DIGITIZATION OF PROCESSING OF INTERIM PAYMENT CERTIFICATE (IPC) USING BUILDING INFORMATION MODELLING

By

Abdul Mannan

MS CE&M (00000276624)

Department of Construction Engineering and Management

School of Civil and Environmental Engineering (SCEE)

National University of Sciences and Technology (NUST),

Islamabad, Pakistan

(2022)

DIGITIZATION OF PROCESSING OF INTERIM PAYMENT CERTIFICATE (IPC) USING BUILDING INFORMATION MODELLING

By

Abdul Mannan

(2018-NUST-MS-CE&M 00000276624)

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

in

Construction Engineering & Management

Thesis supervisor: Dr. Ing. Abdur Rehman Nasir

School of Civil and Environmental Engineering (SCEE)

National University of Sciences and Technology (NUST),

Islamabad, Pakistan

THESIS ACCEPTANCE CERTIFICATE

Certified that the final copy of MS thesis written by Mr. Abdul Manan (Registration No. NUST2018MSCE&M00000276624), of PG Wing – SCEE has been examined by undersigned, found complete in all respects as per NUST statutes / Regulations/MS Policy, is free of plagiarism, errors, and mistakes and is accepted as partial fulfillment for award of MS/MPhil degree. It is further certified that necessary amendments as pointed out by GEC members and foreign/local evaluators of the scholar have also been incorporated in the said thesis.

Signature: _____

Name of Supervisor: Dr.-Ing. Abdur Rehman Nasir

Date: _____

Signature (HOD): _____

Date: _____

Signature (Dean/Principal): _____

Date: _____

National University of Sciences and Technology

MASTER′S THESIS WORK

We hereby recommend that the dissertation prepared under our supervision by Abdul Manan (Registration No. NUST2018MSCE&M00000276624) Titled: **Digitization Of Processing of Interim Payment Certificate (IPC) Using Building Information Modelling** be accepted in partial fulfillment of the requirements for the award of **Master of Science** degree with _____ grade.

Examination Committee Members

1. Name: Dr. Khurram Iqbal Ahmad Khan Signature: _____

2. Name: Dr. Muhammad Usman Hassan Signature: _____

Supervisor's name: Dr.-Ing Abdur Rehman Nasir Signature: _____

Date: _____

_____

Date

_____

Head of Department

COUNTERSINGED

_____

Date: _____

Dean/Principal

Certificate of Approval

This is to certify that the research work presented in this thesis, entitled "Digitization of processing of Interim Payment Certificate (IPC) using Building Information Modelling (BIM)" was conducted by Mr. Abdul Manan under the supervision of Dr. Ing. Abdur Rehman Nasir.

No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the School of Civil and Environmental Engineering (SCEE) in partial fulfillment of the requirements for the degree of Master of Science in Field of Construction Engineering and Management

School of Civil and Environmental Engineering, National University of Sciences and Technology, Islamabad, Pakistan.

Student Name: Abdul Manan Signature: _____

Examination Committee:

a) Dr. Khurram Iqbal Ahmed Khan Signature: _____

Assistant Professor

Department of Construction Engineering & Management (CE&M)

b) Dr. Muhammad Usman Hassan Signature: _____

Assistant Professor

Department of Construction Engineering & Management (CE&M)

Supervisor: Dr-Ing Abdur Rehman Nasir Signature: _____

Name of HOD: Dr-Ing Abdur Rehman Nasir Signature: _____

Author's Declaration

I, Abdul Manan, hereby state that my MS thesis titled Digitization of processing of Interim Payment Certificate (IPC) using Building Information Modelling (BIM) is my own work and has not been submitted previously by me for taking any degree from this University National University of Sciences and Technology (NUST) or anywhere else in the country/ world.

At any time if my statement is found to be incorrect even after I graduate, the university has the right to withdraw my MS degree.

Name of Student: Abdul Manan

Date: _____

Plagiarism Undertaking

I solemnly declare that research work presented in the thesis titled "Digitization of processing of Interim Payment Certificate (IPC) using Building Information Modelling (BIM)" is solely my research work with no significant contribution from any other person. Small contribution/ help wherever taken has been duly acknowledged and that complete thesis has been written by me.

I understand the zero-tolerance policy of the HEC and National University of Sciences and Technology (NUST) towards plagiarism. Therefore, I as an author of the above titled thesis declare that no portion of my thesis has been plagiarized and any material used as reference is properly referred/cited.

I undertake that if I am found guilty of any formal plagiarism in the above titled thesis even after award of MS degree, the University reserves the rights to withdraw/revoke my MS degree and that HEC and the University has the right to publish my name on the HEC/University website on which names of students are placed who submitted plagiarized thesis.

