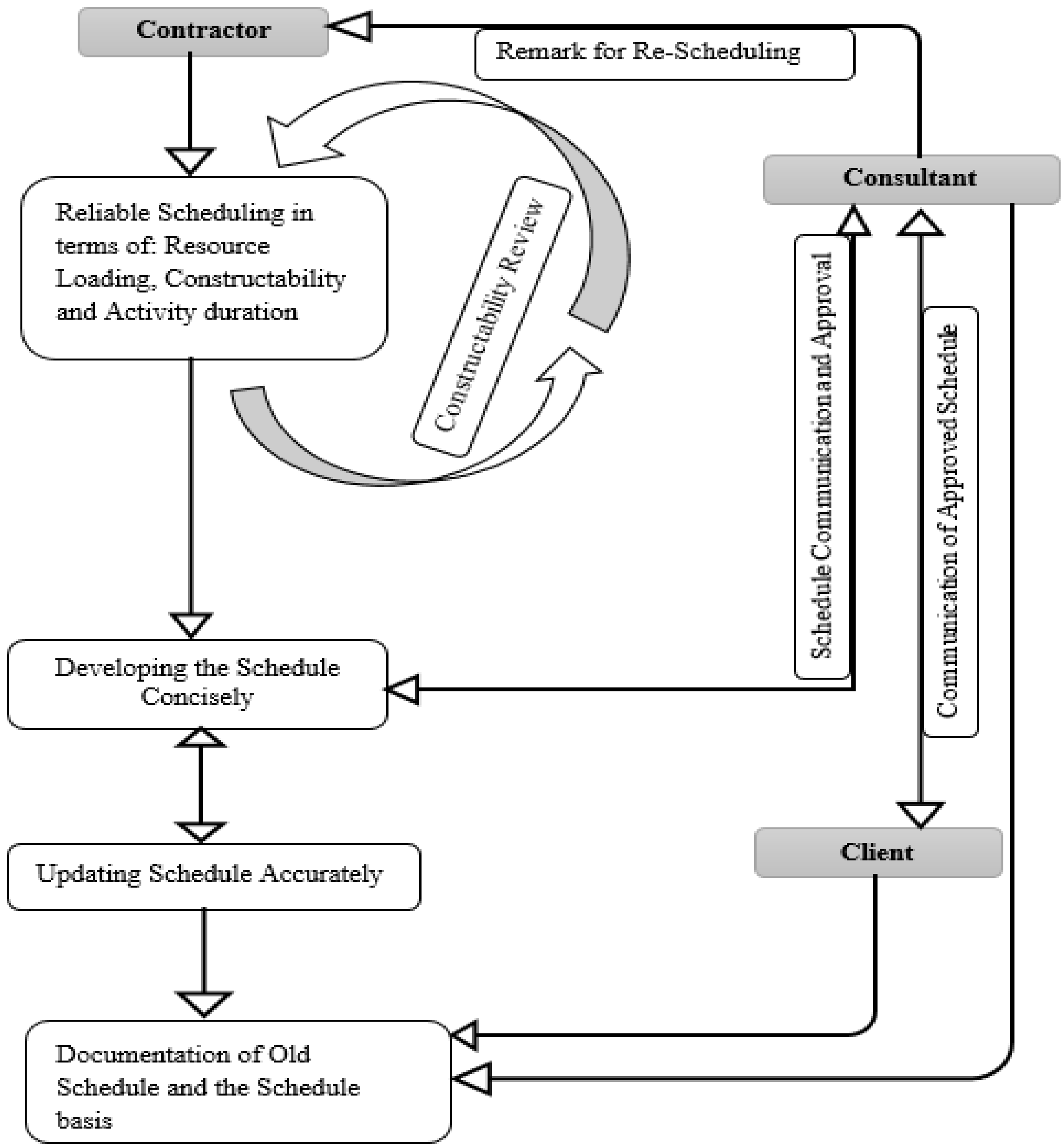
Winter, R. PSP F. Evrenosoglu. B., P. C. P. (2011). MS project for construction schedulers. *The AACE International 55th Annual Meeting*.

