BIM-BASED KNOWLEDGE MANAGEMENT SYSTEM FOR CONSTRUCTION COST CLAIMS

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This work is dedicated to my beloved Laala (Father), Abayi (Mother) & siblings.

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LIST OF ABBREVIATIONS

AEC	Architectural, Engineering & Construction
AIA	American Institute of Architects
API	Application Programming Interface
B-CMS	BIM-based Claims Management System
BIM	Building Information Modeling
BIM-CCMS	BIM-base Cost Claims Management System
CAD	Computer Aided Designs
DNP	Defects Notification Period
FIDIC	International Federation for Consulting Engineers
GCC	General Conditions of Contract
HOOH	Home Office Overheads
ICT	Information Communication Technology
IDSS	Integrated decision support system
IFC	Industry Foundation Classes
NEC	New Engineering Contract
NEC-ECC	NEC for Engineering & Construction Contract
PSOM	Particle Swarm Optimization Model
RII	Relative Importance Index
ROI	Return of Investment
SCE	Small Construction Enterprises
SCL	Society of Construction Law
TFM	Total Float management

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ABSTRACT

Construction Projects go through many changes during, but not limited to, their designing and execution phases. These changes may occur due to the involvement of multiple uncertainties. These uncertainties lead to different kinds of claims. Almost in every claim, one of both the additional time and the cost or both are pursued. Handling claims is a complex procedure requiring multiple scrutiny layers of documents and negotiations between contract parties. There are many inefficiencies in the conventional method of handling claims. These inefficiencies were found from literature review and verified by the construction industry through an initial survey. Building information modeling (BIM) and Information communication technologies (ICT) provide innovative solutions to reduce inefficiencies in claims management. This study aims to develop a BIM-based knowledge Management System for Cost Claims (BIM-CCMS) in a BIM environment to handle cost claims in the construction industry. Some of the key features of the BIM-CCMS prototype are i) breakdown of different kinds of direct and indirect costs; ii) involvement of internationally used standard contracts like FIDIC and NEC3, iii) Visualization of variations in design and its impacts on costs; and iv) summarizing and formatting cost results to provide bases for cost claims. The prototype was then presented to industry experts using a case study project. Industry experts later evaluated this Prototype through semi-structured interviews. Experts were selected based on their vast knowledge and experience of contracts, Planning and BIM. Some barriers in its implementation and future recommendations were also recorded and discussed.

Chapter 1

INTRODUCTION

1.1 PREFACE

Engineering and construction projects are subject to sizable risks and uncertainties (Ali D. Haidar, 2011). These uncertainties may include site conditions, weather, labor, and materials availability, local or government body intervention, and inflation (Pishdad-Bozorgi & de la Garza, 2012; Tang, Li et al., 2013; Wenzhe Tang et al., 2007); As the projects proceed, these uncertainties make a project prone to go through variations or change orders issued (El-adawayet al., 2016). Studies show that almost 40% of the construction projects tended to go through the change of more than 10%, as evaluated by their ratio of final project costs to their initial costs of projects (Ibbs, 2012). These change orders could further lead contractors to different claims (Abdul-Malak et al., 2002).

Changes to the schedule of works caused by owners often become contentious issues, especially when one or more changes result in delay and disruption (Ali D. Haidar, 2011; Enshassi et al., 2009; Levin, 2013; Revay, 1993). A claim can be stated as an assertion of a right to an extension of time or a payment that may arise under the agreed conditions of a contract (Chappell, 2011; Revay, 1993). 'Delay Claim' is usually defined as a budgetary claim that follows from a delay to the completion of the projects (Gibson, 2014b). The reason could be the delay in responsibilities by either party to a contract. For example, the client's submission drawings provided to a contractor are late (Ibbs, Nguyen, & Simonian, 2011; Revay, 1993). 'Disruption claim' is used to mention a monetary claim where part of the works has been disrupted (Gibson, 2014a). Usually, quantifying delays of activities on the critical path may help a claim for the 'prolongation costs' (Thomas, 2015).

Although most of these claims are justifiable and do not tend to create confrontation between different parties (Enshassi et al., 2009), all parties, including the client, designer, and contractor, need to understand the claim process (Enshassi

et al., 2009). Construction claims seriously affect the duration and cost of a construction project (Chovichien & Tochaiwat, 2015). The parties in a contract need to understand the provisions, roles, and responsibilities in case of any change event (or events) to reduce cost, time, and disputes (El-adaway et al., 2016).

Many claims consume plenty of managerial time to scrutiny and compile (Vidogah & Ndekugri, 1998a). To deal with or control claims effectively, all parties to a contract should establish and maintain good construction claim management processes in their organizations (Chovichien & Tochaiwat, 2015). Researchers suggest that claims management is as important as understanding contractual terms (Vidogah & Ndekugri, 1998a). If not properly managed, time and cost claims lead to serious onsite and offsite overhead (Davis & Ibbs, 2016).

The conventional claim management system is onerous and prone to errors because it is time-consuming and uses a lot of paper (Vidogah & Ndekugri, 1998a). The claims management obstacles can be majorly found in claim justification, quantification, retrieval of supporting data, and sufficiency of retrieved data (Ali D. Haidar, 2011; Chovichien & Tochaiwat, 2015; Gibson, 2014a; Vidogah & Ndekugri, 1998a); because there are no standard methods for effective management of claims (Shahhosseini & Hajarolasvadi, 2018). Sticking to traditional management practices is poor performance, which can be reduced using technology like Building Information Modeling (BIM) tools' implementation (Ali, Zahoor et al., 2018). BIM technology is providing the construction industry with benefits like reduction in cost, improved quality and performance, increased collaboration and communication, improved demonstration and substantiation process, cost estimation, better design and planning, clash detection, sustainability, and facility management (Ismail et al.,, 2017). Analyzing and overlaying Computer Aided Drawing (CAD) files is sluggish work; also, it is short in clarity, prone to errors, and inadequate in providing information (Lanka & Kandy, 2015). However, BIM has overcome this deficiency over the years (Ali et al., 2018).

Due to its visualization and information tracking, BIM is being used actively in the present age (Chou & Yang, 2017; Wang et al., 2014). This information/document tracing characteristic may also help construction stakeholders

manage claims in a much more organized manner. This study aims to help the parties to a contract to understand, quantify and manage the construction cost claims with the help of visualization and analysis at every stage of a claim to manage construction claim.

1.2 PROBLEM STATEMENT

Literature study for claims management shows that the availability of data for proving the claim is one of the main hurdles in handling claims (Shahhosseini & Hajarolasvadi, 2018). Every claim combines two main segments, which are 1) identification of change event and entitlement to recovery and 2) quantification (Mcmanus & Starr, 2016). Most of the construction claims involve additional costs which need critical attention. If not solved at the right time, these claims can lead to disputes (Kumaraswamy, 1997). Preparation and assessment of cost claims according to contract clauses is a time-consuming and complex process. This procedure includes direct and indirect costs under specific heads in preparation of the claims. Timely management of cost claims can save the project from conflicts and delays (Vidogah & Ndekugri, 1998a).

Although there are some suitable expert systems to handle claims, no comprehensive approach is designed for claims (Shahhosseini & Hajarolasvadi, 2018). Building Information modeling has brought a revolution to the technology used in Architecture, Engineering, and the Construction Industry. However, BIM has not been fully utilized in contracts, especially in claims management. (Ali et al., 2018). BIM can be used to take full advantage of its lucid abilities like coordination, visualization, a centralized repository for contract parties to act as a transparent system to resolve claims.

1.3 RESEARCH OBJECTIVES

Objectives of this study are listed as below:

- To identify the issues in the cost claims management process in the construction industry

- To develop a framework for a BIM-based knowledge management system for cost claims.
- To develop a digital platform for implementing the framework in the BIM authoring platform.

1.4 SIGNIFICANCE OF STUDY

Retrieval of relevant information/document is the first step in making claims and their link to analysis of delay and disruption (Valavanoglou et al.,, 2017). The requirements to document the impact assessment of a changing event include accuracy through continuous updates, a high level of details, and a systematic structure. This research aims to provide a detailed approach to create, quantify, visualize and proactively manage the cost claims in a comprehensive management system for all parties to a construction contract.

Chapter 2

LITERATURE REVIEW

2.1 BACKGROUND

An attempt is made to study inefficiencies in construction claims, specifically, cost claims and their types, standard forms of contracts to extract the events which may lead to cost claims in construction. Recent developments in claims management systems are also observed for this study to deal with such claims.

As Building Information Modeling (BIM) is emerging as one of the reliable technologies adopted in the construction industry, this chapter will also involve an in-depth review of its adoption and benefits in construction Projects. BIM platforms, the role of BIM in the Information and Communication Industry (ICT), Application Programming Interface (API) functionality, and an overview of Revit API are also discussed.

2.2 CONSTRUCTION CLAIMS

In the construction industry, the term "claim" is defined as the request made by any party for an additional time and/or cost following a "change" approved by the other party (Shahhosseini & Hajarolasvadi, 2018). In the broader sense, a claim is a request by one contract party to another for extra time or payment under provisions of the contract adopted (Chappell, 2011). Construction claims are of many types, and they could arise due to many reasons and causes (Koc & SKAIK, 2014). Chen, (2015) made some claim classification based on their purpose, bases, nature, and processing. The classification based on "purpose of claims" will be discussed in this chapter, including time-based claims and cost claims. A contractor may claim extra time and or/cost if the reasons are beyond his control (D. Gibbs, Stephen, Ruikar, & Lord, 2014). EOT claims require owners to extend the project completion date to avoid liquidated damages and compensate for the loss incurred (Yu, 2009). SCL Protocol Mainly decides the criteria for granting EOT to the either party if there is any delay by any contract party (SCL, 2017). The effects of these delays are summarized by Babar (Ali, 2018) which showed how these delays lead to EOT/Cost

claims.

2.2.1 Cost Claims

Critical Delays affect the overall duration of a project (Trauner, 2009), and Excusable Delays are those which are beyond the control of the contractor (Vasilyeva-Lyulina et al., 2015). Both of these delays lead to cost claims in construction (Ali, 2018). Construction claims have a significant effect on the project's total duration and total cost (Chovichien & Tochaiwat, 2015). Initially, these claims need to be handled on a processing basis which means either these claims are to be managed on an event basis, thus calling them "Individual Claims," or to be managed at the end of the project by mixing all of the events and presenting as "Total Claims" (Chen, 2015). Total claims are also termed as "Ex-Gratia Claims" (Ali D. Haidar, 2011; Levin, 2013) or comprehensive claims (Chen, 2015). Since we aim to achieve a claim management system with the help of Building Information Modeling (BIM), we will mainly discuss individual cost claims.

2.2.2 Disruption, Prolongation, and Acceleration Claims

Disruption in construction and engineering contracts means the difference between "intention" and "reality" to achieve a milestone in a given work (Burr, 2016). Usually, the client's changes result in slowing down work progress or, in cases of suspension of work, then the contractor must prove the interruption in his planned work and thus resulting in some loss of productivity. This type of impact is described as "disruption in construction" (Ibbs & Stynchcomb, 2016). Disruption can be caused by a delay, or it may cause a delay (Burr, 2016). Prolongation is the extension of time for which costs are incurred due to a delay (Gibson, 2014b).

Prolongation is caused by delay, and prolongation causes increased costs (SCL, 2017). Not every delay will be on the critical path and thus will result in no general prolongation cost. Therefore delays are divided into two terms known as " Qualifying delays" (i.e., claims which bring with them the right to extra cost) and "Non-qualifying delays" (which do not bring any additional cost with them). The employer's team should keep a record of delays caused by the contractor and for which the employer is not liable to pay (Thomas, 2015). A prolongation claim simply

states that the Employer or the Engineer has failed to act in a timely manner, which resulted in the contractor's inability to complete the project as per contract duration (Chappell, 2011).

In the event of a delay, any party to a contract may be faced with deciding if the acceleration is needed (Thomas, 2015). Acceleration is taken into account by a contractor if there is a need to fast track the project's progress or make up for time lost (Levin, 2013). An employer might see an acceleration that may be beneficial to avoid further loss due to delays and go for substantial savings in early completion. A contractor might see the acceleration as an advantage if it is liable to delay and the acceleration cost is comparatively less than prolongation cost (Thomas, 2015). According to (Levin, 2013; Thomas, 2015), acceleration can be due to these three reasons:

- Voluntary
- Constructive
- Following the owner’s instructions

The contractor makes a reasonable attempt to accelerate and incurs additional expenses (Thomas, 2015).

2.3 CONTRACT STRATEGY FOR COST CLAIMS

A contract is the foundation of the construction process (Harrington et al., 2016). Understanding the contractual procedures for claims will help contract parties efficiently complete their projects (El-adaway et al., 2016). General Conditions of Contract (GCC) of the agreed contract should be reviewed in detail to completely understand the matter and different conditions that could occur during cost claims (Ali et al., 2018). A brief claim procedure is given in various editions of the most used contract document in international construction, i.e., International Federation of Consulting Engineers (FIDIC), including FIDIC (1987), FIDIC (1999), and the most recent FIDIC (2017).

2.3.1 FIDIC 1987

In sub-clause 53.1 of FIDIC 1987, it is stated that if there is an event or

multiple events which can give rise to a claim, a contractor should provide the notice of additional time or cost to the engineer within 4weeks of its occurrence. The contractor shall also send a copy to the employer of the notice. Sub-clause 53.2 states that the Contractor should keep and send within 28 days the contemporary records to support and for substantiation of the claim as mentioned in sub-clause 53.3. If the contractor fails to follow, then sub-clause 53.4 states that the Engineer/Arbitrator should entitle the contractor of only the costs for which the contemporary records are available. The contractor shall be entitled to include the amount in any interim payment certificate after the Engineer has verified them and notify the Employer.

2.3.2 FIDIC 1999

Clause 20.1 states that "If the contractor considers himself to be entitled to additional time or payment under any clause of conditions or in connection with the contract, the contractor shall give notice to the Engineer within 28 days after Contractor became aware or should have become aware of the event/circumstances. If the contractor fails to do as mentioned above, the party will not be granted additional money or time. The contractor shall write a detailed claim including full supporting particulars, within 6weeks after the contractor became aware of the situation giving rise to the claim; if the situation giving rise to the claim has a continuing effect, then this fully detailed claim to be considered as interim and contractor shall send further interim claims on monthly bases, giving accumulated delay and/or the amount claimed. The contractor, within four weeks, shall send the final claim after the end of the effects resulting from the event. The Engineer shall respond with either approval or rejection to contractor's claims within 6weeks after receiving a claim."

2.3.3 FIDIC 2017

Clause 20.2 of FIDIC 2017 edition states that: "The claiming Party shall give a Notice to the Engineer, describing the event or circumstance giving rise to the cost, loss, delay, or extension of DNP (Defects Notification period) for which the Claim is made as soon as practicable, and no later than 28 days after the claiming Party became aware or should have become aware of the event/circumstance (the "Notice of Claim" in these Conditions)." It further goes on to elaborate time limits for the

burden of proof by the claimant and further process as, “Detailed supporting particulars of the amount of additional payment claimed (or amount of reduction of the Contract Price in the case of the Employer as the claiming Party), and/or EOT claimed (in the case of the Contractor), or extension of the DNP claimed (in the case of the Employer) Within either:

A. “*84 days after the claiming Party became aware, or should have become aware, of the event or circumstance giving rise to the Claim, or”*
B. *“Such other period (if any) as may be proposed by the claiming Party and The Engineer shall give the Notice of his/her agreement/determination within42 days or within such other time limit as may be proposed by the Engineer and agreed by both Parties.”*

2.3.4 NEC3 Engineering and Construction Contracts (NEC3 ECC)

In NEC3, “compensation event” is used as terminology for additional time or money, loss, and expense, variation. The term “compensation” does not always mean that the prices can go up; depending upon circumstances, they can go down as well (Evans, 2017). In New Engineering Contract for Engineering and Construction Contract (NEC-ECC), the method regarding compensation events is given; it states the definition of compensation events in its clause no. 60. In clause 61.1, it is said that if the Project Manager instructs Contractor due to which a compensation event arises, the Project Manager will require Contractor to submit quotation. Clause 61.3 states that if the contractor becomes aware of the change or a compensation event and fails to notify the Project Manager within Eight weeks when he became aware, then the Contractor will not be entitled to additional cost or time. Clause 61.4 describes that the Project manager decides whether the contractor's notification is legible or not and then acts accordingly. If the change assessed by the project manager is understandable, then the Project manager will ask the Contractor to submit a quotation for a notified compensation event. The contractor then needs to submit a quote within three weeks after being instructed. The Project needs to reply within two weeks of the submission (clause 62.3). If the Project manager does not reply within the time allowed and the contractor has submitted more than one

quotation for the compensation event, then the contractor should state in the notification that his quotation is to be accepted (clause 62.6). Clause 63 & 64 describes the compensation event assessment by the contractor and project manager during the time allowed in the contract. Clause 65 states the final step, which is the implementation of the compensation event. New Engineering Contracts (NEC3) handles claims mainly in clause number 60 (Laryea, 2016). Evans (2017) discussed in detail that there are 19 core clauses for handling the compensation events, which are listed as below:

- *"The Project Manager deals with "the change" to the works information, except the change provided by the contractor*
- *Denial of Permission by the Employer to use the site as per contract dates.*
- *Employer's Refusal to provide something that is his responsibility as per accepted programme date*
- *The Project manager instructs to modify or stop or change any key date*
- *The Employers or Others do not conform with the accepted programme or work information*
- *Project Manager does not reply to Contractor's communication within required period*
- *Instructions by Project Manager to deal with Valuables found within the site*
- *Project Manager changes previously agreed dates*
- *Project manager can withhold an acceptance for a reason not stated in contract*
- *Supervisor orders the Contractor to search for a defect, and no defect is found*
- *An unnecessary Delay caused by the supervisor's inspection*
- *Physical Conditions encountered by Contractor*
- *Recording of weather measurement*
- *Event which is by the contract an Employer's Risk*
- *The Project Manager certifies takeover of a part of the works before both the completion and the completion date*

- *Employer's failure to comply with providing the agreed facilities mentioned in the Works Information*
- *The Project Manager notifies a correction to an assumption which he has stated about a compensation event.*
- *A breach of contract by the Employer which is not one of the other compensation events in this contract.*
- *Force Majeure Events"*

2.4 GUIDELINES FOR COMPREHENSIVE COST CLAIMS PREPARATION

Assessment and evaluation of disruption claims will depend upon the pricing and accounting policy of the contractor (Thomas, 2015). Pricing of claims can be divided into two categories which are post pricing (pricing is done after the work is done) and forward pricing (pricing is negotiated before the work is done) (Harrington et al., 2016; Levin, 2013). (Harrington et al., 2016) mentioned some of the basic pricing elements for a claim proposal. Those elements are:

- Summary
- Narrative
- Schedule analysis (if applicable)
- Pricing

The summary should be inclusive of sub-elements like entitlement, requested amount, an extension of time (if any), parties involved in a claim, and finally, the reference to the contract clause.

Similarly, the narrative will include sub-elements like the resulting growth in cost amount and time with supporting facts. Delay analysis techniques shall be used if schedule analysis is applicable. (Vasilyeva-Lyulina et al., 2015) discussed in detail different techniques for delay analysis. The main element of the claim proposal is pricing, which further is divided into direct costs (labor, supervision, permanent materials, job materials, and equipment) and impacted costs (impact on other activities, delay costs, i.e., standby time and escalation, acceleration costs, e.g., overtime and premium hours, lost profits, lost productivity costs and lost overheads).

Last but not least among elements is mark-up which includes the Jobsite overheads, home office overhead, profit, bond, and insurance.

Heads of a claim arising out of prolongation of the contract period are site overheads and office overheads (Thomas, 2015). (Gibson, 2014a) discussed these heads and further divided into sub-heads like Site overheads contains the costs for staff and site establishment (plant and equipment, small tools, scaffolding, electricity and telephone charges, etc.), while head office overheads in a claim are for recovery of, or contribution to the contractor's overheads and profit (Gibson, 2014a). To calculate loss, the contractor needs to justify the head office overheads and profit (Thomas, 2015).