Student/Author Signature: _____

Name: Abdul Manan

Acknowledgements

I, Abdul Manan, am grateful to Almighty Allah for giving enough strength to complete the research work. Furthermore, I would be inclined to pay debt of appreciation to my advisor Dr. Ing. Abdur Rehman Nasir, for his fathomless supervision, valuable time and help, to complete my research work. I am also in debt to Dr. M. Usman Hassan and other fellows for their support.

I am highly indebted to Mr. Usman Aftab, who has been a tremendous help during the whole digitization process of the research. I am thankful to all the respondents who were seminal to complete the research. I pay gratitude to the respected GEC members for their constant support and guidance. I am thankful to my friends, the esteemed faculty and administration of the Department of Construction Engineering and Management (CE&M) of National University of Sciences and Technology (NUST), Pakistan, for providing the required technical inputs, support, and resources for the work.

Abstract

Construction contracts are vital for any project, and therefore right choice of payment system is extremely important. Research have shown that about 62.8% of contractors have faced these payment delays on Construction projects. One of the key reasons for delay in payments is that Interim Payments are still manually prepared by the Contractor and physically verified by the Client which requires a lot of time to process. The adaption of new technologies has not kept pace with the growth of industry due to lack of studies on the impact of these technologies in construction industry. However, advance technologies like BIM are now being adapted. Thus, this research purposes to digitize the processing of IPC using BIM technology. Three objectives guide this research: To identify the existing inefficiencies, present in processing of Preparation & Certification of IPC; To develop a BIM-based framework for efficient Preparation & Certification of IPC; To validate the developed framework through a digital platform using case study. Based on detailed Literature Review, 30 inefficient factors were identified. A preliminary survey was done to authenticate the inefficiencies found from literature and sample of thirty was considered and in total thirty responses were recorded. After that those BIM features were identified from the literature which can adequately resolve the identified inefficiencies and a Feature-Factor matrix is developed. Feature – Factor matrix is used to visualize that which factor of BIM could mitigate the effect of any inefficiency found in literature and then research methodology is developed. Following that, a prototype plug-in is developed in BIM platform and an under-construction House project is used as a case study. The developed plug-in includes two panels of "generate" and "Approval" for Contractor and Consultants respectively. Using those, a contractor must generate WCRs and after approval from consultant, the quantity of WCRs has to be added in Measurement sheet to update "Abstract of Cost" following that, the Contractor needs to re-submit all the documents for approval from consultant. Third IPC of the said house project has been prepared and validated using the developed system and the working of developed plug-in has been shared with

industry experts for validation of the developed system in the form of Questionnaire survey. The results obtained from that Questionnaire are satisfactory and signifying that the plug-in could be implemented to automate the processing of IPC in construction projects.

Table of Content

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Background Study

Construction contracts are vital for any project, and the right choice of payment system is extremely important(Odeh & Battaineh, 2002). The efficacious execution of any construction project is highly dependable on the appropriateness of payment system adapted as per the Project's characteristics and client's demand from the project.(Abotaleb & El-adaway, 2017). The pace of the work progress for any construction project can be directly related to uninterrupted funding of project (Ramachandra & Rotimi, 2015; Cheng et al., 2010). i.e. the flow of cash of the Contractor executing the project can be highly affected by delaying the approval process of check requests, invoices, release of retention money to the Contractor (Odeyinka et al., 2008). If we look from another point of view, the client failure to abide by the specified payment program will directs the Contractors injecting extra finances and enhance the risk of insolvency (Odeyinka et al., 2008). To this upshot, the release of timely interim payments to the Contractor is required to finance the construction work advancement (El-adaway et al., 2014).

Delay in payments to the Contractor have always been linked to the Client's liability such as some author (Odeyinka et al., 2008; Sin, 2006)suggests that delays in payment are deliberate and caused by upper-tier construction parties in many countries. However, the payment system that has been devised by the Construction contracts allow the Consultant to authenticate all the construction activities incorporated by the Contractor in monthly progress payment which is a time taking process. The delay in payment to the Contractor could affect the project adversely in terms of degradation of quality by the Contractor, dispute generation between the Client and the Contractor and also could lead to the

suspension of work. (Abotaleb & El-adaway, 2017). So, by accelerating the process of quantities validation by the Consultant, the payment process can also be fast-tracked by the Client.

This research will focus on the automation of payment system to the Contractor which will aid to lessen the mandatory time for Client to authenticate the quantities provided by the Contractor in the interim payment application thus reducing the overall time for payment to the Contractor. The process starts by automating the check request which includes the work executed by the Contractor and forms the basis of interim payment. The consultant then physically examines the executed quantity and confirms or rejects the work through automated channel resulting in addition of obligatory monthly compensation to the Contractor by the Client or rework by the Contractor for later case. Using that technique, the Contractor will be able to automate all his executed work and once achieved the targeted payment criteria set forth by the Client in Contract documents, he will be able to claim the interim payment in an automated way from Client who will be well aware of the Contractor obligatory payment using the same platform. In order to automate the whole interim payment process, Building Information Modelling (BIM) technique would assist to carry all the stakeholders of the project on a solely platform as integration of BIM with Building Automation System (BAS) is already being used to automate energy managing, building design optimization and building fault detection (Tang et al., 2020). So, BIM technique would be helpful to automate the process of IPC generation as well.