Winter, R. (2006). *Making CPM more transparent*. http://ronwinterconsulting.com/Making_CPM_Transparent.pdf

Zewdu, Z. T. (2016). Construction projects delay and their antidotes: The case of Ethiopian construction sector. *International Journal of Business and Economics Research*, *5*(4), 113. https://doi.org/10.11648/j.ijber.20160504.16

APPENDICES

Appendix I: Proposed Framework of Construction Scheduling Improvement



Appendix II: Profile of Pilot Survey Respondents

S.N	Work Experience (in years)	Education Level	Current Working Position	Current Construction Category
1	20	MSc.	General Manager	Building Construction
2	16	MSc.	Project Manager	Infra Structure
3	23	BSc.	Director, Contract Administration	Infra Structure
4	16	BSc.	Project Manager	Water Works
5	18	BSc.	Project Coordinator	Water Works
6	15	PhD.	Academics	-
7	16	MSc.	Project Coordinator	Building Construction
8	15	MSc.	Resident Engineer	Infra Structure
9	14	BSc.	Deputy General Manager	Infra Structure
10	13	BSc.	Senior Contract Administrator	Infra Structure
11	10	BSc.	Project Manager	Water Works
12	8	BSc.	Head, Project Office works	Infra Structure

Appendix III: Survey Questionnaire

Section 1: Description of the Study

Dear Construction professional Respondent,

This is a questionnaire survey for thesis of MSc. in COTM program at Hawassa University, ontitle of 'Practice of Construction Scheduling and its Impact on Delay Claim Analysis'. Results of the thesis work will be highly helpful to improve practice of delay claim analysis by providing construction scheduling framework for better delay claim analysis. It also puts down basic schedule output & scheduling requirements from perspective of better delay claim analysis in the industry.

The questionnaire body has 5 sections which will take you around 30 minutes of your valuable time to complete. All the information you provide here will be used for research purpose only.

Your timelyresponse is highly required and appreciated.

Sincerely,

Section 2: General Information

1. Please enter your email for purpose of respondent listing

You can skip this question if you don't like to provide your email.

____

2. Please choose your level of education *

Mark only one oval.

- Associate Degree
- BSc.Degree
- MSc. Degree
- Ph.D. Degree
- Other: ______________________________

3. Please choose your work experience in the construction industry (in years). *

Mark only one oval.

- 0-2
- 3-5
- 6-9
- 10-15
- 16 and above

4. Which category of organization have you worked in most in the past?

Mark only one oval.

- Consultant
- Contractor
- Client

5. Are you an officer/expert of scheduling/contract administration related tasks? *

Mark only one oval.

- Yes
- No

6. What software package do you think is mostly used for scheduling in the Ethiopian construction Industry? *

Check all that apply.

☐ MS Excel ☐ MS Project

☐ Primavera ☐ Other____________________

7. Why do you think the above software package/s is/are chosen? *

Check all that apply.

☐ It is Easy to work with ☐ It is easily available on market

☐ It is because of client's requirement ☐ It is by choice of the contractor

☐ Other: ____________________________

8. In your opinion, how much of CONTRACTORS in Ethiopia are aware that updating a schedule is a contractual responsibility. *

Mark only one oval.

◯ Almost none of them ◯ Some of them

◯ Most of them ◯ Almost all of them

9. In your opinion, how much of CONSULTANT organizations in Ethiopia are aware that updating a schedule is a contractual responsibility. *

Mark only one oval.

- Almost none of them
- Some of them
- Most of them
- Almost all of them

10. In your opinion, how much of CLIENTS in Ethiopia are aware that updating a schedule is a contractual responsibility. *

Mark only one oval.

- Almost none of them
- Some of them
- Most of them
- Almost all of them

11. In your opinion, how often delays caused by contractors in Ethiopia, are inappropriately forgiven (considered excusable)? *

Mark only one oval.

- never
- sometimes
- usually
- always

12. Strict implementation of penalties on a party responsible for a delay can influence construction organizations to improve the scheduling practice. *

Mark only one oval.