2.5 WHICH FORMULA IS TO BE USED FOR HOME OFFICE OVERHEADS CALCULATION?

Various formulae can be used in case of prolongation (Thomas, 2015). The selection of the formula for head office overheads will depend on the situation in each case (Gibson, 2014b). Home office overheads expense damage incurred due to project delays is called un-absorbed overheads (Taam & Singh, 2003). According to SCL, three famous and most common formulae for the calculation of head office overheads are:

a. Hudson Formula
b. Emden Formula
c. Eichleay Formula

2.5.1 Hudson's Formula

The Hudson Formula (Equation 1) can be found in HUDSON'S BUILDING AND ENGINEERING CONTRACTS 1970 (Gibson, 2014a). This formula includes a percentage in the contractor's tender for overheads as a basis for the contractor's loss of contribution to overheads (Thomas, 2015).

$$\frac{Head\ office\ \ Overeheads\ (profit)\%}{100} x \frac{Contract\ sum}{Contract\ Period} x\ Period\ of\ delay$$

Equation 1 for HOOH calculation using Hudson Formula

Hudson's formula relies on the accuracy and reliability of the contractor's tender (Gibson, 2014a). SCL protocol guidance part C mentions the use of the Hudson formula. It states that as it is dependent upon head office overhead and profit mentioned in tender, which is already counted in the contract

2.5.2 Emden's Formula

This formula was put forward in EMDEN'S BUILDING CONTRACTS AND PRACTICE, 8th edition (Thomas, 2015). The advantage of this formula is that it uses a head office overhead percentage based on the contractor's total business rather than on the specific contract in dispute (Gibson, 2014a; Thomas, 2015). This formula may not necessarily reflect the real effect on overhead costs, but it may provide a reasonable approximation (Gibson, 2014a). It contains two stages (Equation 2 & Equation 3) as follows:

$$\frac{Company\ overhead\ cost/profit}{Company\ revenue} = z\%$$

Equation 2 – Formula for cost/profit ratio

$$\frac{z\%}{100} x \frac{Contract\ price}{Contract\ period\ (weeks)} xPeriod\ of\ delay(weeks) = weekly\ recoverable\ rate$$

Equation 3 – Formula for Weekly recoverable rate

2.5.3 Eichleay's Formula

The most commonly used formula for calculation Home Office Overheads claims is this formula (Taam & Singh, 2003). The original Eichleay Formula consists of three steps or equations (Davis & Ibbs, 2016; Ness & Carper, 2010; Taam & Singh, 2003). First of all, from Equation 4, overheads aloocable to delayed contracts are determined. After that daily contract overheads are found from Equation 5. In the

last step, overheads for delayed contract period are found from Equation 6.

$$\frac{Actual\ Billings\ for\ delayed\ contract}{Total\ actual\ billings\ for\ period} x\ Total\ homeoffice\ overheads = Overeads\ allocable\ to\ delayed\ contract(\$)$$

Equation 4- Formula for finding of Overhead allocable to delayed contract

$$\frac{Overhead\ allocable\ to\ delayed\ contract}{Days\ of\ performance} = Daily\ contract\ overhead\ for\ delayed\ contract\ (\frac{\$}{day})$$

Equation 5 – Formula for finding of Overhead per day

$$Daily\ contract\ overhead\ for\ delayed\ periodxnumber\ of\ delayed\ days = Overhead\ claim\ amount\ for\ delayed\ contract\ (\$)$$

Equation 6 - Formula for Overhead Claimed for delayed contract

Gibson (2014) discussed the same formula using "weeks" instead of "days" in its calculations. Davis & Ibbs, (2016) discussed criteria for selection of Eichleay formula, based on the exploration of historical court cases. All conditions must be met for Eichleay Formula to apply:

1. *"This is used mainly for the Main Contractor vs. Owner Disputes.*
2. *Unabsorbed Home Office Overheads (HOOH) resulted from force majeure events cannot be recovered*
3. *The formula is applicable when the project's schedule is extended past the contract performance period*
4. *Unrealistic figures produced by this formula will simply be disallowed*
5. *Oral agreements may be enforceable regardless of a written contractual agreement stating otherwise*
6. *Contractual agreements are upheld regardless of actual damages*
7. *Inability to calculate actual damages warrants the use of this formula."*

2.6 CLAIMS MANAGEMENT

Claims management is an important part of contract management (Chen, 2015). Major steps of claims management system include identification, notification, analysis, quantification, presentation, and documentation (Ali et al., 2018; Zaneldin, 2006), as shown in (Figure 2-1):

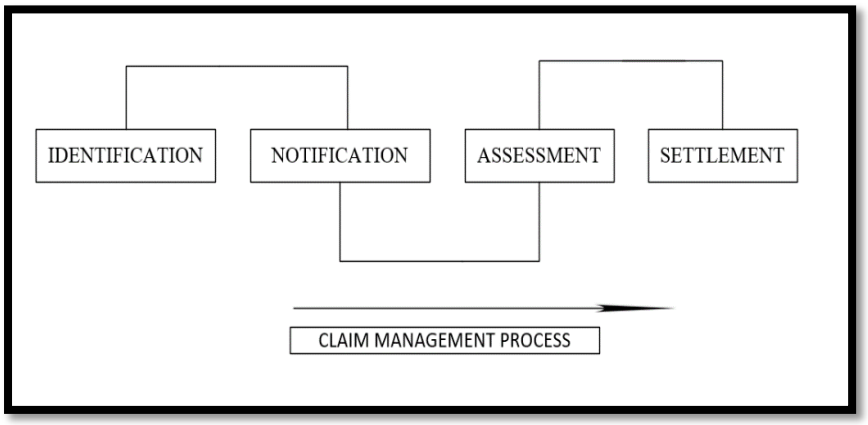


Figure 2-1 Claim management Steps

Proper claims management starts with identification followed by notification, also known as the second step (Mcmanus & Starr, 2016). Construction claim identification depends upon timely and accurate knowledge of 'the change(Ali, 2018). Notifying the other party of the problem makes the identification step more important (Levin, 2013). The contract specifies the responsibilities of each party during this stage (Ali, 2018; Ali D. Haidar, 2011). legal and factual grounds are established by the claimant in the examination stage (Ali, 2018). For the examination stage, the assessing party will need documentation that supports the claim made by the claimant (Levin, 2013; Thomas, 2015). Documentation plays a vital role in the management of every claim. The claimant will need all binding documents, including supporting detailed drawings, specifications, work schedule (Bakhary et al., 2015). Once the notification stage is over, a detailed claim analysis is followed (Gibson, 2014a). Once the engineer gets an official claim, the next stage is assessing claims (Bakhary et al., 2015; Thomas, 2015). the final stage of claims management is negotiation/ settlement (Ali, 2018; Ali D. Haidar, 2011; Thomas, 2015). If all the parties are not agreed to the negotiation and settlement, resulting in failing to reach an agreement, then there should be alternative methods to resolve claims or, in this case, ' disputes' (Bakhary et al., 2015). Since every

claim can turn into a dispute for various reasons, it is necessary to resolve a claim as soon as possible effectively (Ali, 2018; D. Gibbs et al., 2014). Claims management in the current construction industry needs strategic steps for improvement (Ren, Anumba, & Ugwu, 2001).

2.7 DEVELOPMENT IN CLAIMS MANAGEMENT

Several researchers have suggested various methodologies and systems to manage claims in the construction industry (Ali et al., 2018). Although BIM includes an abundance of information, there is a lack in using BIM in claims management (Shahhosseini & Hajarolasvadi, 2018). Different methods using computers and software are adopted during the past three decades to improve claims management (D.-J. Gibbs et al., 2017; Marzouk, et al.,2018; Vidogah & Ndekugri, 1998a). Computer-aided claim management systems are being considered instead of conventional claims handling practices (Shahhosseini & Hajarolasvadi, 2018). Some expert systems predict the outcome of claims to avoid unreasonable claims. For example, a particle swarm optimization model (SWOM) is practiced in Hong Kong (Chau, 2007). A prototype model developed by (Palaneeswaran & Kumaraswamy, 2008) is an integrated Decision support system (IDSS) that helps deal with EOT claims. (Al-Gahtani, Al-Sulaihi, & Iqupal, 2016) introduced a web-based software called Total Float Management (TFM) software, which can import all schedule data directly from other digital tools like Primavera P6 and Microsoft Project (MS project) in various formats. (Shahhosseini & Hajarolasvadi, 2018) proposed a rule based conceptual framework for dealing BIM based claims management inputs. (Ali, 2018) developed a prototype Application Program Interface (API) to deal with EOT claims using BIM Platforms.

2.8 INEFFICIENCIES IN MANAGEMENT OF CONSTRUCTION COST CLAIMS FROM LITERATURE

The inefficiencies in the management of cost claims were identified from the literature. These inefficiencies were considered for every contracting party in a construction project (Ali, 2018). For extraction of inefficiencies, 42 papers were studied to extract a total of 39 Inefficiencies in construction cost claim processes. Due to the overlapping nature of some of the inefficiencies, the total number of

inefficiencies was reduced to 30 inefficiencies in cost claims (Ali, 2018). Inefficiencies were then grouped into nine groups for further processing and discussion, as was done by (Chan, 2012). The groups were divided into Procedure, Contractual, Coordination, Cost, Documentation, Resources, Presentation, Technology, and Time. Table 2-2-1 shows literature review-based inefficiencies in their grouping. These inefficiencies were further used to find the literature score and its relationship with Field Score. The results were discussed in chapter 3.

Table 2-2-1 Literature Review Based Inefficiencies

Sr. no.	Inefficiencies in cost claims	Group	Reference
1	lack of contract awareness	Contract	(Mcmanus & Starr, 2016), (Song, 2015), (Hadikusumo & Tobgay, 2015), (Parchami Jalal, Noorzai, & Yavari Roushan, 2019), (CHO. et al., 2019),
2	legibility of claim in verbal and technical terms	Contract	(Song, 2015), (Enshassi et al., 2009), (Benjamin T. Davis, 2017), ((Abdul-Malak et al., 2002), (Hashem M. Mehany & Grigg, 2014)
3	Not updating the schedules	Coordination	(Hashem M. Mehany & Grigg, 2015), (CHO. et al., 2019),
4	Coordination gap between Site and office	Coordination	(Ibbs et al., 2011), (CHO. et al., 2019),

5	Difference in quantification of damages calculated by different parties	Cost	(Chovichien & Tochaiwat, 2015), (Mcmanus & Starr, 2016), (Hadikusumo & Tobgay, 2015), (Ibbs, 2016), (Harmon, 2017), (Abdul-Malak et al., 2002), (Hashem M. Mehany & Grigg, 2014)
6	Difficulty in quantification of indirect costs	Cost	(Iyer & Manan Bindal, 2019), (Levin, 2013), (Davis & Ibbs, 2016), (Davis & Ibbs, 2016), (Harmon, 2017), (Hashem M. Mehany & Grigg, 2014), (Ibbs & Stynchcomb, 2016),
7	Burden of Proof to support a claim (complexity of determining cause and effect)	Cost	(Moayeri, Moselhi, & Zhu, 2016), (Ibbs et al., 2011), (Hadikusumo & Tobgay, 2015), (Levin, 2013), (Williams, Ackermann, & Eden, 2003), (Harmon, 2017), (Fawzy, El-Adaway, & Asce, 2013),
8	Lack of Accuracy in estimation of Loss of Productivity	Cost	(Enshassi et al., 2009), (Davis & Ibbs, 2016), (Harmon, 2017), (Zhao & Dungan, 2018),

9	Exaggerated claims made by contractors	Cost	(Palaneeswaran & Kumaraswamy, 2008), (Ali D. Haidar, 2011), (Ali et al., 2018)
10	Absence of standard formula for evaluation and calculation of damages	Cost	(Bakhary et al., 2015), (Ali, 2018)
11	High cost associated with retrieving required information	Cost	(Bakhary et al., 2015), (Ali, 2018)
12	Adequacy of Information in documents	Documentation	(Vidogah & Ndekugri, 1998b), (Enshassi et al., 2009),
13	poor Maintenance of Overhead Records (site and head office)	Documentation	(Iyer & Manan Bindal, 2019), (Hashem M. Mehany & Grigg, 2014), ((Chester & Hendrickson, 2005), (Ibbs & Stynchcomb, 2016)
14	No Computerized documentation system	Documentation	(Bakhary, Adnan, & Ibrahim, 2015), (Enshassi et al., 2009)
15	Unstructured Documents	Presentation	(Shahhosseini & Hajarolasvadi, 2018), (Vidogah & Ndekugri, 1998a), ((Harrington, McSwain, Snyder, & Giles, 2016),

16	complexity of information in contract	Presentation	(Chovichien & Tochaiwat, 2015), (Chester & Hendrickson, 2005),
17	Poor Presentation of Claim	Presentation	(Ali, 2018), (D.-J. Gibbs, Lord, Emmitt, & Ruikar, 2017), (D.-J. Gibbs et al., 2013), (Allen, 2016)
18	No standard format	Presentation	(Bakhary et al., 2015), (Chovichien & Tochaiwat, 2015), ((Enshassi et al., 2009), (Hassanein & El Nemr, 2008)
19	No Comprehensive method for Claim Management	Procedure	(Shahhosseini & Hajarolasvadi, 2018), (Vidogah & Ndekugri, 1998a), (Hashem M. Mehany & Grigg, 2015)
20	time taking process due to complex procedure	Procedure	(Bakhary et al., 2015), (Chovichien & Tochaiwat, 2015), (Vidogah & Ndekugri, 1998b), (Yoke-Lian, Hassim, Muniandy, & Mee-Ling, 2012)
21	Use of unsuitable Techniques for claim analysis	Procedure	(Palaneeswaran & Kumaraswamy, 2008), (Ali et al., 2018)

22	Time shortage of claim preparation and analysis	Procedure	(Bakhary et al., 2015), (Ali, 2018)
23	Too Many Documents for Claims preparation and assessment	Procedure	(Bakhary et al., 2015), (D.-J. Gibbs et al., 2013)
24	on-site inaccessibility of Supporting Document	Resources	(D.-J. Gibbs, Emmitt, Ruikar, & Lord, 2013), (Abdul-Malak et al., 2002), (Hashem M. Mehany & Grigg, 2014),
25	Delay in notice to claim by contractor	Resources	(Mcmanus & Starr, 2016), (Song, 2015), (Hadikusumo & Tobgay, 2015), (Hashem M. Mehany & Grigg, 2015), (CHO., Leite, Behzadan, & Wang, 2019)
26	poor Maintenance of Claim Records	Resources	(Song, 2015), (Valavanoglou et al., 2017), (Ness & Carper, 2010), (Abdul-Malak et al., 2002), (Hashem M. Mehany & Grigg, 2015), (CHO. et al., 2019), (Davis & Ibbs, 2016),
27	Ambiguities in responsibilities of construction team	Resources	(Bakhary et al., 2015), (Enshassi et al., 2009),

28	Insufficient skilled personnel for claim management	Resources	(Bakhary et al., 2015), (Chovichien & Tochaiwat, 2015), (Enshassi et al., 2009), (Pujiwidodo, 2016),
29	Less dependency on new software-based systems	Technology	(Ali, 2018)
30	Overdue in Retrieving Information	Time	(Shahhosseini & Hajarolasvadi, 2018), (Vidogah & Ndekugri, 1998b), (D.-J. Gibbs et al., 2013)

2.9 BIM CONCEPTS & BENEFITS

Building Information Modeling (BIM) is a process of modeling, sharing, and managing digital information during the designing, construction, and post-construction phases (Ali et al., 2018; Ghaffarianhoseini et al., 2017; Volk, et al., 2014).Figure 2-2 shows that the information can be of parametric geometrical, technical and contractual type (Ali et al., 2018; Ghaffarianhoseini et al., 2017). BIM is a process that starts from conceptual diagrams to the n-dimensional digital footprint (Azhar, 2013). This information separates themselves from individual processes in traditional construction to an integrated process and thus dividing BIM into separate levels (Cerovsek, 2011; Hooper & Widén, 2015) (see Figure 2-3).

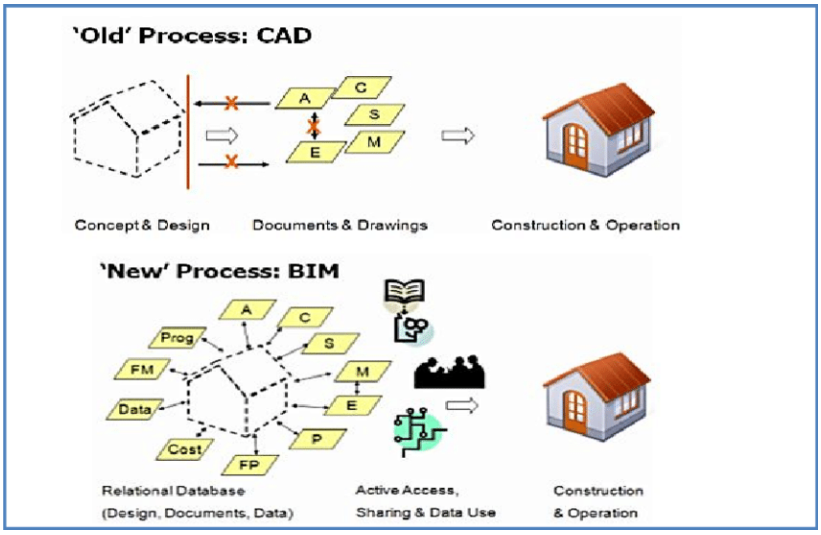


Figure 2-2 BIM process vs Conventional CAD Process

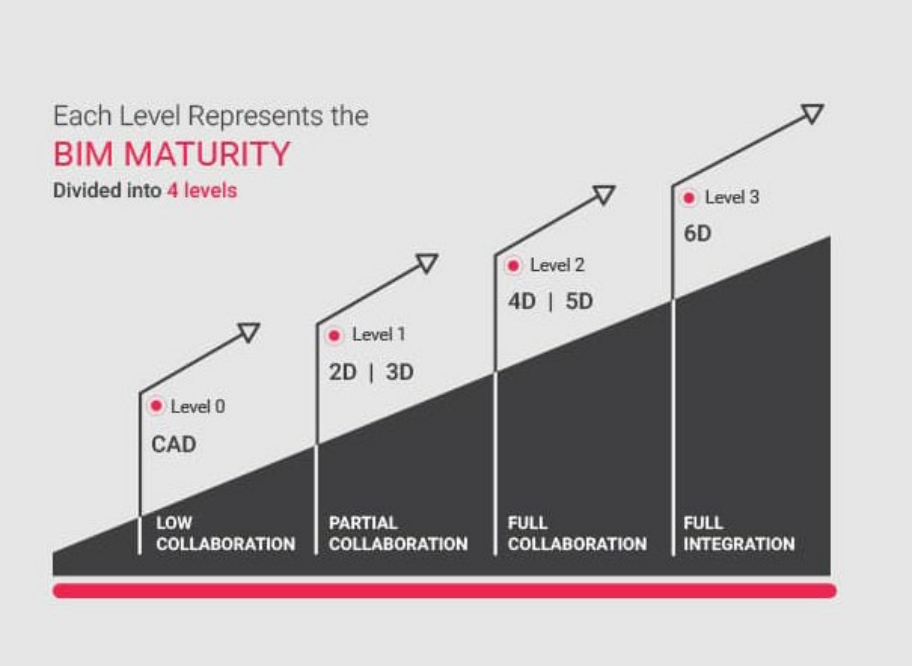


Figure 2-3 BIM Maturity Level

In the Architectural, Engineering, and construction (AEC) industry, these dimensions provide significant benefits to users (Cerovsek, 2011; Ghaffarianhoseini et al., 2017; Volk et al., 2014). 1st and foremost, differences are realized using its parametric 3D information (Ali et al., 2018; Ghaffarianhoseini et al., 2017). Using this 3D information, BIM can be used for 4D, which is time and is mostly used in schedule simulation (Ali et al., 2018; Volk et al., 2014). This 3D model provides the basis for checking up on cost diagrams during and after construction

(Ghaffarianhoseini et al., 2017), lighting analysis, and facility management (Volk et al., 2014) , see Figure 2-4.

Figure 2-4 BIM dimensions

BIM separates itself from current construction by allowing the main parties to a contract as early in the process and thus enhancing the collaboration between them (Cerovsek, 2011). Project team will be communicating to the related stakeholders in the form of groups. Every team will deal with its responsibilities in a collaborative environment (Figure 2-5) where there is the least confusion about information sharing. Contractors and suppliers are added to the stakeholders' group early in the process (Azhar, 2013; Construction Industry Council, 2018; Moayeri et al., 2016) to avoid and resolve problems efficiently (D.-J. Gibbs et al., 2017). NEC contracts offer guidance regarding integrating BIM into NEC contracts so that all the parties know their responsibilities (NEC, 2013).

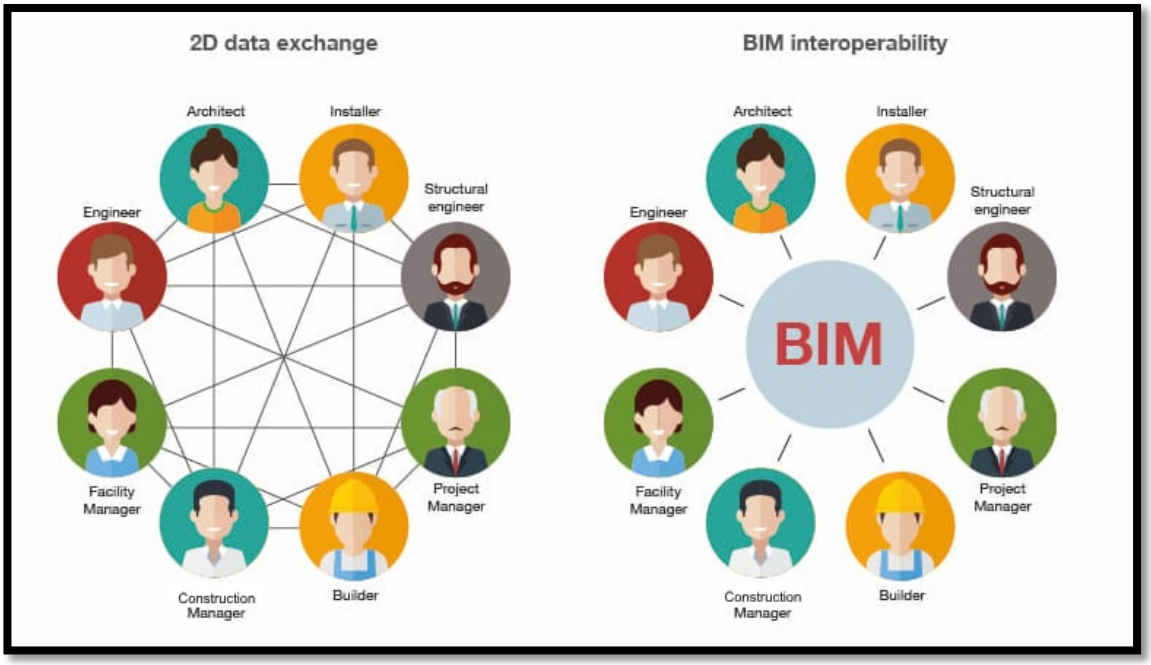


Figure 2-5 Conventianal Vs BIM collaboration

2.10 BIM PLATFORMS

Conventional Computer Aided Drawings (CAD) consists of text and lines only. It cannot communicate with all the stakeholders simultaneously in a complex project (Chou & Yang, 2017; Moayeri et al., 2016). That's when BIM is realized as a necessity of the future (Ali et al., 2018; Azhar, 2013). Building information modeling is of two types, naming "open BIM" and "closed source BIM." Close BIM means all the project work must be done using one tool, whereas open BIM means the information sharing between teams is done through many tools(Hudson et al., 2017). BIM uses interoperable data sharing, allowing it the flexibility to not rely on a singular software (Ghaffarianhoseini et al., 2017). All the teams work simultaneously using more than one but interoperable software (Ali, 2018; Volk et al., 2014).