1.2 Level of Research Already Carried Out on the Proposed Topic

A lot of research accomplished on the issues related to interim payment certificate generation and suggestions have been made regarding proper administering the payment process like (Demachkieh & Abdul-Malak, 2019) proposed a framework that highlights set of practices which will actively avoid the disagreement over executed work. Similarly, the research carried out by (Abdul-Rahman et al., 2014) provides the indicators that causes delay in payment by the Client. As (Kartam & Kartam, 2001)

designates delayed payments as second main operative risk that grounds for project to be delayed. As per findings of (Van der Merwe et al. 2011) the main reason of delayed payments is Client in Construction projects being executed in South Africa.

Similarly, automation is not a novel perception in construction industry (Ali et al., 2020) automates the claims management system using Building Information Modelling (BIM) technique and a plugin is established in Autodesk Revit for proper management of EOT claims. (Song et al., 2017) works on linking BIM with Daily Work Orders from Construction industry and conclude that BIM based Bill of Materials cannot be created with the elements modeled in LOD 300 and must be modeled on LOD 400 for that purpose. Another handy research carried out (Davidson et al., 2019) on integrating the Virtual Reality VR with BIM for factually generation of Bill of Quantity. But this research is only limited to windows and furniture items.

Hence up till now, work have been carried out on automation of Bill of Quantity and constraints that have been encountered during the preparation of monthly payment have also been pointed out (Sopihia et al., 2016).

1.3 Reason/Justification for the Selection of the Topic

Construction projects are very dynamic and timely payments are required to pay for the materials, sub-contractor, labor and other liabilities (Abdul-Rahman et al., 2014) and once payment related issues starts emerging it got worse with time and moves the financial load from one stakeholder to the other (Scholnick et al., 2013). Therefore, there is an immense need of such a payment system which resolves the matter of physical verification of all the executed items by the contractor at time of interim payment by the Client and hence results in overall reducing the time for interim payment to the Contractor.

The solution to this delayed payment issue and laborious work of physical verification of incorporated items is automation of the Interim payment application generated by the Contractor which not only

help the Contractor to claim his monthly payment without any delay but also keep the Client well aware regarding obligatory payment of the Contractor for executed work all the time thus reducing the payment related disputes as well.

1.4 Objectives

Main objectives for this research are:

- To identify the existing inefficiencies, present in processing of Preparation & Certification of IPC.
- To develop a BIM-based framework for efficient Preparation & Certification of IPC.
- To validate the developed framework through a digital platform using case study.

1.5 Relevance to National Needs

Pakistan construction industry is still working on manual system which is quite laborious and time taking and hence most of the construction projects in Pakistan results in time overrun from the actual completion date specified in the contract. This situation led to disputes among the stakeholders and generation of Cost Claims by the Contractor. To improve the financial condition of the project, BIM technology must be acquainted by the Pakistan construction industry like other developing countries. This study will help the Contractor to automate its examination of project activities being executed and generation of payment against each activity and also diminish the risk of overbilling by the Contractor which will help the procedure.

1.6 Advantages

This research will be quite helpful for all the stakeholder as money is consider as “King” of the construction industry and as most of the disputes are related to timely payment issues in construction industry (Kartam & Kartam, 2001; Ramachandra & Rotimi, 2015; Abdul-Rahman et al., 2014; Chan & Suen, 2005; Cheung & Yiu, 2006; Kennedy, 2006). So, by automating the process of payment

generation against the executed activities will not only reduce the effort of Contractor but also help the Consultant in validation of the executed quantity. Thus, the process will reduce the effort and time of all stakeholders in generation of payment and on the other hand Client will also be well aware of its liability as well.

1.7 Areas of Application

This research mainly focuses on payment issue related to construction industry and hence provides a solution to reduce the payment related disputes among the stakeholders. It also emphasis on implications of modern techniques in the construction industry as well. It encourages the use of BIM on construction sites for better management of construction activities and to reduce the uncertainty in construction projects up to some extent.

1.8 Thesis Organization

In this thesis, Chapter 01 includes the introduction of the topic in detail, the research gap, the objectives of this research and also includes the significance of this research in our industry. Chapter 2 consists of background of this research and all the research that has been done earlier related to the selected topic. It also elaborates those inefficiencies present in the current system for preparation and Certification of IPC through vast literature review and those BIM features were identified which can nullify those inefficiencies present up to maximum extent. Based on these findings, a feature factor matrix is developed. Chapter 3 involves the methodology adapted to achieve the required results and to meet the objectives. Results will be discussed in upcoming chapters.