- I agree
- I don't agree

Section 3: Practice of ConstructionScheduling in Ethiopia

From your experience, rate the constructionscheduling practices as below:

No.	Element of Scheduling practice	1	2	3	4	5
3.1	Organizational structure of the planning and scheduling team in Ethiopian construction organizations					
3.2	Showing the critical path of a schedule clearly					
3.3	Activity Resource loading on schedules					
3.4	Showing dates of Major Supplies & Plant Erection in schedules					
3.5	Using the appropriate type of software package for scheduling (based on contractual requirement, allowing CPM method...)					
3.6	Reliability of schedules in terms of constructability (construction sequence)					
3.7	Accuracy in estimating activity duration					
3.8	Smoothing of resources assigned to activities of schedules					
3.9	Use of reasonable amount of float time/Slack time					
3.10	Use of reasonable number of constraints					

3.11	Schedules for submission being simple and summarized (simplicity & conciseness)					
3.12	Documentation of assumptions and considerations of a schedule (Rainy times, holidays, manpower availability, space constraint ...)					
3.13	Communicating assumptions and considerations of a schedule (Rainy times, holidays, manpower availability, space constraint ...)?					
3.14	. Timely submission of a baseline schedule (the starting schedule)? *					
3.15	Timely submission of update schedules					
3.16	Involvement of consultant organizations during the baseline schedule					
3.17	Involvement of client organizations during the baseline schedule (the starting schedule) preparation					
3.18	On time transfer of update schedules to client					
3.19	Documentation of previous/old schedules					
3.20	Mitigation of software based automatic schedule updating risks					
3.21	Incorporate feedback of client on update schedules					

3.22	What parameters do consulting organizations in Ethiopia use to check BASELINE schedule of a contractor? *Check all that apply.* ☐ Type of software package used for developing the schedule. ☐ Whether the schedule time frame is within the project duration. ☐ Whether the critical path is shown clearly. ☐ Whether the schedule is resource loaded. ☐ Whether dates of Major Supplies & Plant Erection are shown. ☐ Whether the amount of float time/Slack time used is reasonable. ☐ Whether number of constraints used are reasonable. ☐ Whether sequence of work activities in the schedule is reliable. ☐ Other:_______________________________________
3.23	What parameters do consulting organizations in Ethiopia use to check UPDATE schedule of a contractor? *Check all that apply.* ☐ Type of software package used for developing the schedule. ☐ Whether the schedule time frame is within the project duration. ☐ Whether the critical path is shown clearly. ☐ Whether the schedule is resource loaded. ☐ Whether dates of Major Supplies & Plant Erection are shown.

	☐ Whether the amount of float time/Slack time used is reasonable. ☐ Whether number of constraints used are reasonable. ☐ Whether sequence of work activities in the schedule is reliable. ☐ Other:____
3.24	What measures do consulting organizations in Ethiopia take on a contractor that doesn't update a schedule or updates lately? *Check all that apply.* ☐ The Consulting Engineer continues to withhold an amount of money stated in the special conditions of contract from the next payments until the update program is submitted. ☐ They don't take measure. ☐ They just write notification letters. ☐ Other______________________

Section 4: Impact of practice of construction scheduling on performance of delayclaim analysis:

From your experience, rate the level of impact of thecurrent construction scheduling practice (from section 3 above) on delay claim analysis:

No.	**Element of Scheduling practice**	**1**	**2**	**3**	**4**	**5**
4.1	Impact of organizational structure of the planning and scheduling team in Ethiopian construction organizations					
4.2	Impact of showing the critical path of a schedule clearly					
4.3	Impact of activity Resource loading on schedules					
4.4	Impact of showing dates of Major Supplies & Plant Erection in schedules					
4.5	Impact of using the appropriate type of software package for scheduling (based on contractual requirement, allowing CPM method...)					
4.6	Impact of reliability of schedules in terms of constructability (construction sequence)					
4.7	Impact of accuracy in estimating activity duration					
4.8	Impact of smoothing of resources assigned to activities of schedules					

4.9	Impact of use of reasonable amount of float time/Slack time					
4.10	Impact of use of reasonable number of constraints					
4.11	Impact of schedules for submission being simple and summarized (simplicity & conciseness)					
4.12	Impact of documentation of assumptions and considerations of a schedule (Rainy times, holidays, manpower availability, space constraint ...)					
4.13	Impact of communicating assumptions and considerations of a schedule (Rainy times, holidays, manpower availability, space constraint ...)?					
4.14	Impact of timely submission of a baseline schedule (the starting schedule)? *					
4.15	Impact of timely submission of update schedules					
4.16	Impact of involvement of consultant organizations during the baseline schedule					
4.17	Impact of involvement of client organizations during the baseline schedule (the starting schedule) preparation					
4.18	Impact of on time transfer of update schedules to client					
4.19	Impact of documentation of previous/old schedules					

4.20	Impact of mitigation of software based automatic schedule updating risks					
4.21	Impact of incorporate feedback of client on update schedules					

Section 5: Performance of Delay Claim Analysis

5. 1. How often do Ethiopian contractors claim cost compensation/additional payment with their claim of time extension due to damage by a schedule delay caused by client?