As a result of its take on complex projects, BIM is now used as an emerging mechanism for construction (Ali et al., 2018). Most of the platforms being used for BIM are Autodesk Revit, Tekla Structure, Graphisoft ArchiCAD, Bentley Architecture, Nemetschek Vectorworks, Nemetschek AllPlan, Trimble SketchUp, Gehry Technology Digital Projects, 4MSA IDEA Architectural, and Rhino BIM (Ali et al., 2018).

2.11 API

Most BIM tools use application Programming Interface (API) for their extended utilities (Olugbenga O Akinade et al., 2016; Ali et al., 2018). These APIs provide the means of providing functions absent from BIM software (Ali et al., 2018). APIs are used to develop Add-ins or plugins that utilize the existing BIM software's modeling and visualization capabilities to accomplish specialized tasks(Olugbenga Olawale Akinade, 2017). Developers are provided with the ability to customize the application by leveraging on the functionality of existing BIM platforms through these APIs that serve as building blocks for different types of latest software applications(Olugbenga O Akinade et al., 2016).

2.12 REVIT API

Many of the BIM projects are handled using Autodesk Revit. (Ali et al., 2018; Shahhosseini & Hajarolasvadi, 2018). It covers major areas like Architecture, structure, and MEP as "built-in features" (Volk et al., 2014). Its user-friendly user interface helps its adoption and widespread usability in the construction industry (Ali et al., 2018; Eoition, To, & Information, n.d.). Another reason for its adoption is that Revit is compatible with other BIM tools like Navisworks, Infraworks, 3Ds Max, AutoCAD, AutoCAD Civil, ArchiCAD, Google Sketchup for further analyses like lighting, structure, and sustainability(Ali et al., 2018). It can use formats like DWG, DXF, IFC, SKP, and gbXML, which are interoperable with most other BIM tools (Ali et al., 2018). Revit API provides a highly customizable .NET software development toolkit (SDK) for user interface, which is why it is being used as a third-party tool (Ali et al., 2018).

Some of the famous plugins currently being used are BIMobject, used to find the model library for a project. Enscape is being used as a Revit Render plugin for better quality renderings. CADtoEarth is being used for the integration of Google Maps with Revit. Ideate BIM Link is another plugin to import-export anything from Revit in the form of excel data.

Dynamo is another plugin being used for Revit to make complex 3D models. IFC 2015 is used to improve the export/import capabilities. Some researchers also developed Revit plugins to enhance the functionalities of Revit API (Ali, 2018). A

plugin was developed by (Moayeri et al., 2016) to calculate the extra time required whenever there is a change in design. (Ali, 2018) developed a Revit plugin for EOT claims management in BIM Environment Researches, like mentioned above, indicate the abilities of API to develop BIM-based cost claims.

2.13 ROLE OF BIM IN COST CLAIMS MANAGEMENT

Since claims management is a time-consuming process, it is costly yet prone to errors (Shahhosseini & Hajarolasvadi, 2018; Shen et al., 2017). Most of the data is missing, which leads to real-time loss or profit of the claims. Also, it is not easy to visualize what caused the claims in the first place (Ibbs et al., 2011; Moayeri et al., 2016). As BIM is making its progress in the construction industry due to its acceptability to many of the platforms and thus helping to find the solutions, it is more likely to adopt BIM in electronic construction tools in the future (D. Gibbs et al., 2014). If BIM is utilized from the conception phase of a project, all the data, either geometrical or numerical, will be helpful in visualization, identification, and quantification of claims (Ali, 2018; D. Gibbs et al., 2014). The visualization aspect of BIM in claims can be used for disputes and adjudication (Vidogah & Ndekugri, 1998b). key animations based on the construction progress can be used in courts (Ali et al., 2018; D. Gibbs et al., 2014). In the past, courts have made judgments based on Eichleay Formula, Hudson formula, and many more; we are in a position to say that BIM can also play a key role to resolve claims related issues in the future (Ali D. Haidar, 2011; Ghaffarianhoseini et al., 2017; D. Gibbs et al., 2014).

Chapter 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter discusses in detail the research strategy carried out to achieve research objectives. Different techniques need to be applied to achieve the research objectives. These techniques include reviewing inefficiencies in previous studies carried out by other researchers to achieve their goal in claims management.
After review, a prototype will be developed for construction cost claims using Autodesk Revit API, and then the evaluation of the prototype will be carried out by field experts.

3.2 RESEARCH DESIGN

Figure 3-1 shows the research design for this study. A systematic review of literature studies was carried out to identify the inefficiencies in the management of cost claims, which was our first objective of the study. Those inefficiencies were discussed in detail in the previous chapter. Those inefficiencies were then verified from construction industry. The results are discussed ahead in this chapter.

In the second stage, standard construction contracts were studied to make bases for a conceptual framework. BIM-related studies were also made to know the benefits of BIM to assist claims management (Babar, Thaheem, & Ayub, 2017). Making of the conceptual framework was our second objective. This conceptual framework elaborates the workflow of data in the prototype built. The workflow will be discussed later in the chapter. The prototype was built using coding BIM platforms like Dynamo, Revit and other tools like Primavera, SQL and Python etc to make integrated BIM-CCMS. Experts reviews were collected carefully in the last stage and evaluated the BIM-CCMS to check its effectiveness.

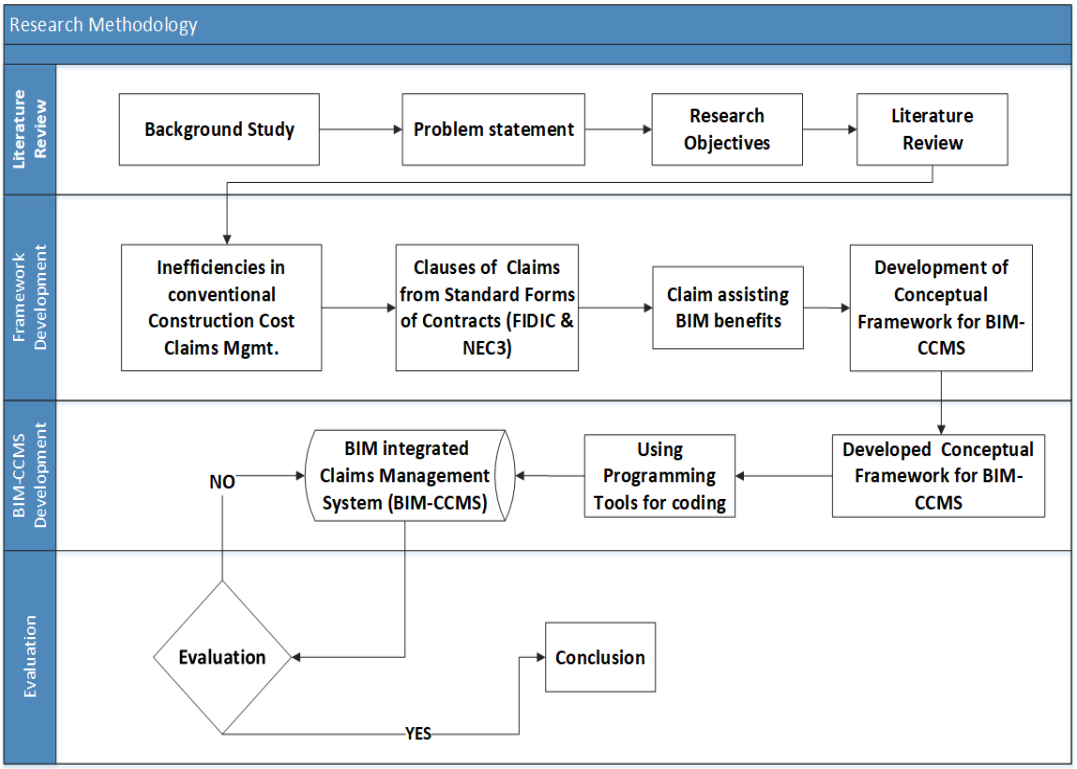


Figure 3-1 Researrch Design

3.3 VERIFICATION OF ISSUES IN COST CLAIMS IN CONSTRUCTION INDUSTRY

Following a literature review, a questionnaire was developed, and responses were collected to identify the same issues in the industry. Data were collected from 35 respondents, out of which four responses were rejected because their experience was less than five years. Experts from the field included all nature of contract parties, including clients, contractors, design consultants, and sub-contractors. The field experts have a vast knowledge of construction and are specifically related to claims. Many of the experts are working in contracts departments in their representative organizations. Their experience and organizations' nature are shown in Figure 3-2 & Figure 3-3, respectively. The outcome of the questionnaire-based preliminary survey will be discussed in the next chapter. Field Experts were also asked if there were any additional inefficiencies, they were no additional inefficiencies founded due to their merging nature with existing inefficiencies. After finding out the field score, a 50-

50 ratio with the literature score was calculated to avoid any biasness. The final inefficiencies are then presented in Table 3-1.

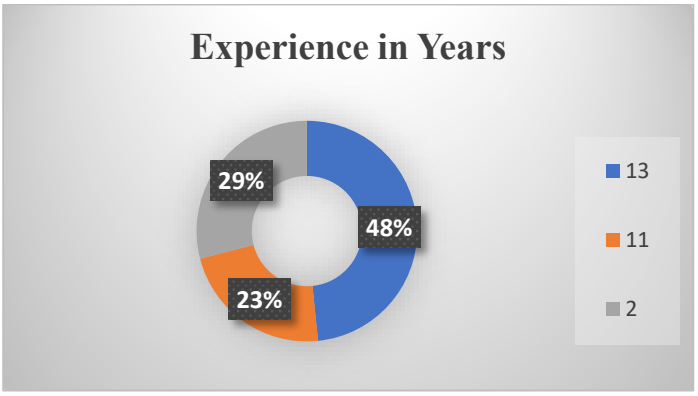


Figure 3-2 Respondent's Experience

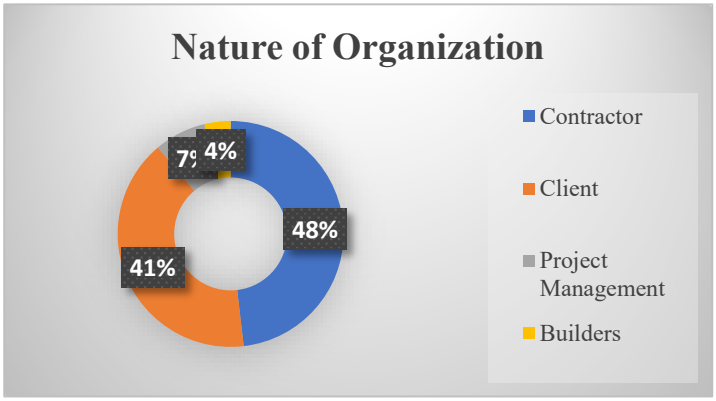


Figure 3-3 Type of Organization

Table 3-1 Finalized Inefficiencies

Sr. No.	Inefficiencies	Group	Field Score	Literature Score	50-50 Analysis
1	Lack of Contract awareness	Contract	0.78065	0.26829	0.04251
2	Lack of Clear information in Contracts		0.68387	0.0439	0.0295

3	Legibility of claims in verbal and technical terms		0.74194	0.05854	0.03244
4	Not updating the schedules	Coordination	0.72258	0.02927	0.03047
5	Coordination gap between Site and office staff		0.8	0.02927	0.03361
6	Difference in quantification of damages calculated by different parties	Cost	0.76774	0.04878	0.03309
7	Difficulty in Quantification of indirect costs		0.75484	0.10244	0.03475
8	Burden of Proof to support a claim, e.g., complexity of determining cause and effect		0.76129	0.16098	0.03738
9	Lack of Accuracy in Estimation of Loss of Productivity		0.7871	0.05854	0.03427

10	Exaggerated claims made by contractors		0.72258	0.01463	0.02988
11	Absence of use of standard formula for evaluation and calculation of damages		0.78065	0.02927	0.03283
12	High cost associated with retrieving required information		0.65161	0.07317	0.02938
13	Lack of adequate Information in drawings	Documentation	0.69677	0.19512	0.03615
14	Poor Maintenance of Overhead Records (site and Head Office)		0.78065	0.14634	0.03757
15	No computerized documentation system		0.76129	0.05854	0.03323
16	Unstructured Documents	Presentation	0.69677	0.07317	0.03121

17	Poor Presentation of Claims		0.8	0.0439	0.0342
18	No standard Format		0.7871	0.07317	0.03487
19	No Comprehensive method for Claim Management	Procedure	0.76129	0.09756	0.03481
20	Time taking process due to complex procedures		0.78065	0.0439	0.03342
21	Use of unsuitable techniques for claim analysis		0.69677	0.00488	0.02844
22	Insufficient time for claim preparation and analysis		0.69032	0.02927	0.02916
23	Too Many Documents for Claims preparation and assessment		0.71613	0.02927	0.03021

24	On-site Inaccessibility to Relevant Document when needed	Resources	0.73548	0.14634	0.03574
25	Delay in notice to claim by Contractor		0.7871	0.12195	0.03684
26	Poor Maintenance of Claim Records		0.76774	0.21951	0.0342
27	Ambiguities in responsibilities of construction team		0.73548	0.00976	0.0302
28	insufficient skilled personnel for claim management		0.76774	0.01463	0.03171
29	Less dependency on new software-based systems	Technology	0.75484	0.00488	0.03079
30	Overdue in retrieving Information	Time	0.72903	0.0439	0.03133

3.4 PROTOTYPE DEVELOPMENT

In this phase, a prototype will be created to solve the issues identified in the first phase. Initially, applicable standard contracts worldwide were studied to draw out the events and clauses for cost claims. Contract Provisions for the cost under traditional standard contracts were reviewed. The contracts studied were those published by International Federation of Consulting Engineers (FIDIC) 1987 4thedition (FIDIC 1987), FIDIC 1999 1stedition (FIDIC 1999 Red Book, Silver Book), FIDIC 2017 2nd edition (Red Book, Silver Book, Yellow Book), New Engineering Contract (NEC) 2005 edition. It was done to have a sound knowledge of all permissible compensating events and develop a prototype that can manage all events for cost claim. Also, in this phase of research, Building Information Modeling software API functioning is studied, and a plugin will be developed for BIM Based Claims Management System (B-CMS) for effective management of Cost claims. Most BIM software provides API to extend their functionalities (Olugbenga O Akinade et al., 2016). The workflow used for the development is as follows: Autodesk Revit Architecture 2020 (BIM Software); Dynamo for visual coding, python software for back-end coding for scripts, Primavera P6 for tracking and comparing activities, and Microsoft Excel For Database management. Autodesk Revit Architecture 2020 is used because of its high quality and user-friendly interface and ease of connectivity with the external database. The reason for selecting Autodesk Revit as a BIM platform for plugin development is that it is widely used and provides a rich API platform (Olugbenga Olawale Akinade, 2017).

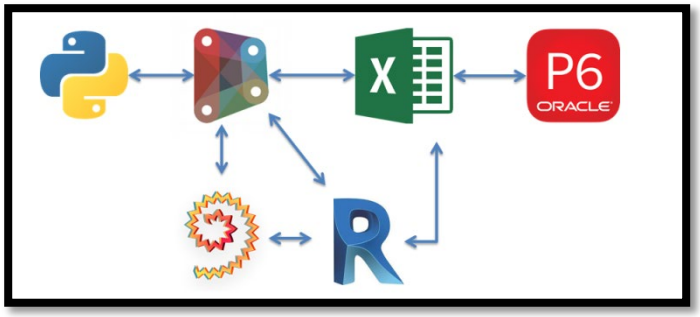


Figure 3-4 Data Work flow

3.5 PROTOTYPE EVALUATION

The system was checked and evaluated through field experts. Filed experts were selected on their working experience and expertise related to Contract, Planning, and Building Information Modeling. Overall, 15 of the Field experts were carefully chosen for this purpose. Some of the experts were selected on their experience bases. Others were approached during the preliminary survey. Among selected experts, five were Planning Experts, 7 were Contract Experts, and 3 were BIM experts. Experts were given the background of the topic and issues identified in the literature. After that, experts were presented with the tool's working to let them decide how well the developed system can handle the identified issue.

A warehouse project in the under-construction stage was selected as a case study. It was targeted due to its ease in demonstrating to small construction enterprises (SCE) professionals (Sebastian, Haak, & Vos, 2009). The BIM model of the selected warehouse is shown in Figure 3-5. Planned vs. Actual schedule was developed in Primavera P6, which is used by planning and field experts. Delays in activities were introduced to calculate their effects on different types of costs within a project. These costs were related to both on-site and home office. Then these costs were presented as a test basis for cost claim generation.

Field experts were then presented with a questionnaire-based interview. The appendix of the Performa is attached as annexure. The questions were based on issues identified during the preliminary survey. The expert asked Questions during and after the presentation. Answers were given at the time and tried to explain through a developed system. Experts were asked beforehand for their permission to record the interview. They were also asked regarding the usefulness, barriers in system implementation, and need for improvement (Ali, 2018). Respondents provided their opinions in the form of a Likert scale (Likert scale represents: 1= Strongly Disagree; 2=Disagree; 3= Neutral; 4=Agree; 5= Strongly Disagree) (Ali et al., 2018). The relative importance index (RII) value was also calculated from Equation 7 to rank the inefficiencies and the usefulness of the system to handle those inefficiencies(Babar et al., 2017).

$$RII = \frac{\sum W}{A \; x \; N} \qquad (0 \leq \text{RII} \leq 1)$$

Equation 7 for Relative Importance Index

Where W = weight given to each factor by the respondents; A =highest weight, i.e., 5 in this case; and N = the total number of respondents. N=30 for this specific case.

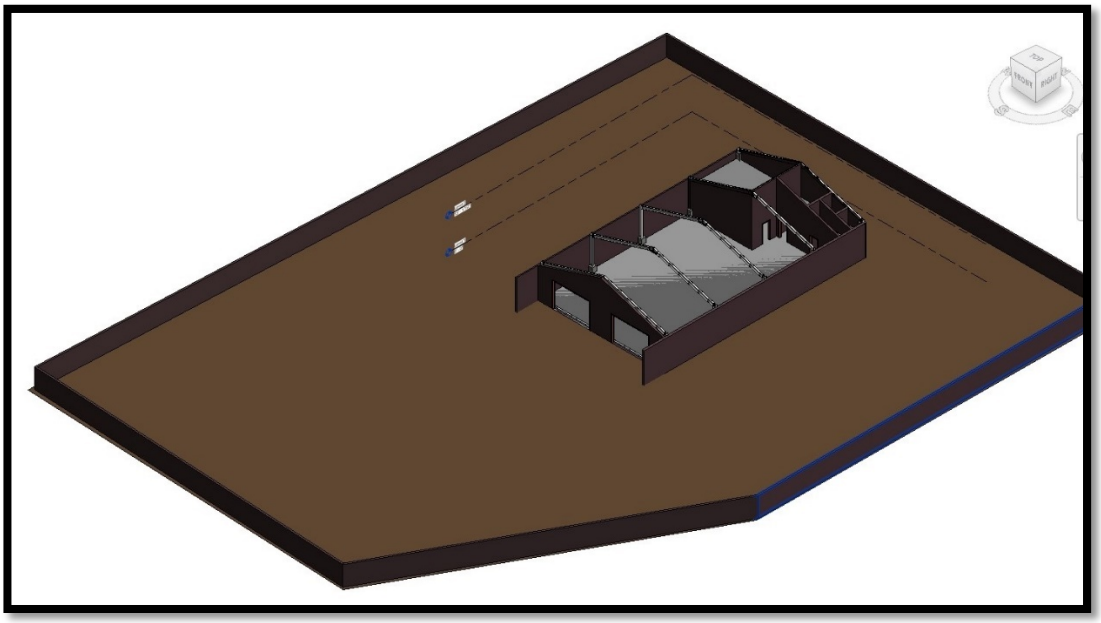


Figure 3-5

Chapter 4

RESULTS AND DISCUSSIONS

4.1 PREAMBLE

This chapter describes the details of the conceptual framework to provide the basis for a digital platform-based plugin. Then it elaborates on the architecture of the BIM-based knowledge management system for construction cost claim (BIM-CCMS) and its evaluation from filed experts.

4.2 BIM-CCMS FRAMEWORK

Figure 4-1 shows a cross-functional conceptual framework for the development of the prototype. It indicates that our BIM MODEL needs to be launched in BIM Platform, i-e, Revit in this case. After that, BIM-CCMS will need to import the schedule and check any delays in activities. The delayed activities will be further treated based on their delayed period and contractual liability. Resources assigned and their respective costs will be sorted and calculated. The prototype will also see any changes to designing, then visualize and quantify the variations. The prototype will also be enabled to calculate site overheads and Home office overheads with the help of additional supporting documents like photos and PDFs. The system will be able to enlist the details of all the costs and their summary also for printing purposes.

4.3 SIGNIFICANCE OF DYNAMO

The use of the Dynamo plugin for visual coding plays a pivotal role in front-end scripting for developing prototype architecture. Due to its wide variety of nodes and acceptance of script-making packages, it enhances its potential in both Open-BIM & Closed-BIM platforms. Dynamo has a very dynamic compatibility range with Revit, Python, and Excel regarding data inputs and outputs. Users need to input the data through Revit or Microsoft Excel. That data will be stored in a database. The data flow or script flow in dynamo starts from the left side; all the nodes and strings push the logic of scripts from the left side and end on the right side. Dyno browser

has been used to read the script from Dynamo atmosphere to make buttons and respective panels in the Revit Interface. The script behind every button runs in the Dynamo atmosphere. Short descriptions of these scripts will be mentioned below.