CHAPTER 2: LITERATURE REVEIW

2.1 Background

This Chapter focuses mainly on the past studies carried out on processing of payments in the Construction industry. It will also explain the payment, types of payments in Construction Industry, the Standards which Construction Industry is ensuing in processing of payments. Timely release of payment in construction industry is vital because the Construction projects are considered as mega projects and involves a huge capital (Abotaleb & El-adaway, 2017). The performance of Contractor also depends on the timely payment for smooth running of activities (Ramachandra & Rotimi, 2015; Cheng et al., 2010). Delays in processing of these payments disturb the cash inflow and outflow of the Contractor leading to consequence delay in completing the project(Cheng et al., 2010). Most of the time delay in payment has been associated with the failure of Paymaster to finance the project (Odeyinka et al., 2008; Sin, 2006).

2.2 Payment in Construction Industry:

It is considered as the summation of amount paid to the Contractor after execution of the task assigned to them (Ansah, 2011). For a successful completion of the project timely payments to the Contractor plays a pivotal role (Arditi & Chotibhongs, 2005). The methods and mode of payment varies from project to project and guidelines of various types of payments are provided in traditional Standard Construction Contract documents. It is up to the concerned authorities to choose the payment type and method of payment(Odeh & Battaineh, 2002). This study will brief about types of payment provided in several traditional contracts that are regularly used in construction industry and are most related to this research.

2.3 Types of payment:

Due to the scope constraint of the study advance payment and final payment are not discussed here. Periodic payments, also known as progress or interim payments, and phase payment, also known as stage payment, are found to be most relevant to this research. Therefore, only these two types of payments are briefly discussed here. (Ansah, 2011) defined these payment types as follow

2.3.1 Interim Payment:

Interim payments (Periodic payments) are made after specified periods in a project. Periods are specified by concern parties for generation of payment bill by contractor, vetting by engineer and payment of this bill by client. Durations for each step of the whole process of payment is generally the time period as fixed in the contract conditions signed.

2.3.2 Phase Payment:

Payments are usually made at the definite stages of work. Also in some projects, specified monetary value of work is defined as a stage where payment has to be made. This payment type is mostly opted for in combination with small lump sum contract where measurements are not finalized and a fixed proportion of the total sum of contract is decided to be paid over certain phases.

2.4 Standard interim payment duration of various traditional standard construction contracts:

This comparison of standard interim payment duration is made among the traditional standard traditional contracts of American Institute of Architects (AIA), Consensus Docs, Engineers Joint Contract documents committee (EJCDC), International Federation of Consulting Engineers (FIDIC), the New Engineering Contracts (NEC) and Pakistan Engineering Council (PEC).

In construction contracts standards published by FIDIC and PEC standard duration for interim payments is 56 days and 44 days respectively (Getachew, n.d;PEC, 2007). Whereas other standard contracts offer a lesser duration such as NEC-3 (21Days), ConsensusDocs-200 (20 Days), EJCDC-C700 (20 Days), AIA-A201 (10 Days). Thus, traditional contracts offer various methods and duration of interim payments and parties involved have the choice to agree upon any method suited to their project. Any payment made after the contractual duration is a delayed payment and incurs either a financial penalty or an extension in deadline. Various traditional contracts along with their interim payment duration are shown in Table 2-1.

Table 2-1: Contract Types & Payment duration

Type of Contract	**Application to be submit by Contractor**	**Approval by the Consultant**	**Payment by the Client**	**Total time duration for payment release**
FIDIC 1987 (1992)	At the end of the month.	Within the duration of twenty-eight days after Contractor Application	Within the duration of twenty-eight days after The Engineer's Certification	56 Days
FIDIC 1999	At the end of the month.	Within the duration of twenty-eight days after Contractor Application	Within the duration of fifty-six days after Contractor application	56 Days
PEC	At the end of the month.	Within the duration of twenty-eight days after Contractor Application	Within the duration of twenty-eight days after The Engineer's Certification	56 Days
NEC 3	Predetermined assessment date	Within seven days after assessment date	Within the duration of twenty-one days after assessment date	21 Days
Consensus Docs 200	Specified calendar date of each month	Undefined	Within 20 days after Contractor application	20 Days
EJCDC C700	At least 20 days before due date of payment	Within 10 days after Contractor application	Within 10 days after application approval	20 Days

Type of Contract	Application to be submit by Contractor	Approval by the Consultant	Payment by the Client	Total time duration for payment release
AIA A201	At least 10 days before due date of payment	Within 07 days after Contractor application	Within 03 days after application approval	10 Days

2.5 Elongation in interim payment processing and its effects:

Construction industry deals with large physical projects which involve big cash flows (Abdul-Rahman et al., 2014). Cash inflow after an elongated duration cause dire consequences to contractor's financial health and project successful completion (Ye & Rahman, 2010). Cash flow problems due to elongated interim payment duration have existed for a long time in industry and still persist (Wu et al., 2008). Cash flow problems, construction disputes, construction insolvencies, construction delays, low construction productivity, addition of extra amount in bids are some of major negative effects of elongated interim payment duration (Touran et al., 2004; Wong & Hui, 2006).