Mark only one oval.

◯ Never ◯ Sometimes ◯ Usually ◯ Always

5. 2. Assuming as built records of a construction project are available, how do Ethiopian consultants/clients determine delay due to events?

Mark only one oval.

◯ By deducting completion date of the as planned schedule from the as built one.

◯ By adding delay duration to relevant individual activity of the as planned schedule chronologically, and deduct completion date of as planned schedule from it.

- By adding delay duration to relevant individual activity of the as planned scheduleof a particular party (either contractor or client) and deduct completion date of the as-planned from each.
- By Removing delay durations of each party from the as-built schedule network separately, so that the resulting schedule will give the completion date.
- I don't know

NO		1	2	3	4	5
5.3	How do you rate the consultant's practice of delay claim analysis in terms of timeliness, in reference to time limit set in special conditions of contract?					
5.4	How do you rate the consultants' practice of delay claim analysis in terms of accuracy?					
5.5	How do you rate the satisfaction of construction stakeholders with results of delay claim analysis?					
5.6	How do you rate the practice of documentation of as-built records (historicalrecords such as letters, approved shop drawings, inspection requests…) in the construction industry?					

Section 6: Challenges ofConstruction Scheduling

From your experience, rate the level of challenges onconstruction scheduling (practice) as below:

NO		1	2	3	4	5
6.1	Construction specifications don't specify sufficient schedule requirements.					
6.2	Absence of national scheduling standards for uniform estimation of resources or activity durations					
6.3	Large number of construction work's activities (in thousands) of construction projects having a complex logical relationships which also compete for resource.					
6.4	A challenge to the accuracy of a schedule arising from task of estimation of activity duration.					
6.5	Optimum schedule output requires many iterations in a resource constrained environment.					
6.6	The practically difficult joint involvement of key stakeholders (client, contractor &consultant) in task of periodic update of a schedule.					
6.7	Main parties (contractor, consultant & client)					

	consider the purpose of a schedule only a formality purpose					
6.8	Lack of knowledge and understanding on theories of project planning and scheduling Techniques.					
6.9	Low responsiveness of contractor's top management to developed schedules.					
.10	Top management of contractor imposes unrealistic task of schedule crushing during schedule updating.					

Appendix IV: In-depth Interview Questions (Case Study)

1. Does your company have an evaluation/preparation manual for a delay/time extension claim?
2. What documents are referred for evaluating/formulating delay claims in your organization?
3. According to your company, what important documents should be submitted with time claim submissions?
4. Does your scheduling and claim management practice differ from project to project?
5. What has usually caused rejection of part or all of a claim?
6. Are claim for extension of completion date frequent?
7. Are claim for cost compensation due to delay Common?

8. Does the company reject claims with no prior notification?
9. Does the company give attention to the ground contractual condition/ contractual basis for the claim stated?
10. How do you define exceptionally adverse weather condition?
11. How long does it usually take for a final response to be given by the consultant?
12. What do you think should be improved/corrected regarding evaluation of time claims in your organization?
13. Are all necessary records available usually?
14. Do you refer to schedules for evaluating time claim? What information?
15. With what software are schedules usually prepared?
16. Are critical path of schedules clearly shown?
17. Are Schedules resource loaded?
18. Are delay events related to the critical path of the schedule?
19. Are schedules easily understandable/concise?
20. Are previous versions of the schedule available at the time of the claim?
21. Do you believe the information from the schedules are reliable?
22. How long does it take to give final decision response for the claim?
23. What is the most frequent decision on delay related claims?
24. Do you perform schedule validation before evaluating delay claims?
25. If yes, do you refer to any recommended practice guide for validating schedules?
26. Do you know what the USCL and AACE recommended practice are?
27. Do you use these guides at your organization?
28. What important information is usually difficult to get from schedules?

29. Do you use software packages for evaluating the claims?

30. Do you perform schedule simulation?