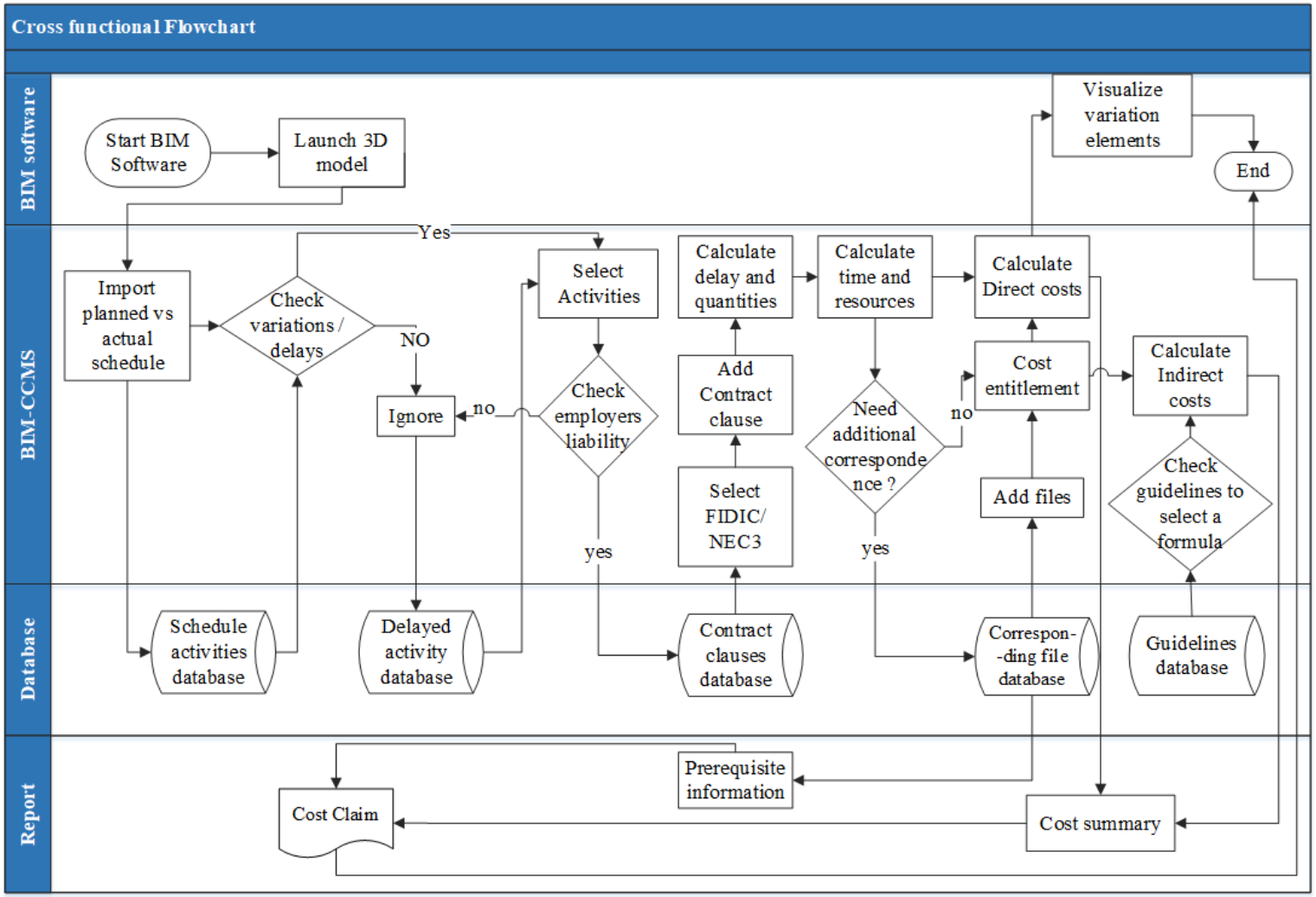


Figure 4-1 Conceptual Framework for BIM-CCMS

4.3.1 Import Schedule Script:

Figure 4-2 shows visual coding and required information flow to import a "Baseline vs. Actual" Schedule in Microsoft Excel or CSV format. The script shows that the user needs to locate the file to be open and stored in the database for further processing. This script needs a button to run and show the results discussed in the Architecture description of the prototype.

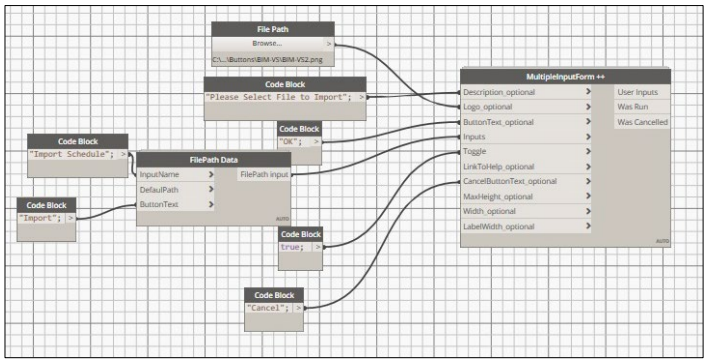


Figure 4-2 Script for Importing Schedule

4.3.2 Delay Calulations

This script will extract the necessary information to calculate and show delays in activities. It will also show other details like activity names, ID and duration, etc., in a tabular format. That table is discussed later in this chapter. The script developed in Dynamo has been shown in Figure 4-3 below.

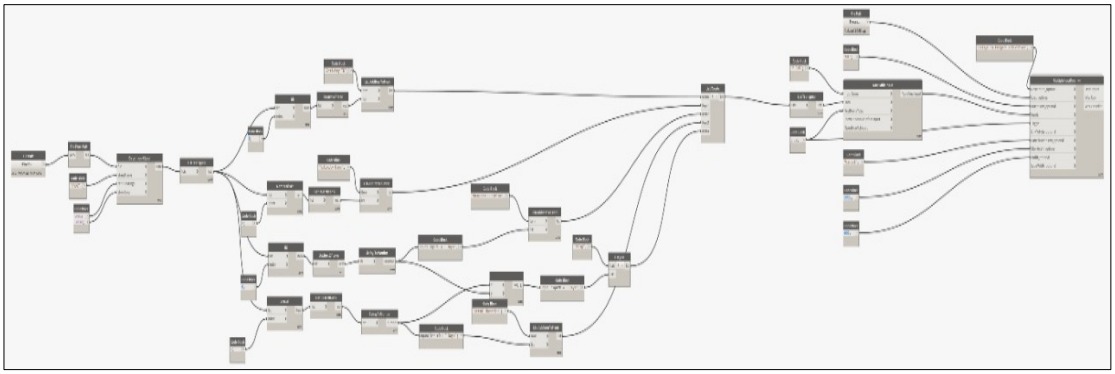


Figure 4-3 Script for Delay Calculations

4.3.3 Baseline and Actual Model

These two scripts are interrelated. One of the scripts is used to set all the geometric information stored in the database as a baseline model. The BIM model

of a project can be set as a baseline model at any stage. The script developed in dynamo for this purpose is shown in Figure 4-4. Once the baseline information is stored and the contractor makes some changes to the BIM model, these changes will act as variations. Figure 4-5 shows the script developed for this purpose. Results of buttons developed based on these scripts are discussed later in this chapter.

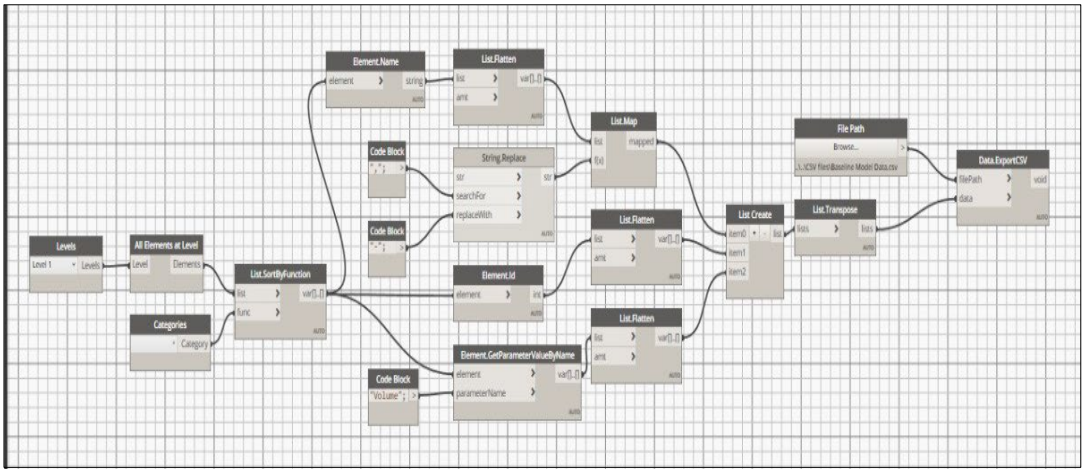


Figure 4-4 Script for Setting Baseline Model

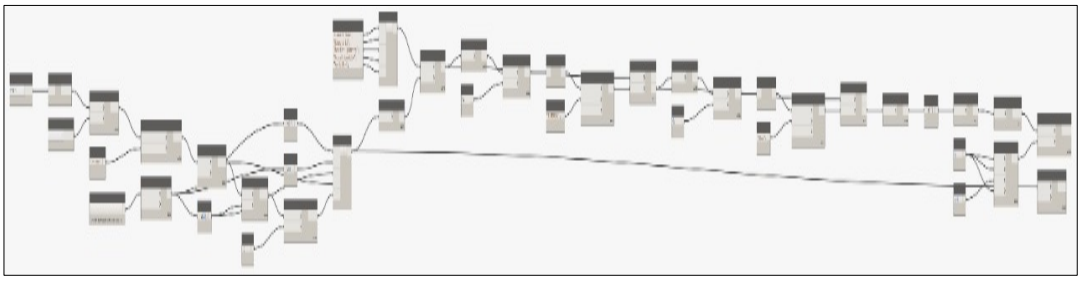


Figure 4-5 Script for Actual Model Variations

4.3.4 Check Liability

This script provides information for buttons in both the Contract Panel and the Cost Panel. This developed script contains a huge number of nodes and strings to flow the information and make logic. This script includes logic developed in Python for decision making and filtering information for further processing of cost calculations. All the necessary information about contracts and their cost claims-related clauses are scripted here to make logic. The development of this script is shown Figure 4-6 and Figure 4-7. Buttons based on this script are discussed later in this chapter.

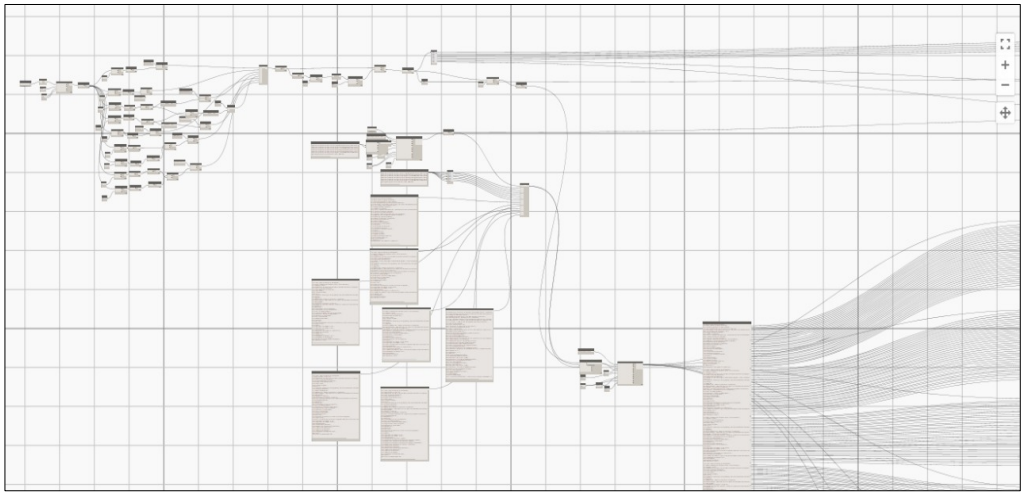


Figure 4-6 Script for Selection of Clauses

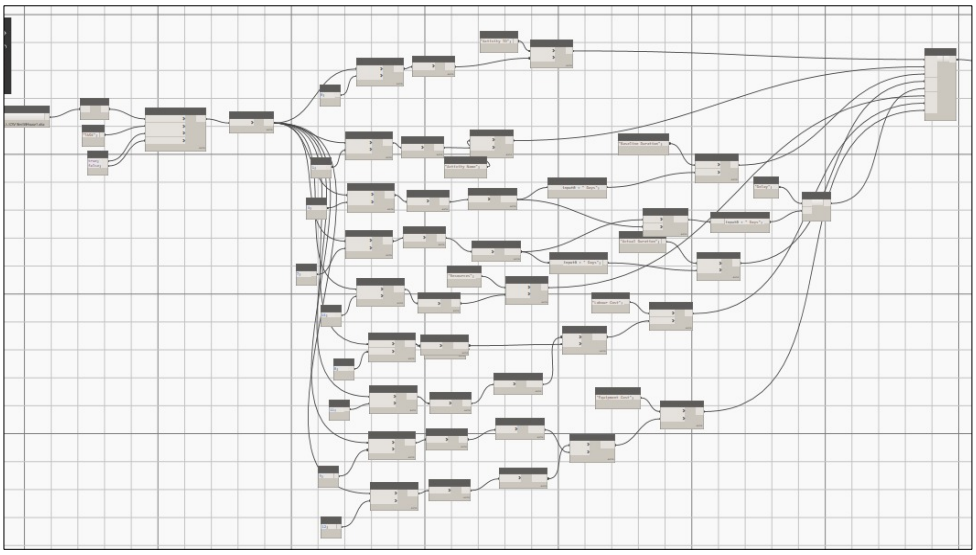


Figure 4-7 Script for Checking Liability

4.3.5 Direct Cost of Varied Material

This script developed in Dynamo uses information extracted from actual model variations. The cost parameter of every type of element is being used to calculate the cost of varied materials. This script shows the results in tabular format, which will be discussed later in this chapter. Figure 4-8 shows the developed script in Dynamo for this purpose.

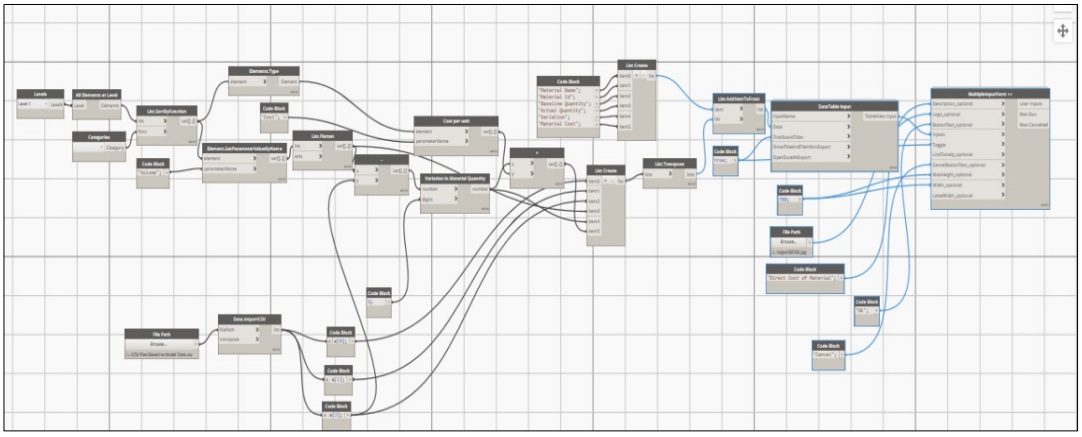


Figure 4-8 Script for Direct material cost

4.3.6 Man & Machinery Cost

Figure 4-9 shows the script developed in Dynamo to achieve resources cost for delayed activities. This script also uses the liability decision made by the previous script for checking liability, to assign entitlement of compensation for resources and their respective costs. The result of this script is a table which is discussed later.

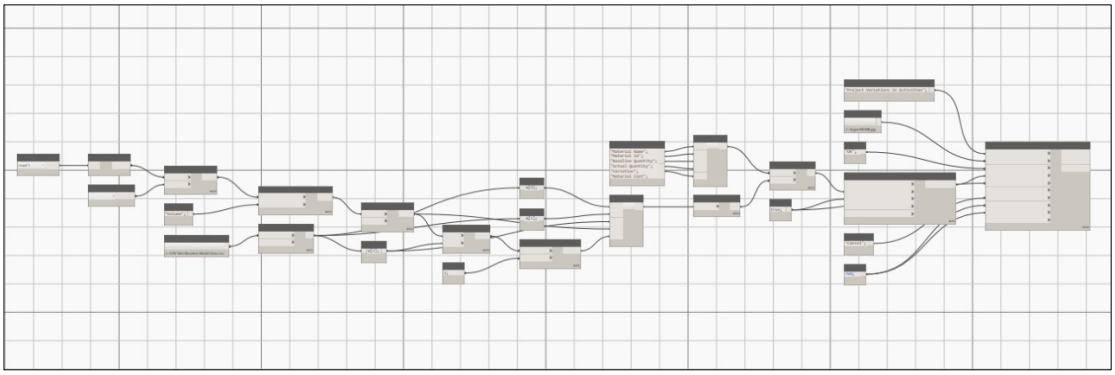


Figure 4-9 Script for Man & machinery cost

4.3.7 Overhead Costs

There are two kinds of overhead costs: home office overheads and site overheads. Scripts have been developed in Dynamo for both types of calculations. For the calculation of HOOHs, the script has three kinds of formulae. Users will be able to select one of the formulae and then entering the required information manually. Site overheads further include site consumable costs and site staff costs. Results of these scripts are shown in tabular format later in this chapter. Figure 4-10

and Figure 4-11 show the Home office overheads (HOOH) and site costs respectively.

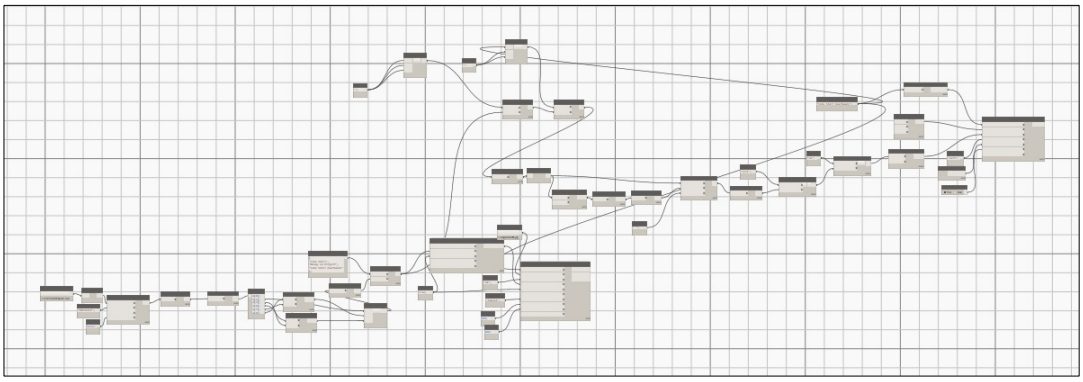


Figure 4-10 Script for HOOHs Cost

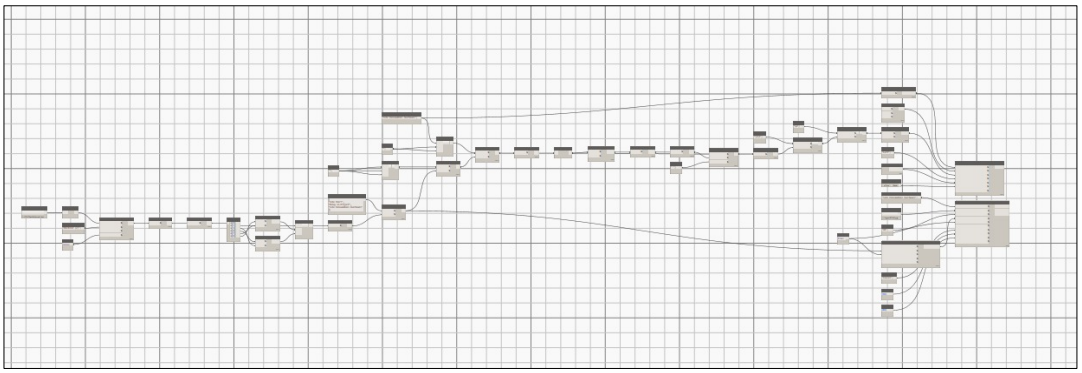


Figure 4-11 Script for Site Overheads

4.3.8 Claim Summary

Script developed in Dynamo for this purpose is shown in Figure 4-12. This script contains the logic to put the required descriptive information manually in their respective sections. Results of the button based on this script will be discussed later in this chapter.

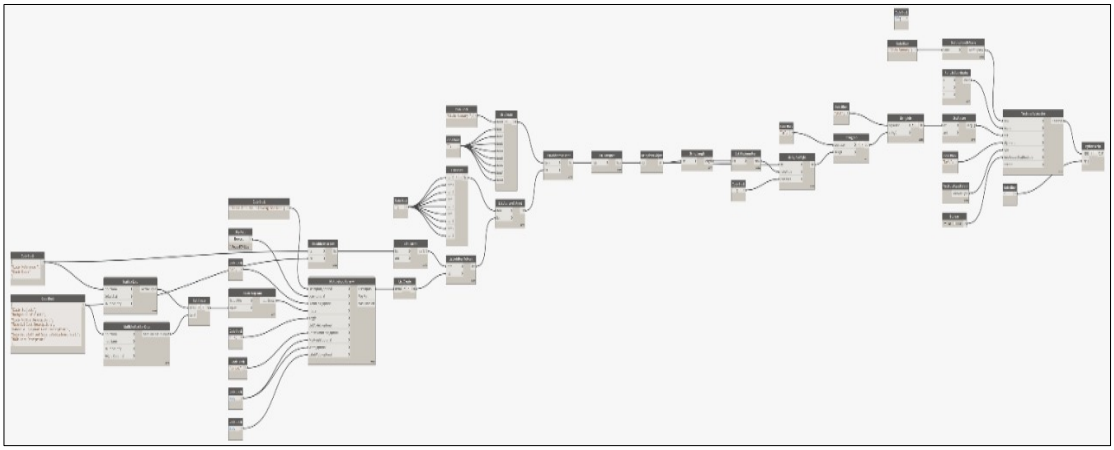


Figure 4-12 Script for Claim Summary

4.4 BIM-CCMS TEMPLATE ARCHITECTURE

This prototype was developed based on recommendations by SCL (2017). Dataflow for this prototype requires visual coding in DYNAMO, a plugin in Autodesk Revit 2020. The data workflow is shown in the previous chapter in Figure 3-4. The developed prototype was introduced in Revit as the "BIM-CCM$" tab as a part of the Revit Ribbon bar as shown in Figure 4-13. It has five main panels named Assessment, Contract, Cost, Visualization, and Summary, respectively.