2.6 Factors causing delay in Processing of Payments:

Numerous factors cause delay in processing of Interim Payment in construction projects. These factors vary in nature depending upon their primary source (Ramachandra & Rotimi, 2015). This study categorizes these factors considering the stage of processing of Interim Payment. The processing of Interim Payment involves three main stakeholders i.e. Contractor, Consultants and Client.

As per Contractual Conditions, the Contractor needs to submitted to the Engineer after the end of each month or time period provided in the Contract copies of Interim Payment Application duly signed by the Contractors' representative as per Sub-Clause 15.1, in such form as the Engineer

may from time to time prescribe, showing the amounts to which, the Contractor considers himself to be entitled up to the end of the month in respect of:

a) Value of the Permanent Works executed.
b) Any other items in the Bill of quantities including those for Contractor's Equipment, Temporary Works, day works and others.
c) Any other sum to which the Contractor may be entitled under the Contract or otherwise.

The Engineer (Consultants' Representative) shall then, within time provided in the Contract, Certify the sum of payment which he considers payable to the Contractor and submit it to the Employer after receiving such statements. The Employer is then bound to arrange the funds for imbursement to the Contractor within the time period provided in Contract documents

A detailed literature review has been carried out and almost 50 research papers were accessed using the keyword "delay in payment to Contractor", "Interim Payment", "Processing of payment", "Factors causing delay in payments" etc. From these papers, initially 40 factors were identified; however, some of these factors were making the same sense. So, these factors were merged under a same head and out of initially identified, 30 factors were finalized and divided phase wise as the Interim Payment processes as explained earlier i.e., Initiation phase (when matter is with the Contractor), Certification/Validation (when matter is with the Consultant), Payment phase (when matter is with the Client) as shown in Table given below along with the frequency of their occurrence in the past papers.

Table 2-2: Factors Causing Delay in Processing of IPC during Initiation Phase

Sr. No.	Phase	Factors Causing delay in Processing of Interim Payment	References
1	Initiation Phase (When matter is with the Contractor)	Breach of any Contract term of Project by the Contractor	(Nor et al., 2014), (M. E. Che Munaaim, 2012), (Ansah, 2011), (Ye & Rahman, 2010), (Peters et al., 2019), (Onososen, 2019), (Senarathne et al., 2020), (Muthi, 2019).
2		Poor documentation procedure practiced	(Ansah, 2011), (Ramachandra et al., 2015), (Ye & Rahman, 2010), (Peters et al., 2019), (Kenyatta, 2016a), (Sopihia et al., 2016), (Muthi, 2019).
3		Disputed work	(Nor et al., 2014), (M. E. Che Munaaim, 2012), (Ansah, 2011), (Ramachandra & Rotimi, 2015), (Peters et al., 2019), (Odenigbo et al., 2020), (Yunianto & Rarasati, 2021).
4		Failure to Understand Contract Agreement	(Ansah, 2011), (Odenigbo et al., 2020), (Kenyatta, 2016a), (Onososen, 2019), (Yunianto & Rarasati, 2021), (Senarathne et al., 2020).
5		Inexperienced Project Personnel	(Abdul-Rahman et al., 2014), (Odeh & Battaineh, 2002), (Ye & Rahman, 2010), (Peters et al., 2019), (Yunianto & Rarasati, 2021).
6		Poor Quality of Work	(Judi et al., 2021), (Odenigbo et al., 2020), (Sopihia et al., 2016), (Kenyatta, 2016b), (Yunianto & Rarasati, 2021).
7		Work done doesn't reach the limit of IPC	(Abdul-Rahman et al., 2014), (Ye & Rahman, 2010), (Peters et al., 2019), (Sopihia et al., 2016),(Senarathne et al., 2020).
8		Wrongly calculated claims	(Onososen, 2019), (Yunianto & Rarasati, 2021), (Senarathne et al., 2020).
9		Non-BOQ work done	(Odenigbo et al., 2020), (Senarathne et al., 2020).