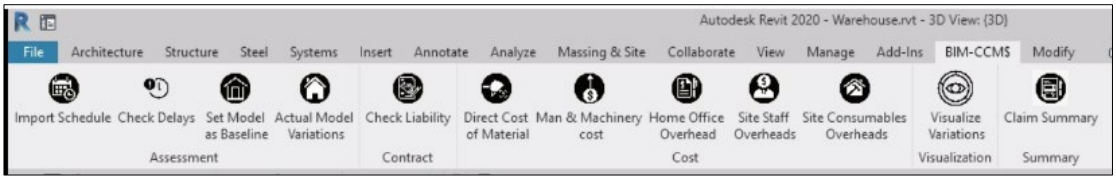


Figure 4-13 BIM-CCMS Protype interface

Each of the panels further contains buttons for their respective tasks. The functions of each button are demonstrated in the following sections.

4.4.1 Assessment Panel

This panel contains Import Schedule, Set Model as Baseline, and Actual Model Variations buttons, respectively. It is shown in Figure 4-13. Their functions are described as followed in the Table 4-1.

Table 4-1 Assessment Panel Buttons and their Functions

Button Name	Icon	Button Function
Import Schedule		This button allows the user to import Baseline vs. Actual Schedule in CSV and .xlsx format. See Figure 4-14.
Check Delays		This button allows the user to view or check Delays in activities. See Figure 4-15.
Set Model as Baseline		Users, through this button, can set the 3D Model as a baseline model at any stage.
Actual Model Variations		This button allows users to view quantities changed in a tabular form. See Figure 4-16.

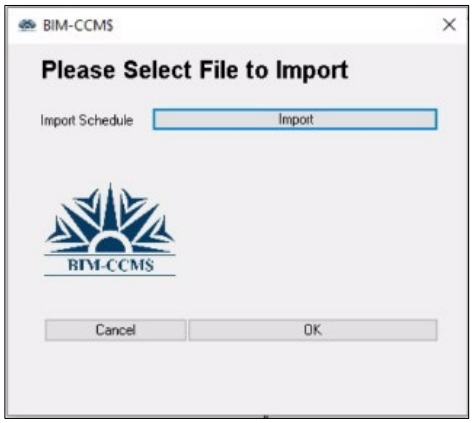


Figure 4-14 Importaing Schedule

User will select the Baseline vs. Actual schedule from the desired folder in the CSV/xlsx format. After importing the Schedule, the user can view delays in

activities and their details in tabular form. The table shows activities' IDs, names, Planned and Actual Durations, and their respective delays. Users can export the table in excel format for further usage.

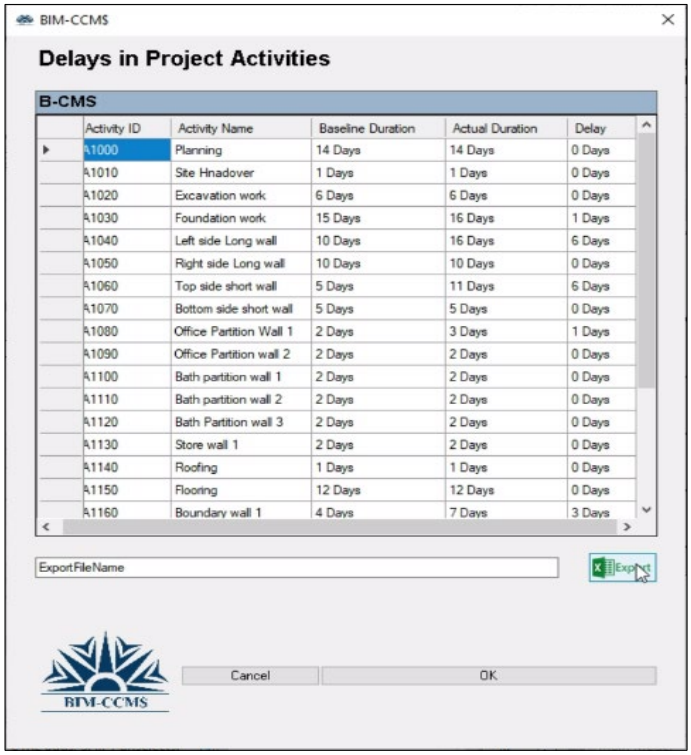


Figure 4-15 Delays in activities

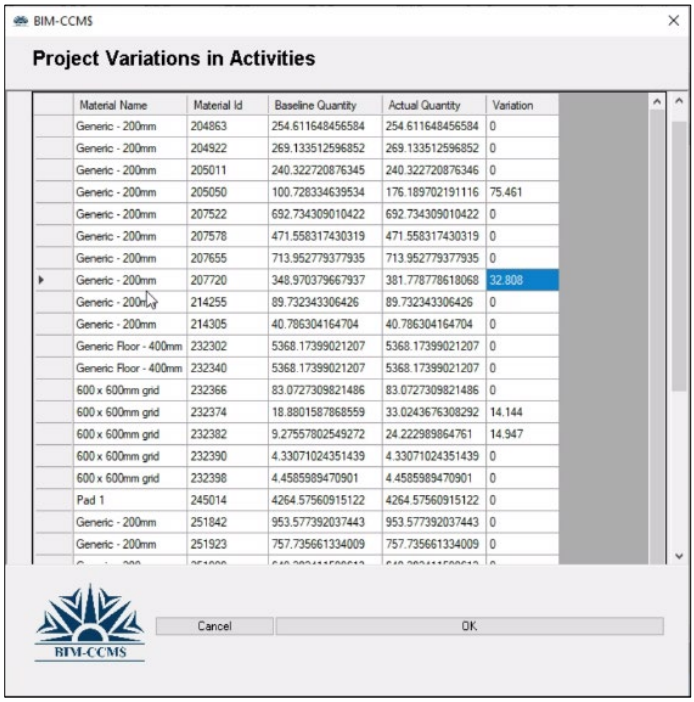


Figure 4-16 Project Varations in Activities

4.4.2 Contract Panel

This panel is shown in Figure 4-13. This Panel includes one button, which is the “check liability” button. This button allows users to select contract types for their projects (Figure 4-17). After selecting the contract type, the user can select contract clauses/sub-clauses from the database for respective delays (Figure 4-18). The database consists of FIDIC 1987, FIDIC RED BOOK 1999, FIDIC SILVER BOOK 1999, FIDIC PINK BOOK 2005 HARMONISED EDITION, FIDIC RED BOOK 2017, FIDI SILVER BOOK 2017 & NEW ENGINEERING CONTRACT NEC3 2005 EDITION. The Clauses/sub-clauses and their liability are attached as an appendix. These delays will get filtered further for liability check (Figure 4-19). The decision of entitlement is derived from the contracts database. The system allows entitlement to only delays which Employer causes. The delays caused by the contractor and concurrent delays are not treated, so they will not be liable to entitlement.

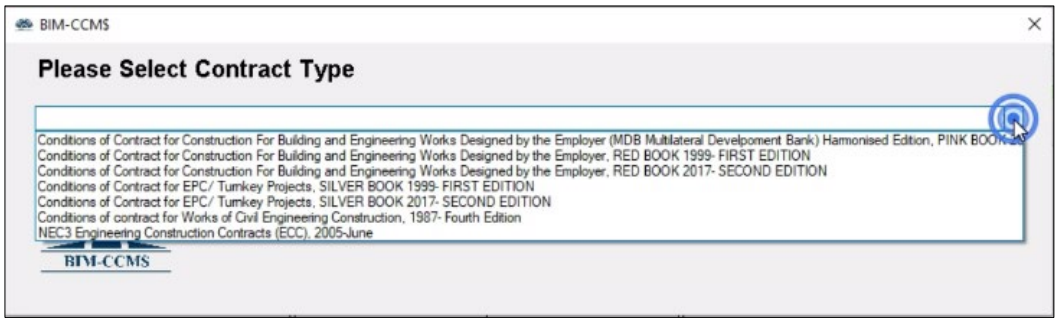


Figure 4-17 Cntract Types

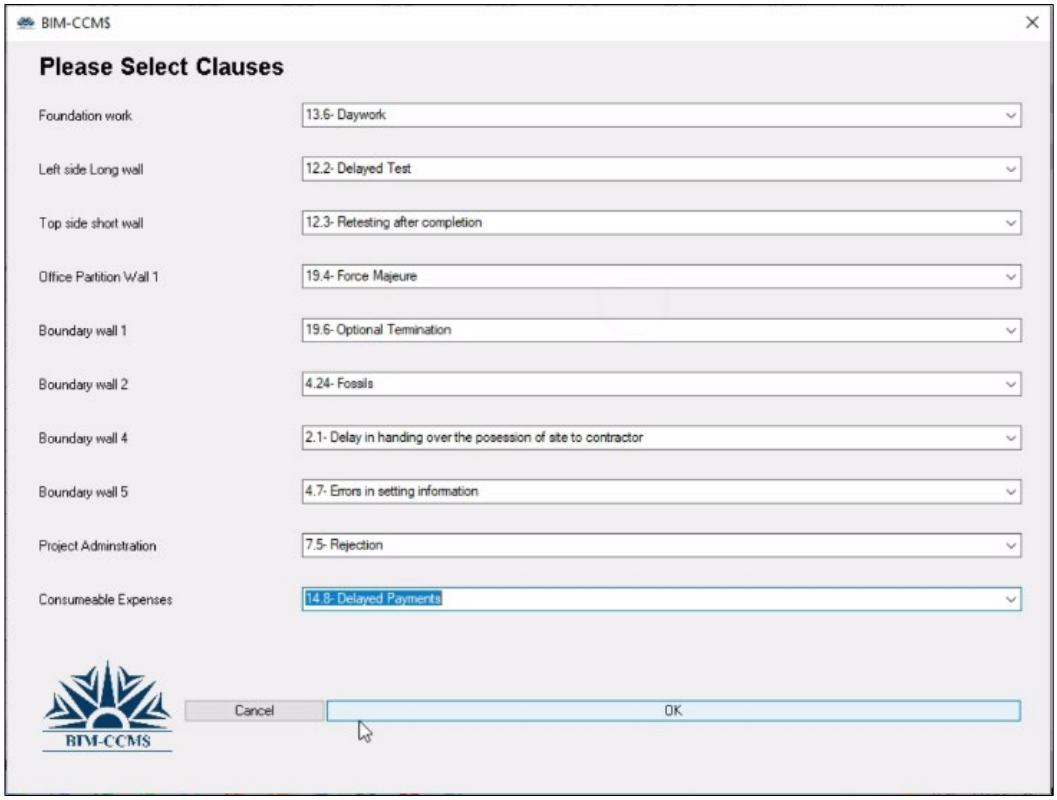


Figure 4-18 Delayed Activities & Contract clauses

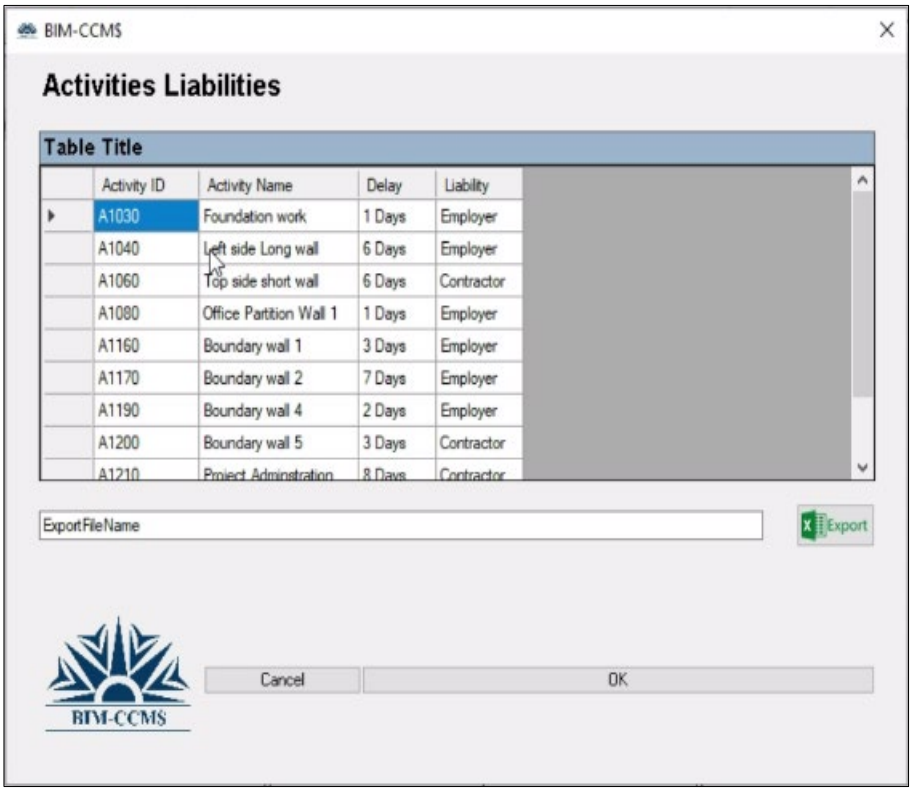


Figure 4-19 Activities Liabilities

4.4.3 Cost Panel

This panel details the costs types related to both activity level and project level. It is shown in Figure 4-13. It has five buttons: Direct Cost of Material, Man & Machinery Cost, Home Office Overheads, Site Staff Overheads, and Consumable Site Overheads. Their functions are described in the Table 4-2.

Table 4-2 Cost Panel Buttons and their Functions

Button Name	Icon	Button Function
Direct Cost of Material		This button helps to see users the details of Material Varied and its cost. See Figure 4-20.
Man & Machinery Cost		This button allows the user to view resources cost in tabular format. See Figure 4-21.
Home Office Overheads Cost		Users can select a formula of their choice to calculate Home office Overhead. See Figure 4-23.
Site Staff Overheads		This button allows users to view cost details of Site staff. See Figure 4-28.
Site Consumable Overheads		This button allows users to view cost details of Site Establishment. See Figure 4-29.

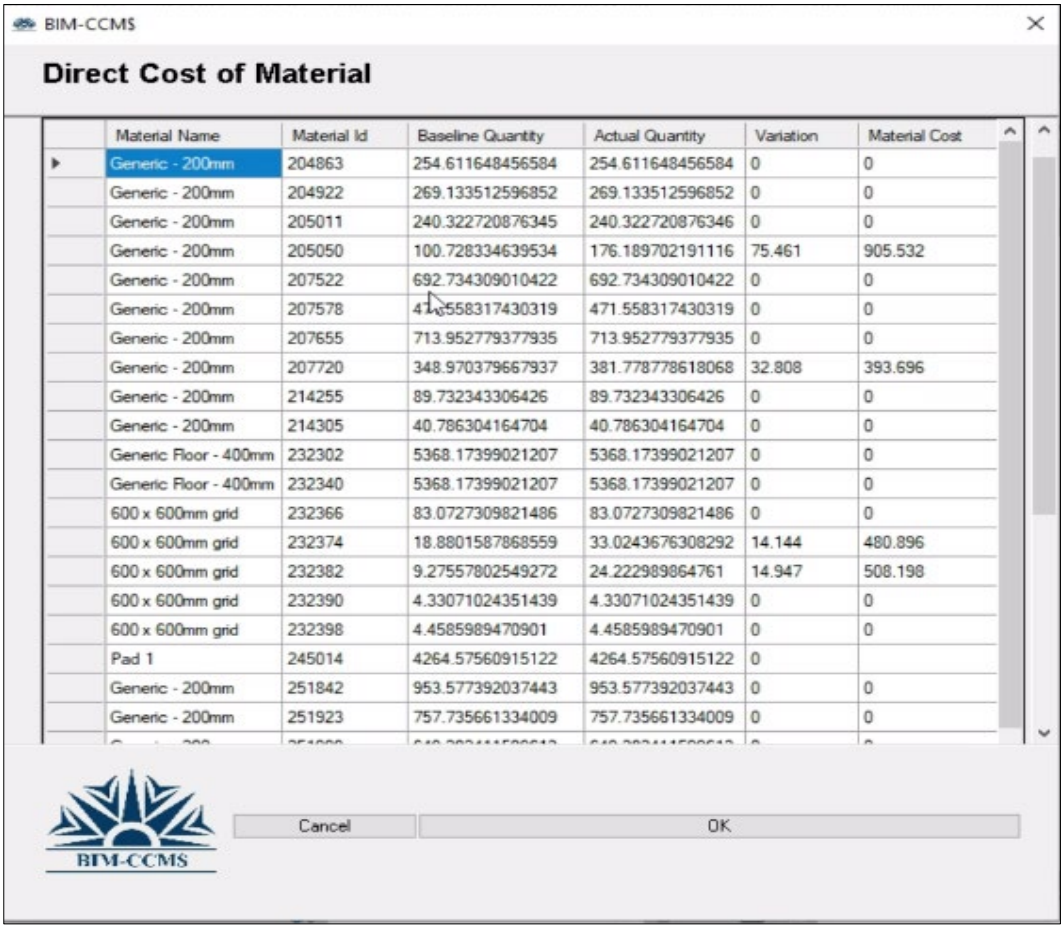


Figure 4-20 Direct cost of material

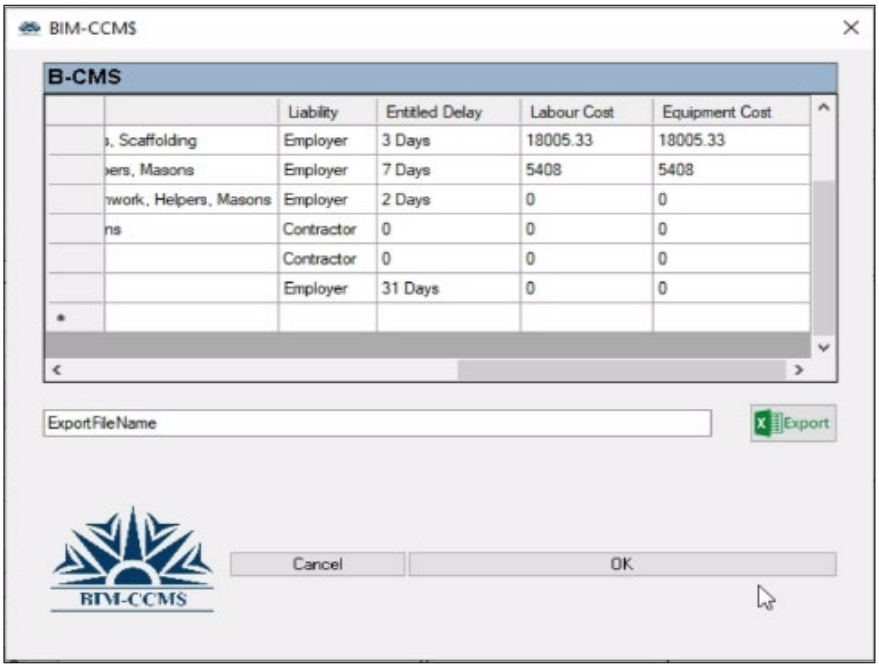


Figure 4-21 Entitled Labour and Equioment cost

Figure 4-20 shows direct costs and variations. Because these costs depend upon activities directly, that's why these costs have activities in their details. SCL protocol recommends three of the mentioned formulae for calculations of Home Office Overheads. As we have discussed the guidelines for selecting Eicheleay's Formula in the Literature Review chapter, some of the guidelines were incorporated into the system. Those guidelines are shown in Figure 4-22. User has to check or uncheck the boxes as per their contract type and nature. If the costs incurring are the reason for a force majeure, then Eicheleay's Formula cannot be used. Since it is unchecked in the selection shown, users can see a list of all three formulae in Figure 4-23. The user has to manually put the details in each box of each formula. The selected formula, in this case, is the Hudson formula, as shown in Figure 4-24. And calculated HOOH by this formula is shown in Figure 4-25. Emden formula and Eichleay Formula are shown in figure Figure 4-26 & Figure 4-27, respectively.

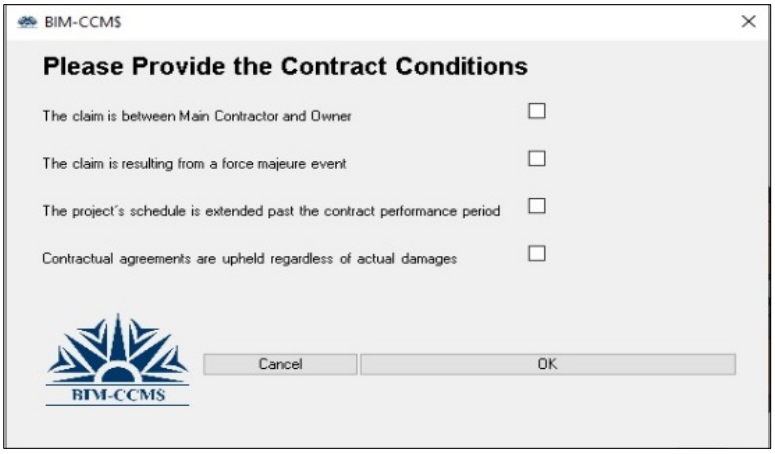


Figure 4-22 Guidelines for Selecting Eichleay's Formula

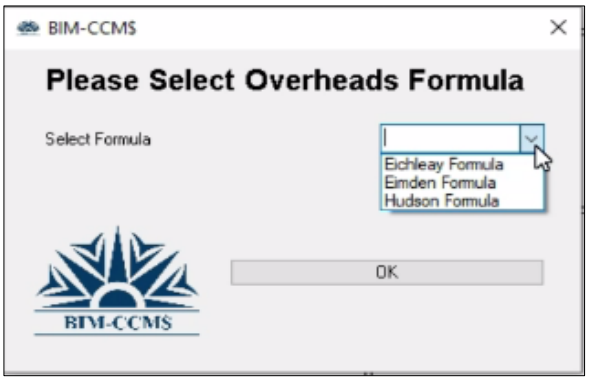


Figure 4-23 Types of Overhead Cost Formula

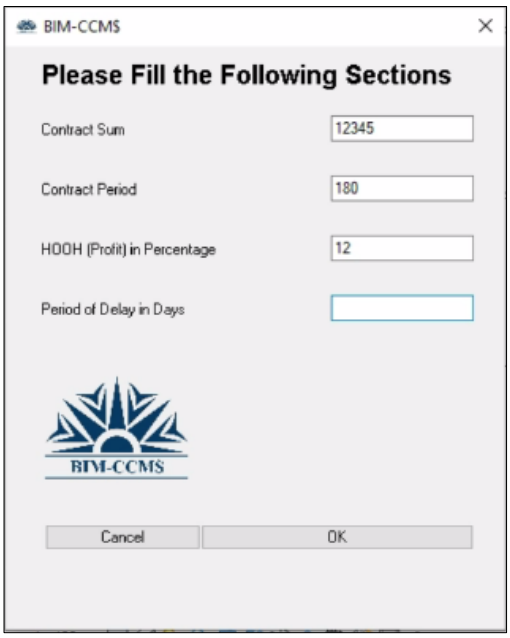


Figure 4-24 Hudson Formula

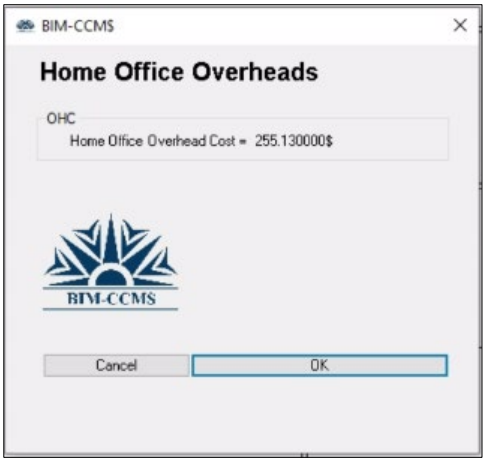


Figure 4-25 Calculated HOOHs using Hudson formula

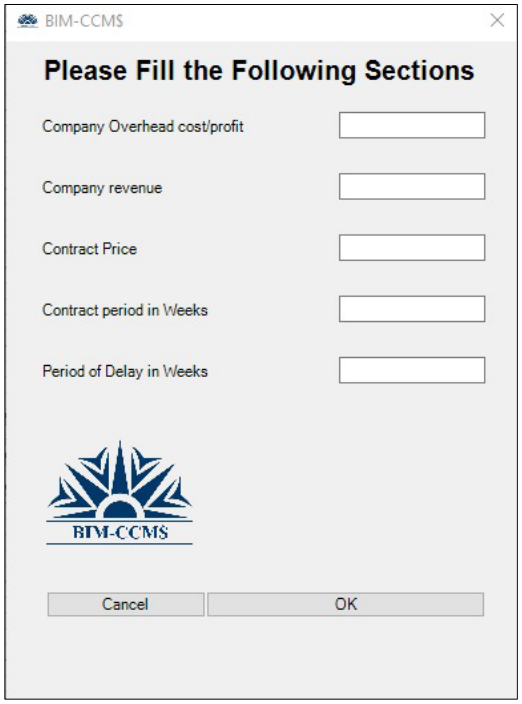


Figure 4-26 Emden formula

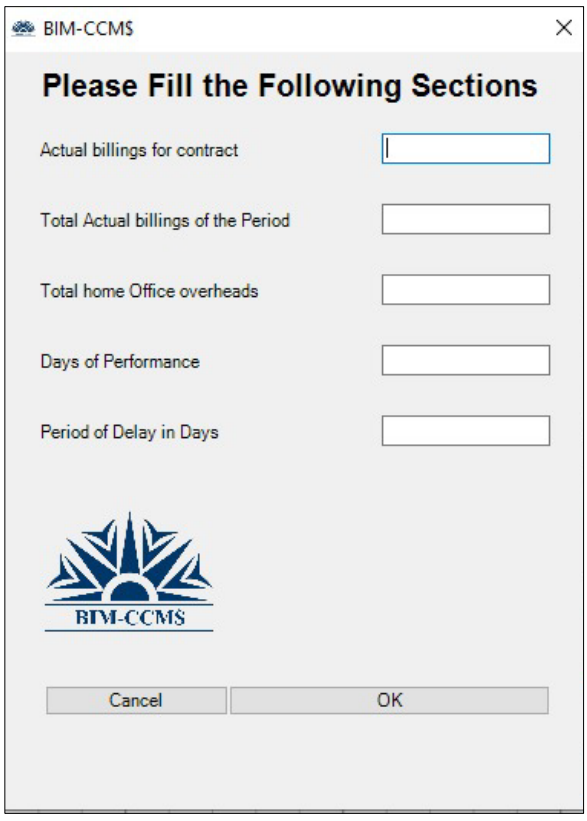


Figure 4-27 Eichleay's Formula

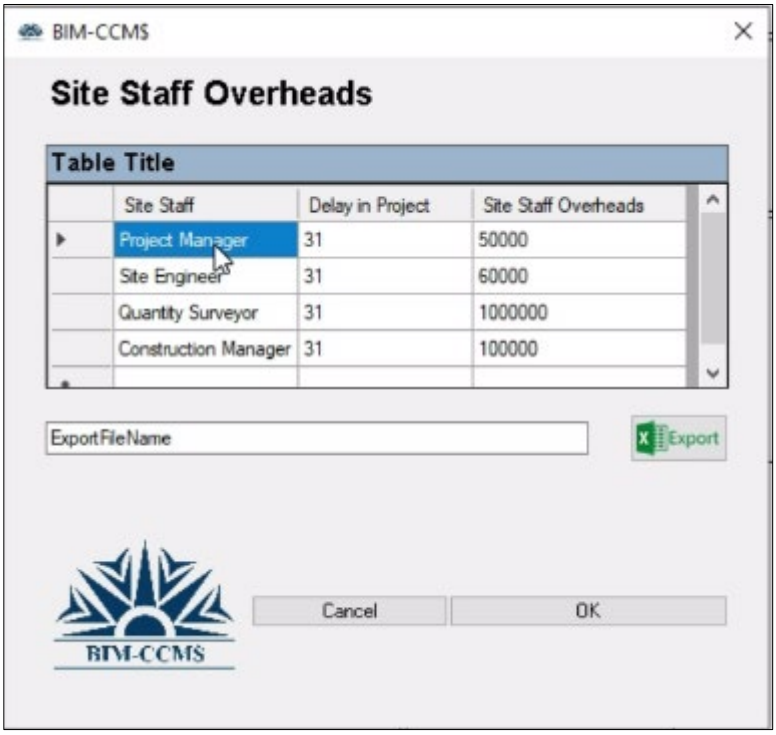


Figure 4-28 Site staff Overheads

Figure 4-28 shows details of salaried staff assigned to a project and their cost details if the project's actual Performance date extends the planned performance date. Similarly, Figure 4-29 will show the site preliminaries and their cost details.

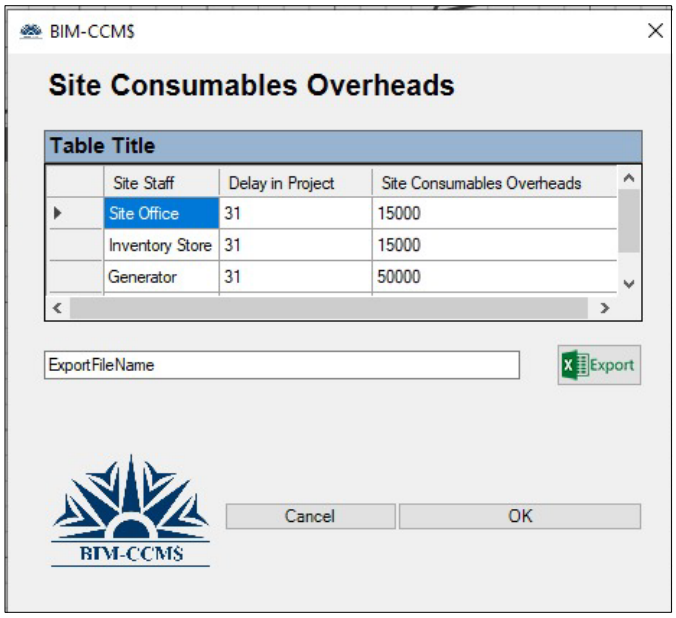


Figure 4-29 Site consumable Overheads

4.4.4 Visualization Panel

This panel contains one button to show variations in the baseline model and actual model. Users have to set the model as a baseline using the "Set model as baseline" button and then make changes to the model to view the changes. Figure 4-30 shows Baseline Model, and Figure 4-31 shows the Actual model after variations.

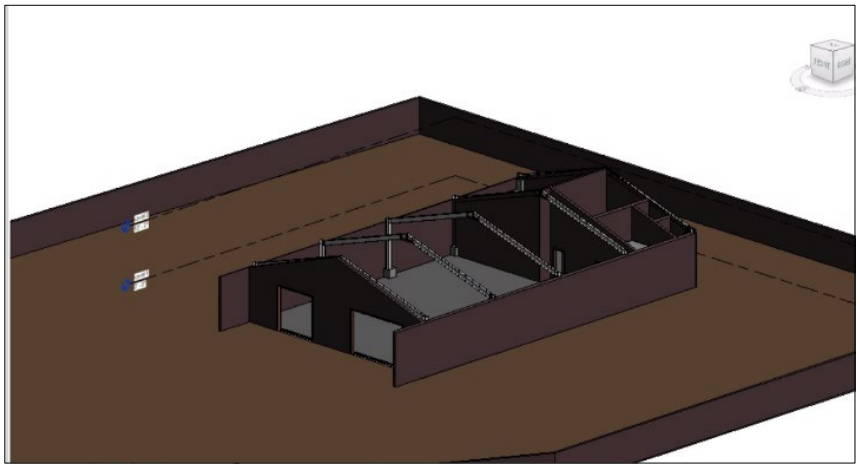


Figure 4-30 Baseline Model

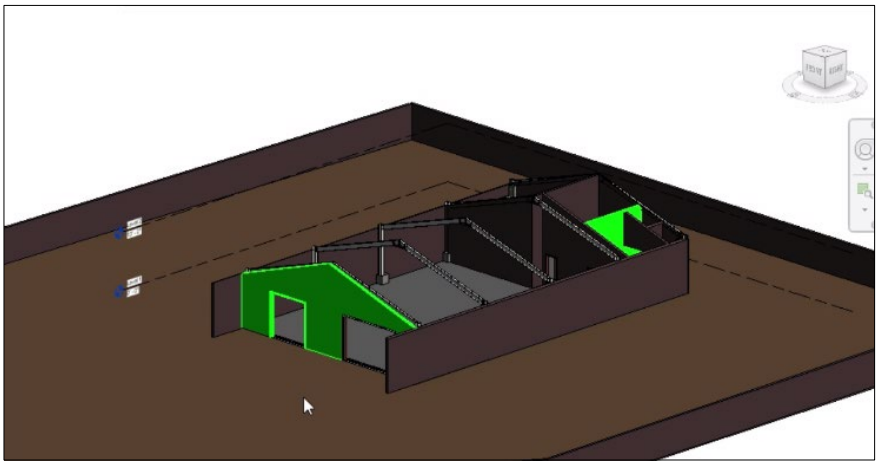


Figure 4-31 Varied Model

4.4.5 Summary Panel

This panel contains a single button that allows users to enter the summary of each type of cost in their respective sections. It also has the option for the user to manually input the prerequisite for a cost claim. It is shown in Figure 4-32.

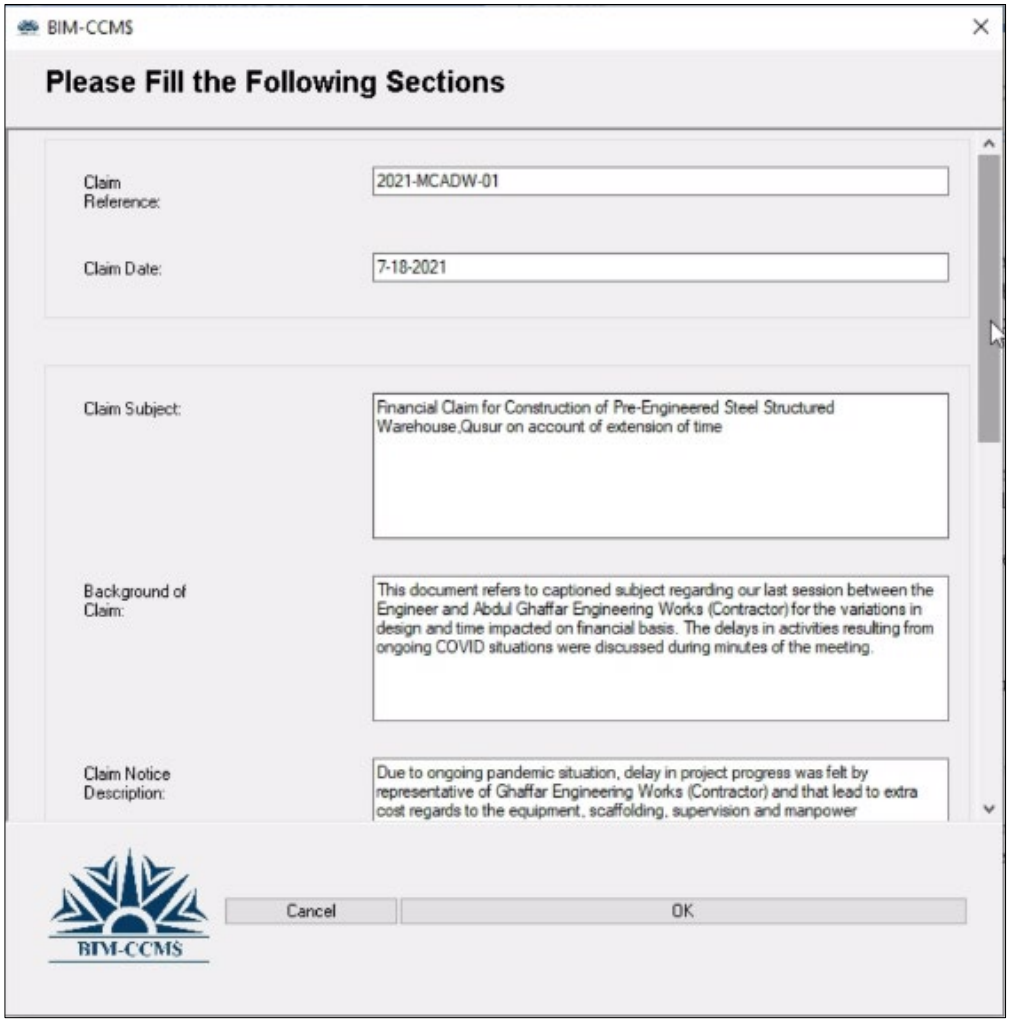


Figure 4-32 Claims Summary

4.4.6 Printing the Output

The system uses default Revit settings for printing. All types of costs and summaries are added as drafting views in Revit Project Browser. Users can select a drafting view to be printed of their choice. It can be shown in Figure 4-33 & Figure 4-34. Revit 2020 and higher versions allow users to add supporting documents like images and PDFs, increasing confidence in substantiating claims.

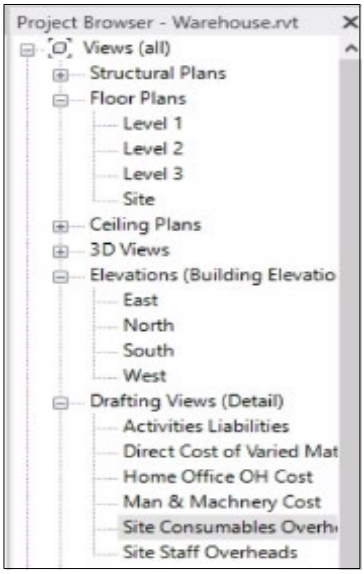


Figure 4-33 Drafting views

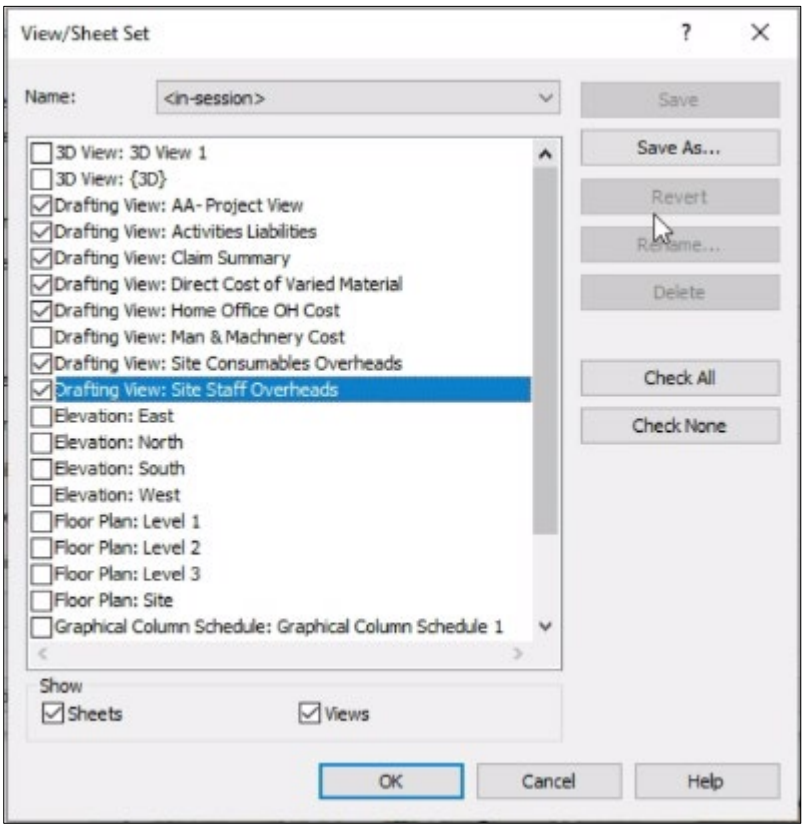


Figure 4-34 Select Drafting views for printing

All the data which was shown in tabular form and entered manually can be printed. Some of the data in output form are shown in the selected drafting views in Figure 4-34 are shown in Figure 4-35to Figure 4-41.

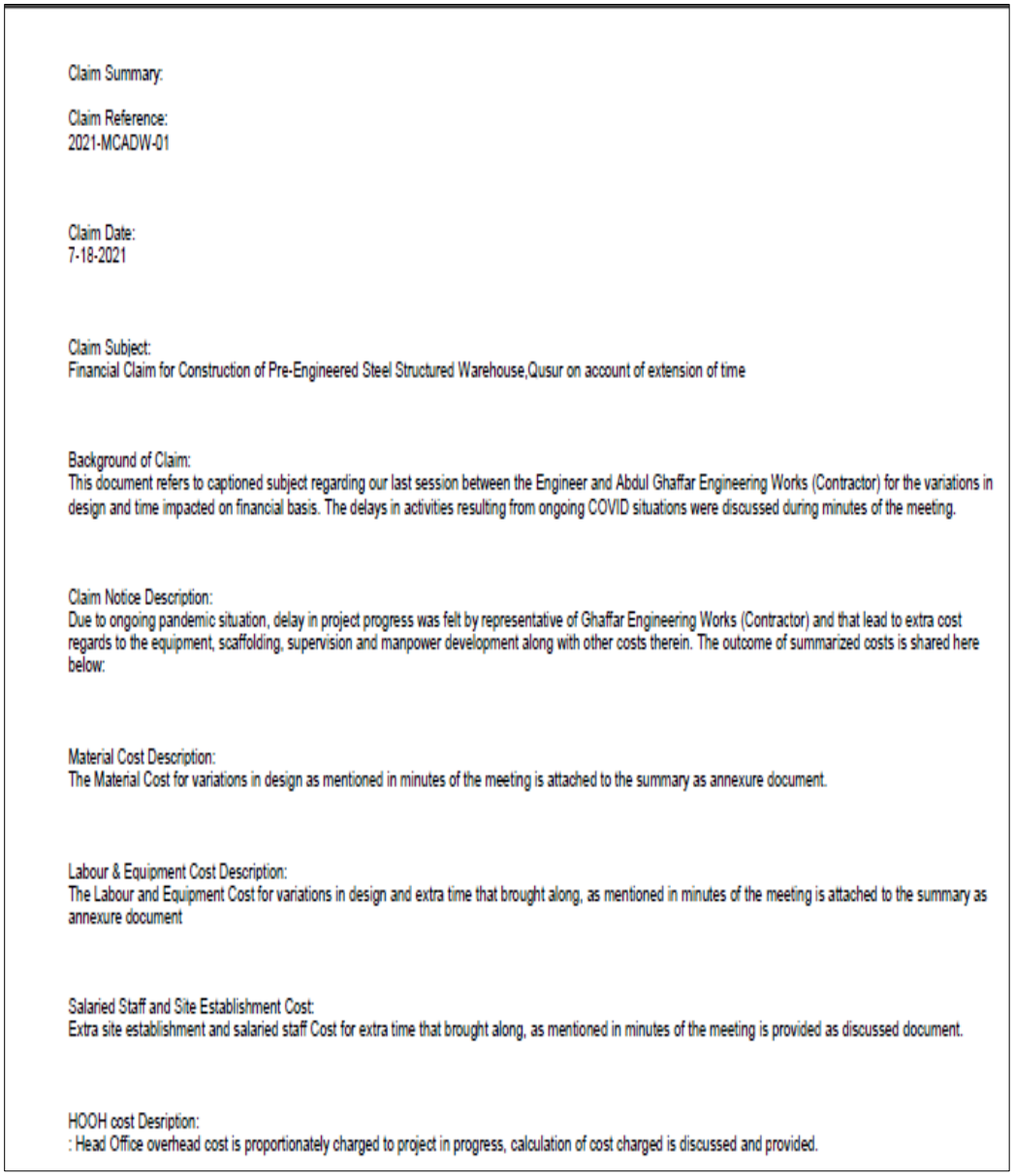
Project Claim Summary

Figure 4-35 Claim title cover output

Activities Liabilities

Activity ID	Activity Name	Delay	Liability
A1030	Foundation work	1 Days	Employer
A1080	Office Partition Wall 1	1 Days	Employer
A1170	Boundary wall 2	7 Days	Employer
A1190	Boundary wall 4	2 Days	Employer
A1200	Boundary wall 5	3 Days	Contractor
A1210	Project Adminstration	8 Days	Contractor

Figure 4-36 Activities Liablities Output



Claim Summary:

Claim Reference:
2021-MCADW-01

Claim Date:
7-18-2021

Claim Subject:
Financial Claim for Construction of Pre-Engineered Steel Structured Warehouse,Qusur on account of extension of time

Background of Claim:
This document refers to captioned subject regarding our last session between the Engineer and Abdul Ghaffar Engineering Works (Contractor) for the variations in design and time impacted on financial basis. The delays in activities resulting from ongoing COVID situations were discussed during minutes of the meeting.