Table 2-3: Factors Causing delay in Processing of IPC during Validation/Certification Phase

Sr. No.	Phase	Factors Causing delay in Processing of Interim Payment	References
1	Certification/Validation Phase (when matter is with the Consultant)	Disagreement on valuation of Work done	(Tun et al., 2021), (Ibrahim et al., 2012), (Nor et al., 2014), (Ansah, 2011), (Ye & Rahman, 2010), (Peters et al., 2019), (Odenigbo et al., 2020), (Kenyatta, 2016a), (Onososen, 2019), (Kenyatta, 2016b), (Yunianto & Rarasati, 2021), (Senarathne et al., 2020), (Muthi, 2019).
2		Failure to value & certify the work done by Contractor	(Tun et al., 2021), (Abdul-Rahman et al., 2009), (Abdul-Rahman et al., 2011), (Ye & Rahman, 2010), (Mara, 2011), (Peters et al., 2019), (Judi et al., 2021), (Odenigbo et al., 2020), (Agyei-kumi, 2017), (Onososen, 2019), (Senarathne et al., 2020), (Muthi, 2019).
3		Insufficient/ambiguous information provided for Certification	(Nor et al., 2014), (Abdul-Rahman et al., 2014), (Ansah, 2011), (Abdul-Rahman et al., 2011), (Peters et al., 2019), (Judi et al., 2021), (Kenyatta, 2016a), (Sopihia et al., 2016), (Onososen, 2019), (Kenyatta, 2016b), (Yunianto & Rarasati, 2021).
4		Slow process of approving Variation Orders	(Oyewobi et al., 2016), (A.A., 2015), (Osman et al., 2009), (Ye & Rahman, 2010), (Peters et al., 2019), (Judi et al., 2021), (Odenigbo et al., 2020), (Kenyatta, 2016b), (Yunianto & Rarasati, 2021), (Senarathne et al., 2020).
5		Conflict among the parties involve	(Tun et al., 2021), (M. E. Che Munaaim, 2012), (Peters et al., 2019), (Judi et al., 2021), (Suhaidah Sahab & Ismail, 2011), (Onososen, 2019), (Yunianto & Rarasati, 2021), (Muthi, 2019).
6		Difficulties in reaching a settlement between stakeholders	(Tun et al., 2021), (Abdul-Rahman et al., 2009), (Abdul-Rahman et al., 2014), (Ye & Rahman, 2010), (Peters et al., 2019), (Agyei-kumi, 2017), (Onososen, 2019), (Kenyatta, 2016b).
7		Major defects in Construction Works	(Tun et al., 2021), (Raman et al., 2016), (M. E. Che Munaaim, 2012), (Ye & Rahman, 2010), (Peters et al., 2019), (Kenyatta, 2016b).
8		Involvement of too many parties for Certification of Payment	(Abdul-Rahman et al., 2009), (Abdul-Rahman et al., 2014), (Abdul-Rahman et al., 2011), (Ye & Rahman, 2010), (Judi et al., 2021), (Onososen, 2019).

Sr. No.	Phase	Factors Causing delay in Processing of Interim Payment	References
9	Certification/Validation Phase (when matter is with the Consultant)	Perception that late certification is acceptable for few days	(Nor et al., 2014), (Abdul-Rahman et al., 2011), (Ye & Rahman, 2010), (Peters et al., 2019), (Suhaidah Sahab & Ismail, 2011), (Yunianto & Rarasati, 2021).
10		Poor Communication / Flow of information among parties involve	(M. E. Che Munaaim, 2012), (Odenigbo et al., 2020), (Agyei-kumi, 2017), (Yunianto & Rarasati, 2021), (Senarathne et al., 2020).

Table 2-4: Factors Causing delay in Processing of IPC during Payment Phase

Sr. No.	Phase	Factors Causing delay in Processing of Interim Payment	References
1	Payment Phase (when matter is with the Client)	Poor Financial Management by the Client	(Tun et al., 2021), (Abdul-Rahman et al., 2009), (Abdul-Rahman et al., 2014), (M. E. Che Munaaim, 2012), (Ansah, 2011), (Abdul-Rahman et al., 2011), (Ye & Rahman, 2010), (Peters et al., 2019), (Judi et al., 2021), (Suhaidah Sahab & Ismail, 2011), (Odenigbo et al., 2020), (Agyei-kumi, 2017), (Kenyatta, 2016a), (Onososen, 2019), (Kenyatta, 2016b), (Yunianto & Rarasati, 2021), (Senarathne et al., 2020), (Muthi, 2019).
2		Deliberate delay for some benefits	(Abdul-Rahman et al., 2014), (M. E. Che Munaaim, 2012), (Ansah, 2011), (Ye & Rahman, 2010), (Peters et al., 2019), (Judi et al., 2021), (Odenigbo et al., 2020), (Kenyatta, 2016a), (Onososen, 2019), (Yunianto & Rarasati, 2021), (Muthi, 2019).
3		Local Culture/Attitude of late payment	(Tun et al., 2021), (Abdul-Rahman et al., 2014), (Ye & Rahman, 2010), (Judi et al., 2021), (Suhaidah Sahab & Ismail, 2011), (Agyei-kumi, 2017), (Kenyatta, 2016a), (Kenyatta, 2016b), (Yunianto & Rarasati, 2021), (Muthi, 2019).
4		Scarcity of Capital to finance Project	(Abdul-Rahman et al., 2009), (Abdul-Rahman et al., 2014), (Ye & Rahman, 2010), (Peters et al., 2019), (Judi et al., 2021), (Odenigbo et al., 2020), (Kenyatta, 2016a), (Kenyatta, 2016b), (Yunianto & Rarasati, 2021).