Claim Notice Description:
Due to ongoing pandemic situation, delay in project progress was felt by representative of Ghaffar Engineering Works (Contractor) and that lead to extra cost regards to the equipment, scaffolding, supervision and manpower development along with other costs therein. The outcome of summarized costs is shared here below:

Material Cost Description:
The Material Cost for variations in design as mentioned in minutes of the meeting is attached to the summary as annexure document.

Labour & Equipment Cost Description:
The Labour and Equipment Cost for variations in design and extra time that brought along, as mentioned in minutes of the meeting is attached to the summary as annexure document

Salaried Staff and Site Establishment Cost:
Extra site establishment and salaried staff Cost for extra time that brought along, as mentioned in minutes of the meeting is provided as discussed document.

HOOH cost Desription:
: Head Office overhead cost is proportionately charged to project in progress, calculation of cost charged is discussed and provided.

Figure 4-37 Claim summary Output

Direct Cost of Varied Material

Material Name	Material Id	Baseline Quantity	Actual Quantity	Variation	Material Cost
Generic - 200mm	204863	254.611648	254.611648	0.000000	0.000000
Generic - 200mm	204922	269.133513	269.133513	0.000000	0.000000
Generic - 200mm	205011	240.322721	240.322721	0.000000	0.000000
Generic - 200mm	205050	100.728335	176.189702	75.461000	905.532000
Generic - 200mm	207522	692.734309	692.734309	0.000000	0.000000
Generic - 200mm	207578	471.558317	471.558317	0.000000	0.000000
Generic - 200mm	207655	713.952779	713.952779	0.000000	0.000000
Generic - 200mm	207720	348.970380	381.778779	32.808000	393.696000
Generic - 200mm	214255	89.732343	89.732343	0.000000	0.000000
Generic - 200mm	214305	40.786304	40.786304	0.000000	0.000000
Generic Floor - 400mm	232302	5368.173990	5368.173990	0.000000	0.000000
Generic Floor - 400mm	232340	5368.173990	5368.173990	0.000000	0.000000
600 x 600mm grid	232366	83.072731	83.072731	0.000000	0.000000
600 x 600mm grid	232374	18.880159	33.024368	14.144000	480.896000
600 x 600mm grid	232382	9.275578	24.222990	14.947000	508.198000
600 x 600mm grid	232390	4.330710	4.330710	0.000000	0.000000
600 x 600mm grid	232398	4.458599	4.458599	0.000000	0.000000
Pad 1	245014	4264.575609	4264.575609	0.000000	null
Generic - 200mm	251842	953.577392	953.577392	0.000000	0.000000
Generic - 200mm	251923	757.735661	757.735661	0.000000	0.000000
Generic - 200mm	251999	649.282412	649.282412	0.000000	0.000000
Generic - 200mm	252062	692.719513	692.719513	0.000000	0.000000
Generic - 200mm	252156	1286.778915	1286.778915	0.000000	0.000000
36" x 84"	253372	1.240826	1.240826	0.000000	0.000000
36" x 84"	253501	1.240826	1.240826	0.000000	0.000000
36" x 84"	253545	1.240826	1.240826	0.000000	0.000000
36" x 84"	253611	1.240826	1.240826	0.000000	0.000000
36" x 84"	253673	1.240826	1.240826	0.000000	0.000000
180" x 120"	253803	2.557140	2.189327	-0.368000	null
180" x 120"	253843	2.557140	2.557140	0.000000	0.000000
36" x 24"	254944	null	null	null	
36" x 24"	255037	null	null	null	
36" x 24"	255062	null	null	null	
36" x 72"	255155	null	null	null	
36" x 72"	255187	null	null	null	
36" x 72"	255313	null	null	null	
18 x 24	276454	6	6.000000	0.000000	null
18 x 24	276547	6	6.000000	0.000000	null
18 x 24	276837	6	6.000000	0.000000	null
18 x 24	276839	6	6.000000	0.000000	null
18 x 24	276859	6	6.000000	0.000000	null
18 x 24	276861	6	6.000000	0.000000	null

Figure 4-38 Direct Cost of varied material

Site Consumables Overheads

Site Staff	Delay in Project	Site Consumables Overheads
Site Office	31.000000	15000.000000
Inventory Store	31.000000	15000.000000
Generator	31.000000	50000.000000

Figure 4-39 Site consumable Overheads

Site Staff Overheads

Site Staff	Delay in Project	Site Staff Overheads
Project Manager	31.000000	50000.000000
Site Engineer	31.000000	60000.000000
Quantity Surveyor	31.000000	1000000.000000
Construction Manager	31.000000	100000.000000

Figure 4-40 Site staff Overheads Output

Home Office OH Cost

Home Office OverHeads	Formula Name	Home Office OH Cost
1	Hudson Formula	255.130000$

Figure 4-41 HOOH cost output

4.5 EVALUATION RESULTS

Experts were asked about the need for the system in construction. Figure 4-42 the results of respondents. 67% of experts strongly agreed, and 33% of experts agreed. None of the experts disagreed with needing BIM-CCMS.

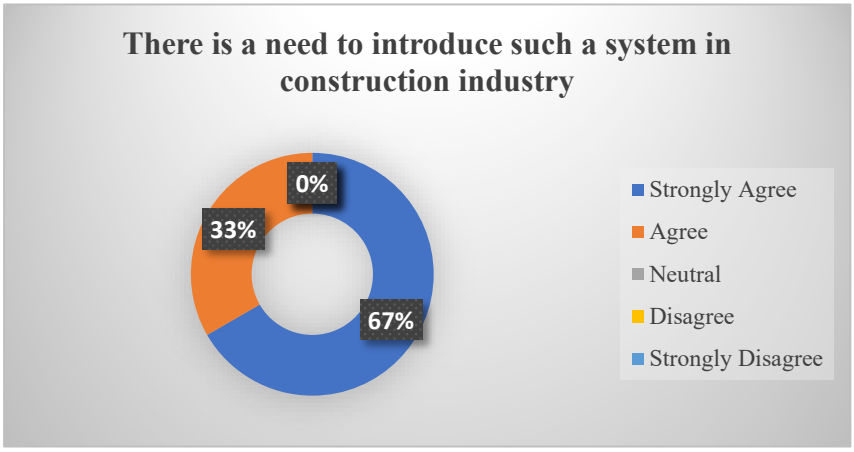


Figure 4-42 Feedback on Need of BIM-CCMS

We also asked experts about the system's usability; the results are shown in Figure 4-43. 67% of the experts said that the system was easy to understand and use, so they strongly agreed to the ease of the system. In comparison, 33% disagreed with system usage and its easiness.

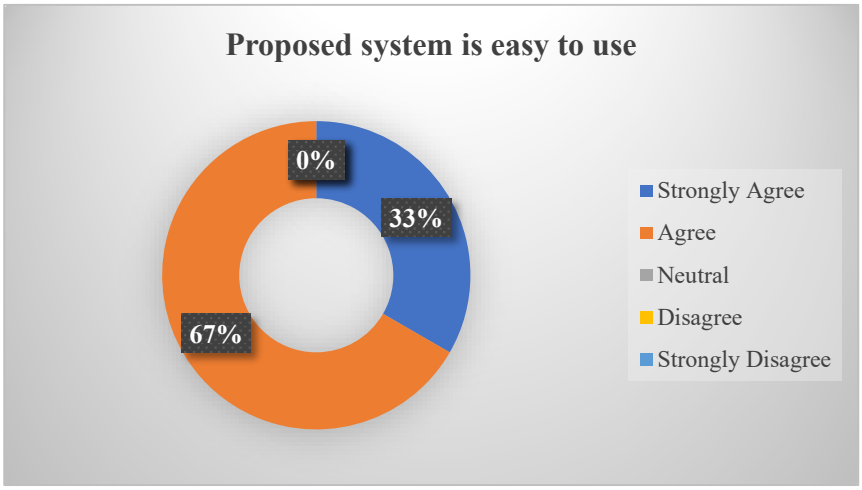


Figure 4-43 Feedback on Usability of BIM-CCMS

Experts were asked if the system is implementable in the construction industry. 46% of experts strongly agreed, and 47% agreed that the system is implementable. There were 7% of the respondents who neither agreed nor disagreed to question asked. Surprisingly there was no one to disagree (Figure 4-44).

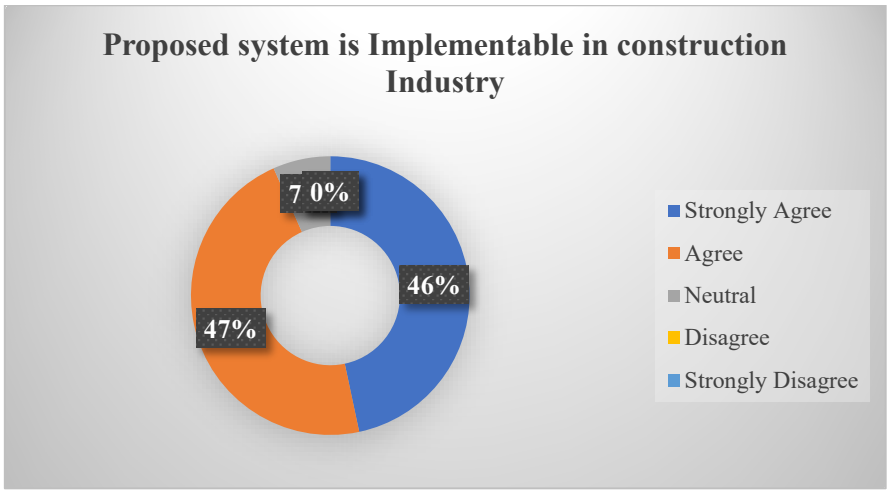


Figure 4-44 Implemenettion of BIM-CCMS

Figure 4-45 shows the overall effectiveness of the system in the management of cost claims. 64% strongly agreed, and 36% agreed to the question asked. No expert disagreed with the effectiveness of the system.

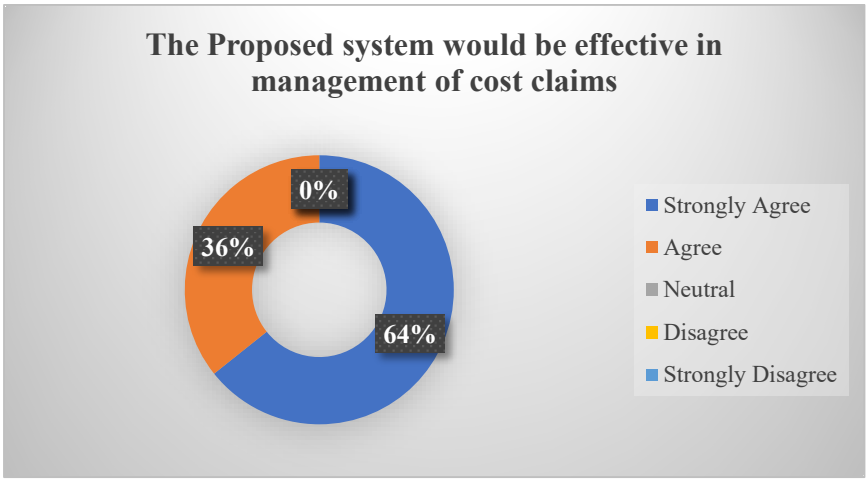


Figure 4-45 Effectiveness of BIM-CCMS

Table 4-3 shows the effectiveness of the developed system to resolve the issues related to cost claims. These values were given rankings on their respective RII values.

Table 4-3 Semi Structured interview-based Evaluation

Inefficiencies	Group	Mean	Sum	RII	Ranking
No Comprehensive method for Claim Management	Procedure	4.066667	1	0.813333	11
Time taking process due to complex procedures		4.133333	62	0.826667	10

Too Many Documents for Claims preparation and assessment		3.933333	59	0.786667	20
Use of unsuitable techniques for claim analysis		3.8	57	0.76	25
Insufficient time for claim-preparation and analysis		4	60	0.8	19
Unstructured Documents	Presentation	4.2	63	0.84	7
Poor Presentation of Claims		4.333333	65	0.866667	4
No standard Format		4.066667	61	0.813333	16
On-site Inaccessibility to Relevant Document when needed	Resources	4	60	0.8	18
Delay in notice to claim by Contractor		3.933333	59	0.786667	22
Poor Maintenance of Claim Records		4.2	63	0.84	8

insufficient skilled personnel for claim management		3.066667	46	0.613333	30
Ambiguities in responsibilities of construction team		4.066667	55	0.733333	28
Legibility of claims in verbal and technical terms	Contract	3.933333	59	0.786667	21
Lack of Contract awareness		4.066667	61	0.813333	13
Lack of Clear information in Contracts		4.066667	61	0.813333	14
Difference in quantification of damages calculated by different parties	Cost	4.133333	62	0.826667	9
Difficulty in Quantification of indirect costs		4.2	63	0.84	6
Burden of Proof to support a claim e.g. complexity of		4.333333	65	0.866667	5

determining cause and effect					
Exaggerated claims made by contractors		4.533333	68	0.906667	2
Absence of use of standard formula for evaluation and calculation of damages		4.066667	61	0.813333	12
High cost associated with retrieving required information		3.733333	56	0.746667	27
Lack of Accuracy in Estimation of Loss of Productivity		4.066667	61	0.813333	15
Poor Maintenance of Overhead Records (site and Head Office)	Documentation	4.066667	61	0.813333	17
No computerized documentation system		4.666667	70	0.933333	1

Lack of adequate Information in drawings		4.533333	68	0.906667	3
Coordination gap between Site and office staff	Coordination	3.866667	58	0.773333	24
Not updating the schedules		3.666667	55	0.733333	29
Less dependency on new software based systems	Technology	3.733333	56	0.746667	26
Overdue in retrieving Information	Time	3.866667	58	0.773333	23

a. Procedure Group: Developed system was able to handle Time taking process due to complex procedures RII value of 82%. But the use of unsuitable techniques for claim analysis issues still needs more time. Filed experts believe that this issue needs to be explored within the system; its RII value is among the lowest ones.

b. Presentation Group: The system handled most of its issues with more than 80% RII value. The data is well represented. Experts said that data is divided into legible sections. All of its issues are resolved and ranked in the top 20 of the resolved issues.

c. Resource Group: This group mostly contains issues that are mostly dependent on human traits. Most of them have an RII value of lowest rankings. Only maintenance of claim records ranks in the top 10.

d. Contract Group: This group's lack of contract awareness issue is resolved pretty much due to the sorted database of related contracts clauses of mostly used

contracts provided in the system. Legibility of claims in verbal and technical terms and lack of clear information needs more attention to be resolved.

e. Cost Group: This group shows the highest resolved issues on average. Due to its Parametric 3D modeling and visualization, most of its issues are resolved and fall in the top 10 RII values list.

f. Documentation Group: Since this system is BIM-based, it resolves most documentation-related issues with more than 70% RII value. It also has the value of the top resolved issue, which is no computerized documentation system with more than 805 RII value.

g. Coordination Group: This group mostly contains issues related to communication and coordination. They have been resolved up to some extent. But it needs more work within the project coordination system.

h. Technology Group: Experts valued this group's issues in the last ten resolved issues. There is still hesitation towards new technology adoption. Experts suggested the system should be validated on a completed project to get the actual values and check the system's compatibility with project size.

i. Time Group: This group shows the resolution of issues related to time overdue to retrieve information. The system resolved it with a 77% RII value.

4.6 FEEDBACK FOR SYSTEM FROM EXPERTS:

Experts were asked if there were any barriers to implement this system in the construction industry. Table 4-4 shows some key barriers and their key comments.

Table 4-4 Barriers in implementing BIM-CCMS

Barriers	Key Comments
Knowledge	The construction industry needs to improve its experience in using new technology. Most of the experts provided the information that many construction firms are still in 2D. 3D is being used for rendering purposes only.
Cost	Proper Training and seminars should be done which will bring extra costs with them.

Data Input	Data Coming from other software which is not BIM can make results less realistic.
Contract	Contractors and other parties should know contracts enough to work within a BIM environment and have contractual knowledge and experience to implement within BIM.

Experts were also asked if there is a need to improve the system; their feedback is recorded in Table 4-5.

Table 4-4 Future Improvements Recommended by Experts

Future Improvements	**Key Comments**
Education	The system should have supporting tutorials, seminars, etc. for the sake of awareness in construction
Realistic Approach	The system should handle real-time cost analysis for large and complex models
Economy	The system should include Tax systems, inflations into considerations

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 DISCUSSION

This study was aimed to achieve the following objectives:

- To identify the issues in the cost claims management process in the construction industry
- To develop a framework for a BIM-based knowledge management system for cost claims.
- To develop a digital platform for implementing the framework in the BIM authoring platform.

The first objective has been achieved by identifying inefficiencies in management of cost claims through literature and verifying them from the construction industry. The second objective has been achieved after refining many conceptual frameworks. The traits of finalized conceptual framework developed have been discussed in previous chapters. The last objective was achieved by using a conceptual framework and putting that information into the development of the BIM-CCMS prototype architecture. The working of BIM-CCMS has been realized through a warehouse project as a case study. BIM-CCMS has then been presented to industry experts to assess the easiness and usability of cost claims management in construction projects.

5.2 CONCLUSION

Construction Projects are complex in nature. Size, location, and the number of parties involved in a project add complexity to a project. These complex projects need modern solutions to avoid financial and time losses actively or reactively. BIM is one of the widely used platforms to take projects from 2D to nD. Its API is rich and friendly to use. Although Revit has strong interoperability within and out of BIM, it does not provide solutions to all the problems. Modern Information and

Communication Technology (ICT) systems have facilitated the construction industry. BIM was used to achieve our goals through this research.

Based on the systematic and action-based nature of the research, both were used partly in methodology. Issues in conventional cost claim management were identified from the literature and verified by field experts. BIM cannot solve all the issues on its own. For that purpose, we had to develop a BIM- CCMS tool. This tool was developed using scripts developed in the Dynamo environment. Dynamo has a huge involvement in decision-making for the calculation of costs. SQL Server database has been connected to Dynamo through nodes packages to store the data in the database. Excel data was imported from planning software, and a contract clauses database was developed and used in the system. A sample cost claim was also generated in the end based on different delays and design variations. Resolved issues found from the literature were aimed to be resolved. Their percentage of resolution is discussed in the last chapter.

5.3 LIMITATIONS

Limitations were faced during the development and working of BIM-CCMS. Industry experts also pointed out these limitations. These limitations are discussed as follows:

- The system relies on the schedule data imported from another software like primavera software, which is not a part of BIM.
- The system also uses frequently used contracts in the region. However, there should be an option to introduce other contracts so that users can manually put their specific type of contract clauses.
- The system can decide the liability solely on the Contractor or Client; in case of concurrent delays where both parties are liable, the system cannot decide liability at this stage.
- Experts suggested that data should be developed and imported from Navisworks, also it should have the ability to synchronize with Navisworks.
- The size of the sample project was small, and it should be tested on large and complex projects.

5.4 RECOMMENDATIONS

Following are the recommendations which should be incorporated into the system:

- The system should develop and show earned value analysis (EVA) within the environment.
- It should be tested from an earlier stage of the project to visualize the impact of delays in terms of costs.
- It should also cover inflation and taxes costs if the project's duration is in years.

5.5 FUTURE RESEARCH DIRECTIONS

During this study, the author learned about other such systems in the construction industry to calculate claims-related costs.

- A reliable study should be made to assess and manage the risk in using such developed systems.
- The system used only three known formulae in the research and case studies to calculate home office overheads.
- For costs of home office overheads, other formulae should be tested and added to the system as annexure.

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APPENDIX-A

Preliminary Survey to Verify inefficiencies and their severity of Cost Claims Management in Construction

This survey is a part of a research study, under degree of MS Construction Engineering & Management at NUST, Islamabad. The main objective and goal of this survey study is to identify the relevancy of critical inefficiencies in claims management related to construction.

30 critical inefficiencies in cost claims management system in construction industry have been identified from a thorough literature review. You are kindly requested to give input by rating each attribute in accordance with your experience. We will be very careful not to disclose any unnecessary information. Your participation is greatly appreciated.

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NUST Islamabad

Expert's Response

Information provided and discussed will be kept anonymous and used for academic purposes only

Section 1:

Please mention the following:

Name: _____

Organization Type: _____

Designation in company: _____

Experience (in years): _____

Email address: _____

Section 2:

The inefficiencies will be ranked on a five-point Likert scale to verify the most critical factors according to expert opinion. For example, "strongly agree" means that the mentioned factors greatly influence the inefficiencies in management of cost claims and vice versa. The critical factors will then be used in development of a framework for the Building Information Modeling (BIM) based knowledge management system for Construction cost claims.

NOTE: If you are attempting the questionnaire on your MOBILE PHONE, kindly use LANDSCAPE MODE for ease of comprehension.

Please choose your answer on the given scale.

(1=strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree)

1) To what extent, do you think the issues listed below will be solved by the proposed

system? These issues can be ranked based on their importance on a 5-point Likert scale

(where 1=strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree)

Inefficiencies	**Group**					
No Comprehensive method for Claim Management	Procedure	1	2	3	4	5
Time taking process due to complex procedures		1	2	3	4	5
Too Many Documents for Claims preparation and assessment		1	2	3	4	5
Use of unsuitable techniques for claim analysis		1	2	3	4	5
Insufficient time for claim preparation and analysis		1	2	3	4	5
Unstructured Documents	Presentation	1	2	3	4	5
Poor Presentation of Claims		1	2	3	4	5
No standard Format		1	2	3	4	5
On-site Inaccessibility to Relevant Document when needed	Resources	1	2	3	4	5
Delay in notice to claim by Contractor		1	2	3	4	5
Poor Maintenance of Claim Records		1	2	3	4	5

insufficient skilled personnel for claim management		1	2	3	4	5
Ambiguities in responsibilities of construction team		1	2	3	4	5
Legibility of claims in verbal and technical terms	Contract	1	2	3	4	5
Lack of Contract awareness		1	2	3	4	5
Lack of Clear information in Contracts		1	2	3	4	5
Difference in quantification of damages calculated by different parties	Cost	1	2	3	4	5
Difficulty in Quantification of indirect costs		1	2	3	4	5
Burden of Proof to support a claim e.g. complexity of determining cause and effect		1	2	3	4	5
Exaggerated claims made by contractors		1	2	3	4	5
Absence of use of standard formula for evaluation and calculation of damages		1	2	3	4	5
High cost associated with retrieving required information		1	2	3	4	5
Lack of Accuracy in Estimation of Loss of Productivity		1	2	3	4	5
Poor Maintenance of Overhead Records (site and Head Office)	Documentation	1	2	3	4	5
No computerized documentation system		1	2	3	4	5
Lack of adequate Information in drawings		1	2	3	4	5

Coordination gap between Site and office staff	Coordination	1	2	3	4	5
Not updating the schedules		1	2	3	4	5
Less dependency on new software-based systems	Technology	1	2	3	4	5
Overdue in retrieving Information	Time	1	2	3	4	5

2) Please describe your comments if you think there are additional inefficiencies and rate them as per Likert scale.

APPENDIX-B

Evaluation of BIM-CCMS from Industry Experts

This exercise is carried out to evaluate the BIM based knowledge management system for construction cost claims, developed by the department of Construction Engineering & Management (CE&M) in National University of Science and Technology (NUST) H-12 Campus to provide visual and digital information supporting Cost Claims.

Information provided and discussed will be kept anonymous and used for academic purposes only. This review consists of two main sections, i-e Experts' Profile (Section-01), Evaluation discussion comprised of questions). The debate will be recorded in both vocal and written formats. Experts may answer depending on their preferable mode.

Thank You for your Cooperation.

Meer Humza,

Graduate Student

Construction Engineering & Management Department

NUST H-12 Campus, Islamabad.

Expert's Response

Information provided and discussed will be kept anonymous and used for academic purposes only

Section 1:

Please mention the following:

Name: _____

Organization Type: _____

Designation in company: _____

Experience (in years): _____

Section 2:

Please choose your answer on the given scale.

(1=strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree)

3) There is a need to introduce such a system in Construction industry.

1	2	3	4	5

4) The proposed system would be easy to use.

1	2	3	4	5

5) The proposed system is implementable.

1	2	3	4	5

6) Please specify the possible barriers you feel in its implementation:

7) Please describe your comments for the barriers in its implementation.

8) To what extent, do you think the issues listed below will be solved by the proposed system? These issues can be ranked based on their importance on a 5-point Likert scale

(where 1=strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree)

Inefficiencies	**Group**					
No Comprehensive method for Claim Management	Procedure	1	2	3	4	5
Time taking process due to complex procedures		1	2	3	4	5
Too Many Documents for Claims preparation and assessment		1	2	3	4	5

Use of unsuitable techniques for claim analysis		1	2	3	4	5
Insufficient time for claim preparation and analysis		1	2	3	4	5
Unstructured Documents	Presentation	1	2	3	4	5
Poor Presentation of Claims		1	2	3	4	5
No standard Format		1	2	3	4	5
On-site Inaccessibility to Relevant Document when needed	Resources	1	2	3	4	5
Delay in notice to claim by Contractor		1	2	3	4	5
Poor Maintenance of Claim Records		1	2	3	4	5
insufficient skilled personnel for claim management		1	2	3	4	5
Ambiguities in responsibilities of construction team		1	2	3	4	5
Legibility of claims in verbal and technical terms	Contract	1	2	3	4	5
Lack of Contract awareness		1	2	3	4	5
Lack of Clear information in Contracts		1	2	3	4	5
Difference in quantification of damages calculated by different parties	Cost	1	2	3	4	5
Difficulty in Quantification of indirect costs		1	2	3	4	5
Burden of Proof to support a claim e.g. complexity of determining cause and effect		1	2	3	4	5
Exaggerated claims made by contractors		1	2	3	4	5

Absence of use of standard formula for evaluation and calculation of damages		1	2	3	4	5
High cost associated with retrieving required information		1	2	3	4	5
Lack of Accuracy in Estimation of Loss of Productivity		1	2	3	4	5
Poor Maintenance of Overhead Records (site and Head Office)	Documentation	1	2	3	4	5
No computerized documentation system		1	2	3	4	5
Lack of adequate Information in drawings		1	2	3	4	5
Coordination gap between Site and office staff	Coordination	1	2	3	4	5
Not updating the schedules		1	2	3	4	5
Less dependency on new software based systems	Technology	1	2	3	4	5
Overdue in retrieving Information	Time	1	2	3	4	5

9) Please describe your comments for above stated scores, and future improvement here.

10) Overall, the proposed system would be effective in improving the process of EOT claim management.

(Scale: 1=strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree)

1	2	3	4	5

APPENDIX-C

- **FIDIC Clauses and Liabilities:**

The following Table shows FIDIC Contract Types, Their clauses/Subclauses which are used in cost claims. The liability of each clause is also derived from respective FIDIC Contracts.

Table 0-1 Cost claim related FIDIC clauses and Liabilities

Sr. No.	Contract Type	Clause/ Sub-Clause	Description	Liability
1.	Conditions of contract for Works of Civil Engineering Construction-1987	6.3	Notice to Disruption of Progress	Contractor
		6.4	Delays and Cost of Delay of drawings	Employer
		6.5	Failure by contractor to submit drawings	Contractor
		12.2	Not foreseeable Physical obstructions or conditions	Employer
		17.1	Setting-out; Error found in the original lines, levels and reference provided by engineer	Contractor
		20.3	Loss or Delays due to Employer's Risks	Employer
		22.1	Damage to Property & Persons	Contractor
		22.3	Indemnity by Employer	Employer
		27.1	Fossils; Expenses incurred on the preservation of items of	Employer

- **NEC3 Contract and Liability:**

			value found on the site which are the property of Employer	
		30.3	Transport of materials and plant	Employer
		31.2	Facilities for other contractors	Contractor
		36.5	Engineer's Determination where Tests not provided for	Employer
		37.4	Rejection; cost of rejections payable to Employer	Contractor
		38.2	Uncoverings and Making openings	Employer
		39.2	Default of contractor in compliance	Contractor
		42.2	Failure to give possession	Employer
		46.1	Rate of progress	Contractor
		49.3	Cost of remedying defects	Contractor
		50.1	Contractor to search defects	Contractor
		51.1	Variations	Employer
		51.2	Instructions for Variations	Employer
		52.1	Valuation of variation	Contractor
		52.3	variations exceeding 15 percent	Employer
		52.4	Daywork	Employer
		53.1	notice of claims	Contractor

		53.4	Failure to comply	Contractor
		53.5	Payment of claims	Employer
		58.1	Definition of Provisional sum	Employer
		58.2	Use of Provisional sum	Employer
		60. 10	Time for Payment	Employer
		65	special Risks;	Employer
		69.4	Contractor's entitlement to suspense work	Employer
2.	Conditions of Contract for Construction For Building and Engineering Works Designed by the Employer-RED BOOK 1999	1.9	timely supply of drawings by the engineer	Employer
		2.1	delay in handing over the possession of site to contractor	Employer
		2.5	Employer's Claims	Contractor
		4.6	Co-operation; any facilities provided to the other contractors on Employer's request	Employer
		4.7	Errors in setting information	Employer
		4.12	Adverse Physical Conditions	Employer
		4.15, 4.16	damages to roads and bridges as determined by engineer in favor of employer	Contractor
		4.24	fossils	Employer
		7.3	inspection; uncovering or making openings that were covered after the compliance of contract	Contractor

		7.4	testing	E+C
		7.5	Rejection	Contractor
		7.6	Remedial Work; default of contractor in compliance	Contractor
		8.6	Rate of Progress ; additional costs of supervision recoverable from contractor due to slow progress rate	Contractor
		8.9	Engineer's instruction to suspend work	Employer
		8. 10	costs incurred by contractor for suspension not by default of contractor	Employer
		10.3	Employer's interference with test on completion	Employer
		11.2	costs of remedying defects	Contractor
		11.4	Contractor's failure to remedy defects	Contractor
		11.8	Contractor to search defect	Employer
		12.1	Works to be measured	Employer
		12.2	Method of measurement	Employer
		12.3	Evaluation	Employer
		12.4	Omissions	Employer
		13.1	Right to vary	Employer
		13.3	Variations carried out by written instructions by engineer	Contractor

		13.7	Adjustments for changes in legislation	Employer
		14.8	Delayed Payments	Employer
		16.1	Contractor's entitlement to suspension work	E+C
		17.1	(indemnities) death or injury to any person/ property except the exceptions mentioned in subclause22.2	E+C
		17.4	Employer's Risk	Employer
		19.4	Force Majeure	Employer
		19.6	Optional Termination	Employer
		20.1	Contractor's Claims	Employer
3.	Conditions of Contract for EPC/ Turnkey Projects- SILVER BOOK 1999	2.1	delay in handing over the possession of site to contractor	Employer
		2.5	Employer's Claims	Contractor
		4.7	Errors in setting information	Contractor
		4.12	Adverse Physical Conditions	Contractor
		4.15	access route	Contractor
		4.16	transport of goods	Contractor
		4.24	fossils	Employer
		7.3	inspection; uncovering or making openings that were covered after the compliance of contract	Contractor
		7.4	testing	E+C
		7.5	Rejection	Contractor

		7.6, 11.4	Remedial Work; default of contractor in compliance	E+C
		8.6	Rate of Progress ; additional costs of supervision recoverable from contractor due to slow progress rate	Contractor
		8.9	Engineer's instruction to suspend work	E+C
		8. 10	Payment for plant and materials in event of suspension for more than 28 days	Employer
		10.3	Employer's interference with test on completion	Employer
		11.2	costs of remedying defects	Contractor
		11.4	Contractor's failure to remedy defects	Contractor
		11.8	Contractor to search defect	E+C
		12.2	Delayed Test	Employer
		12.3	retesting after completion	Contractor
		12.4	Failure to pass test on completion	E+C
		13.6	Daywork	Employer
		13.7	Adjustments for changes in legislation	Employer
		13.8	Adjustments for changes in cost	Employer

		13.5	Works carried on the instructions of engineer under provision of provisional sums	Employer
		14.8	Delayed Payments	Employer
		16.1	Contractor's entitlement to suspension work	Employer
		16.2	Termination by Contractor	Employer
		17.1	(indemnities) death or injury to any person/ property except the exceptions mentioned in subclause22.2	E+C
		17.4	Consequences of Employer's Risk	Employer
		19.4	Force Majeure	Employer
		19.6	Optional Termination	Employer
		20.1	Contractor's Claims	Employer
4.	Conditions of Contract for Construction For Building and Engineering Works Designed by the Employer (MDB Multilateral	1.9	timely supply of drawings by the engineer	Employer
		2.1	delay in handing over the possession of site to contractor	Employer
		2.5	Employer's Claims	Contractor
		4.6	Co-operation; any facilities provided to the other contractors on Employer's request	Employer
		4.7	Errors in setting information	Employer

	Development Bank) Harmonized Edition-PINK BOOK 2005	4.12	unforeseeable Physical Conditions	Employer
		4.15	Access Route	Contractor
		4.16	Transport of Goods	Contractor
		4.24	fossils	Employer
		7.3	inspection; uncovering or making openings that were covered after the compliance of contract	Contractor
		7.4	testing	Employer
		7.5	Rejection	Contractor
		7.6	Remedial Work; default of contractor in compliance	Contractor
		8.6	Rate of Progress ; additional costs of supervision recoverable from contractor due to slow progress rate	Contractor
		8.7	Delay Damages	Contractor
		8.9	Consequences of Employer's Suspension	E+C
		8. 10	Payment for plant and materials in event of suspension for more than 28 days	Employer
		9.2	Delayed Test	E+C
		9.3	Re-testing	Contractor
		9.4	Failure to pass test on completion	Contractor
		10.3	Interference with test on completion	Employer

		11.2	costs of remedying defects	Contractor
		11.3	Extension of Defects Notification Period DNP	E+C
		11.4	Contractor's failure to remedy defects	Contractor
		11.8	Contractor to search defect	Employer
		12.1	Works to be measured	Employer
		12.2	Method of measurement	Employer
		12.3	Evaluation	E+C
		12.4	Omissions	Employer
		13.3	Variation Procedure; Variations carried out by written instructions by engineer	Contractor
		13.1	Right to vary	Employer
		13.6	Daywork	Employer
		13.7	Adjustments for changes in Laws	Employer
		13.8	Adjustments for changes in Cost	Employer
		14.8	Delayed Payments	Employer
		16.1	Contractor's entitlement to suspension work	Employer
		16.4	Payment on Termination	Employer
		17.1	Indemnities	E+C
		17.3	Employer's Risk	Employer
		17.4	Consequences of employer's Risks	Employer

The Following Table shows New engineering Contract Clauses details and liabilities. These clauses are used in construction cost claims.

		19.4	Consequences of Force Majeure	Employer
		19.6	Optional Termination, Payment and Release	Employer
		20.1	Contractor's Claims	Employer
5.	Conditions of Contract for Construction For Building and Engineering Works Designed by the Employer-RED BOOK 2017	1.9	Timely supply of drawings by the engineer	Employer
		2.1	Right to access to the site	Employer
		4.6	Co-operation; any facilities provided to the other contractors on Employer's request	Employer
		4.7	Errors in setting information	Employer
		4.12.4	unforeseeable Physical Conditions	Employer
		4.13	Rights of way and facilities	Contractor
		4.15	Access route	E+c
		4.16	Transport of goods	Contractor
		4.23	Fossils	Employer
		7.3	Inspection; uncovering or making openings that were covered after the compliance of contract	Contractor
		7.4	Testing by contractor	E+C
		7.5	Defects and Rejection	Contractor
		7.6	Remedial Work; default of contractor in compliance	Contractor

		8.7	Rate of Progress ; additional costs of supervision recoverable from contractor due to slow progress rate	Contractor
		8.8	Delay Damages	Contractor
		8.9	Employer's suspension	Employer
		8. 10	Consequences of Employer's Suspension	Employer
		8. 11	Costs incurred by contractor for suspension not by default of contractor	Employer
		8.12	Prolonged Suspension	Employer
		9.2	Delayed tests	Contractor
		9.3	Re-testing	Contractor
		10.3	Interference with test on completion	E+C
		11.2	Costs of remedying defects	Contractor
		11.4	Contractor's failure to remedy defects	Contractor
		11.7	Right of access after taking over	Employer
		11.8	Contractor to search defect	Contractor
		12.1	Works to be measured	E+C
		12.2	Method of measurement	Employer
		12.3	Valuation of works	Contractor
		12.4	Omissions	Employer

		13.3	Variations carried out by written instructions by engineer	Employer
		13.1	Right to vary	Employer
		13.4	Works carried on the instructions of engineer under provision of provisional sums	Employer
		13.6	Adjustments for changes in Laws	E+C
		14.8	Delayed Payments	Employer
		16.2.	Termination by Contractor	Employer
		16.4	Payment after termination by contractor	Employer
		17.2	Liability for care of works	E+C
		17.4	Indemnities by Contractor	Contractor
		17.5	Indemnities by Employer	Employer
		18.4	Consequences of exceptional event	Employer
		20.1	Claims	E+C
		20.2	Claims for Payment and/or EOT	E+c
6.	Conditions of Contract for EPC/ Turnkey Projects-	1.9	timely supply of drawings by the engineer	Employer
		2.1	Right to access to the site	Employer

	SILVER BOOK 2017	4.6	Co-operation; any facilities provided to the other contractors on Employer's request	Employer
		4.7	Errors in setting information	Contractor
		4.12	Unforeseeable Difficulties	Contractor
		4.13	Rights of way and facilities	Contractor
		4.15	Access Route	Contractor
		4.16	Transport of Goods	Contractor
		4.23	Fossils	Employer
		7.3	Inspection; uncovering or making openings that were covered after the compliance of contract	Contractor
		7.4	Testing by contractor	E+c
		7.5	Defects and rejection	Contractor
		7.6	Remedial Work; default of contractor in compliance	Contractor
		8.7	Rate of Progress ; additional costs of supervision recoverable from contractor due to slow progress rate	Contractor
		8.8	Delay Damages	Contractor
		8.9	Employer's suspension	Contractor
		8. 10	Consequences of Employer's Suspension	E+c

		8. 11	Costs incurred by contractor for suspension not by default of contractor	Employer
		8.12	Prolonged Suspension	Employer
		9.2	Delayed tests	Contractor
		9.3	Re-testing	Contractor
		10.3	Interference with test on completion	Employer
		11.2	Costs of remedying defects	Contractor
		11.4	Contractor's failure to remedy defects	Contractor
		11.7	Right of access after taking over	Employer
		11.8	Contractor to search defect	Employer
		12.2	Delayed tests	Employer
		12.3	Re-testing	Contractor
		12.4	Omissions	Contractor
		13.3	Variations carried out by written instructions by engineer	Employer
		13.1	Right to vary	Employer
		13.5	Daywork	Employer
		13.6	Adjustments for changes in Laws	E+c
		13.7	Adjustments for changes in Cost	Employer
		14.8	Delayed Payments	Employer

		15.2	Termination for contractor's Default	Contractor
		15.3	Valuation at the date of termination for contractor's default	Employer
		15.4	Payment after termination for contractor's default	Contractor
		15.6	Valuation at the date of termination for Employer's Convenience	Employer
		15.7	Payment after termination for Employer's Convenience	Employer
		16.1	Suspension by contractor	Employer
		16.2	Termination by Contractor	Employer
		16.4	Payment after termination by contractor	Employer
		17.2	Liability for care of works	Employer
		17.4	Indemnities by Contractor	Contractor
		17.5	Indemnities by Employer	Employer
		18.4	consequences of exceptional event	Employer
		20.1	Claims	E+c
		20.2	Claims for Payment and/or EOT	E+c

Table 0-2 NEC3 Cost Claim related Clauses and Liabilities

Clause Type	CLAUSE/SUB-CLAUSES	DESCRIPTION	LIABILITY
CORE CLAUSES	14.3	PM may give instructions to contractor which changes the works information or key date	Employer
	16.1	Early warning by any party to notify other party of event which could cost time or money	E+C
	17.1	Ambiguities and Inconsistencies	E+C
	19.1	Prevention of event which is not under the control of any party	Employer
	20.1	Providing the works according to works information	Contractor
	25.2	Cost incurred by Employer in case the Contractor does not work with "others" as stated in works information	Contractor
	25.3	additional costs if the work does not meet the condition stated for a key date	Contractor
	31.2	site access is need to show the programme submitted by contractor	contractor
	32.1	Revising the programme	Contractor

	33.1	Access and the use of site	Employer
	34.1	Instructions to stop or not to start the work	employer
	36.1	instruction to Acceleration notice	Employer
	36.2	Reply to Acceleration	Contractor
	40.2	parties need to provide sources for tests and inspections stated in works information	
	40.4	Repetition of failed tests	Contractor
	40.6	assessment by PM if the defect(s) found in the tests	Contractor
	45.1 and 45.2	Uncorrected defects	Contractor
	50	assessing amount(money) due	Employer
	60.1	definition of Compensation events	Employer
	60.2	judging the physical conditions for the purpose of assessing a compensation event	Contractor
	60.3	inconsistency of site information	Contractor
	61.1	Compensation Event Arising from PM instruction	Employer

	61.3	Contractor notifying abour compensation event	Contractor
	61.6	Uncertan effects about compensation event	Employer
	62.1	Submission of quotations for compensation event	Contractor
	63	Assessing Compensation events	Employer
	64.1	conditions for PM assessing a compensation event	Employer
	64.4	Contractor's obligations in case PM does not assess a compensation event	Employer
	80.1	Employer's Risks	Employer
	81.1	Contractor's risks	Contractor
	83	Indemnities	E+C
MAIN OPTION A CLAUSES- PRICED CONTRACT WITH ACTIVITY SCHEDULE	63.14	Assessing Compensation events	E+C
	65.4	Implementing compensation events	
MAIN OPTION B- PRICED CONTRACT WITH BILL OF QUANTITIES	60.6	PM corrects the mistakes in BOQ	Employer
	60.7	Contractor's assessment of Compensation events	Contractor

	63.10 and 63.13	Assessing Compensation events	E+C
MAIN OPTION C- TARGET CONTRACT WITH ACTIVITY SCHEDULE	40.7	Tests and Inspections	Employer
	63.15	Assessing Compensation events	E+C
MAIN OPTION D- TARGET CONTRACT WITH BILL OF QUANTITIES	40.7	Tests and Inspections	Employer
	60.6	PM corrects the mistakes in BOQ	Employer
	60.7	Contractor's assessment of Compensation events	Contractor
	63.14----63.15	Assessing Compensation events	E+C
MAIN OPTION E- COST REIMBURSABLE CONTRAC	40.7	Tests and Inspections	Employer
	63.15	Assessing Compensation events	E+C
SECONDARY OPTION X2	X2.1	Change in Law	Employer
SE ONDARY OPTION X7	X7.1	Delay Damages	Contractor
	X7.2 & X7.3	Delay Damages	Employer
SECONDARY OPTION 15	X15.1	Limitation of the contractor's liability for his design to reasonable skill and care	Contractor