Sr. No.	Phase	Factors Causing delay in Processing of Interim Payment	References
5	Payment Phase (when matter is with the Client)	Complex Contractual Provisions	(Nor et al., 2014), (M. E. Che Munaaim, 2012), (Ansah, 2011), (Agyei-kumi, 2017), (Kenyatta, 2016a), (Yunianto & Rarasati, 2021), (Senarathne et al., 2020), (Wu et al., 2008).
6		Poor Economic & Market Conditions	(Tun et al., 2021), (Ramachandra & Rotimi, 2015), (Ye & Rahman, 2010), (Judi et al., 2021), (Onososen, 2019), (Kenyatta, 2016b), (Yunianto & Rarasati, 2021).
7		Clients' lack of trust on Consultants' Valuation	(Abdul-Rahman et al., 2014), (Ye & Rahman, 2010), (Peters et al., 2019), (Odenigbo et al., 2020), (Kenyatta, 2016a), (Senarathne et al., 2020).
8		Short of Current Year's Project	(Tun et al., 2021), (Nor et al., 2014), (Agyei-kumi, 2017), (Yunianto & Rarasati, 2021).
9		Clients' assumption that Contractor will finance the project	(Abdul-Rahman et al., 2014), (Ye & Rahman, 2010), (Yunianto & Rarasati, 2021), (Senarathne et al., 2020).
10		Elongated Payment terms in Contracts	(Abdul-Rahman et al., 2014), (Ramachandra et al., 2015), (Wu et al., 2008).
11		Inequality of Contractual bargaining power	(Suhaidah Sahab & Ismail, 2011).

2.7 Remedies for delayed Payments:

There is a lot of research done on the issues related to interim payment certificate generation and suggestions have been made regarding proper administering the payment process like (Demachkieh & Abdul-Malak, 2019) proposed a framework that highlights set of practices which will actively avoid the disagreement over executed work. Similarly, the research carried out by (Abdul-Rahman et al., 2014) provides the indicators that causes delay in payment by the Client. As (Kartam & Kartam, 2001) designates delayed payments as second main operative risk that reasons project delays. As per the findings of (Van der Merwe et al. 2011) the main reason of delayed payments is Client in Construction projects being executed in South Africa.

Similarly, automation is not a novel notion in construction industry (Ali et al., 2020) automates the claims management system using Building Information Modelling (BIM) technique and a plugin is established in Autodesk Revit for proper management of EOT claims. (Song et al., 2017) works on the linking of BIM with Daily Work Orders from Construction industry and concludes that BIM based Bill of Materials cannot be produced with the elements modeled in LOD 300 and must be modeled on LOD 400 for that purpose. Another handy research carried out (Davidson et al., 2019) on integrating the Virtual Reality VR with BIM for real time generation of Bill of Quantity. But this research is only limited to windows and furniture items.

Hence up till now, work have been carried out on automation of Bill of Quantity and constraints that have been encountered during the preparation of monthly payment have also been pointed out (Sopihia et al., 2016).

2.8 BIM Concepts & Benefits

Building information Modeling (BIM) is a procedure of modeling, sharing and handling digital information during designing phase, through construction phase and to post construction phases (Ali et al., 2018a; Ghaffarianhoseini et al., 2017; Volk et al., 2014). Figure 2-1 shows that the information can be of parametric geometrical, technical and contractual type (Ali et al., 2018a; Ghaffarianhoseini et al., 2017).BIM is a process which starts from a conceptual diagrams to n-dimensional digital footprint (Azhar, 2013).This information separate themselves from individual process in traditional construction to an integrated process and thus dividing BIM into separate levels (Hooper & Widén, 2015).

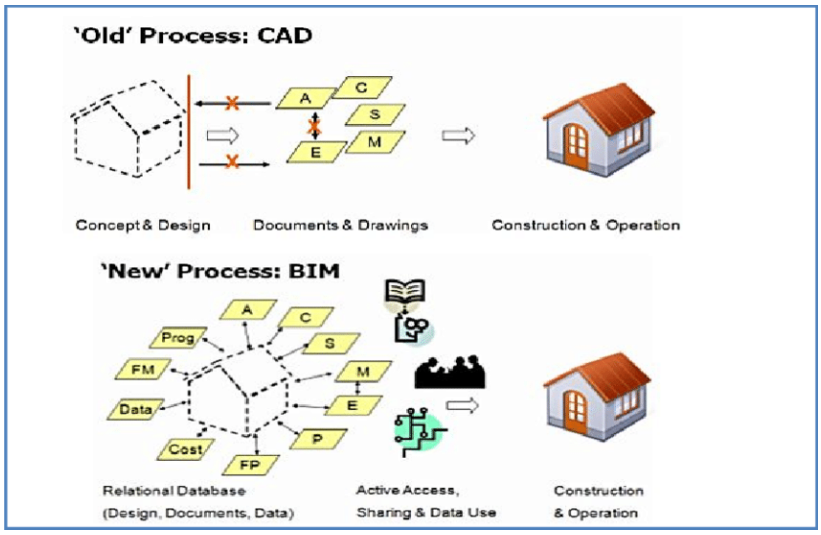


Figure 2-1 Difference between Current and BIM Construction methods

In 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 difference is realized using its parametric 3D information (Ali et al., 2018a; 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., 2018a; 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) Figure 2-2.

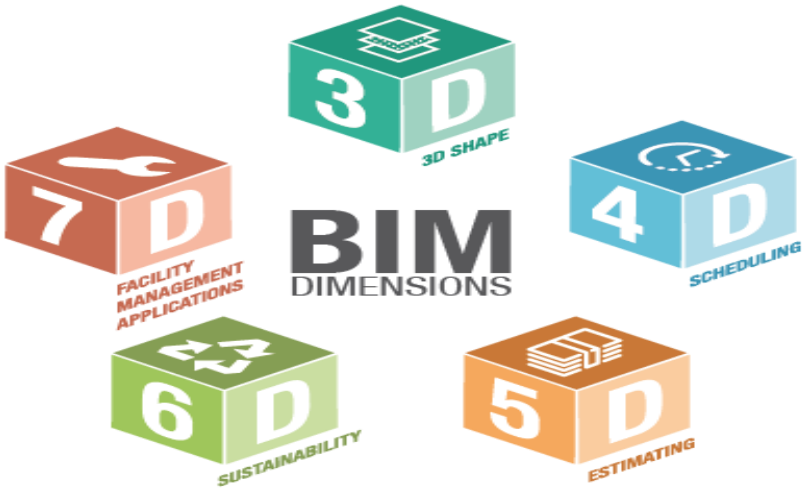


Figure 2-2 BIM Dimensions

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 form of groups and every team will deal with its responsibilities in a collaborative environment. Where there is 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 (Gibbs et al., 2017).NEC contracts provides guidance regarding integration of BIM into NEC contracts so that all the parties know their responsibilities (NEC, 2013).

2.9 BIM Platforms

Conventional Computer Aided Drawings (CAD) consists of text and lines only. It is unable to 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., 2018a; Azhar, 2013). Building information modeling is of two types, naming "open BIM" and "closed source BIM". Close BIM means all the project work has to 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, which allows it the flexibility to not to 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., 2018a). 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., 2018a).

2.10 Feature – Factor Matrix

In the current study, features of BIM which definitely have an effect on the project factors were identified through extensive literature review. 26 Research papers, articles, reports and dissertations were selected to identify features of Building Information Modelling (BIM). After a thorough reading of these readings, 13 features were identified. It is found that BIM features such as 3D visualization (Ghaffarianhoseini et al., 2017; Tulubas Gokuc & Arditi, 2017), Collaboration and Communication or Sharing of information (Doumbouya et al., 2016), (Zhang et al., 2013), On-Site design Changes (Ghaffarianhoseini et al., 2017; Chou & Chen, 2017), Design Coordination (Azhar, 2011; Chen, 2017), Effective and Unambiguous Documentation including drawings (Jin et al., 2017; Bynum et al., 2013), Quantity Takeoff and Cost Estimation (Chou & Chen, 2017), Interoperability (Stanley & Thurnell, 2014), Smart Contracts (Mason, 2017) significantly influence the performance throughout project's lifecycle.

As discussed in the objectives of this research, our first course of action was to find inefficient factors which cause delay in preparation and Certification of IPC through extensive literature review. After achieving this, the next step in the research is to make a factor-feature matrix. The main purpose of

factor-feature matrix is to identify key risk factors which can be resolved using adequate features of BIM. After listing down all the factors along Y-axis and features of BIM along X-axis, we would now be able to visualize that which feature of BIM affects which factor as shown in table.

Those factors reflected in red shade of feature – factor matrix cannot be resolved using any feature of the BIM. However, the factors shown in green shade have the tendency to get resolved by any one or more than one BIM feature shown in feature – factor matrix.

Table 2-5: Feature – Factor Matrix

FACTORS \ BIM FEATURES	3d Parametric Modeling	Collaboration/Communication / Sharing of Information	Design Productivity and Competitiveness	On Site Design Changes	Design Coordination	Better Visualization of on-site Construction	Quantity Takeoff (5D BIM)	Site Situation Awareness of Construction	Integrated Modeling	Smart Contracts	Effective/Unambiguous Documentation, Drawings	Interoperability	Qualitative Work
Poor Financial Management by Client													
Disagreement on Valuation of Work done						1	1						
Insufficient/ambiguous information Provided for Certification		1									1		
Slow processing of Variation Order				1									
Disputed Work					1								
Failure to value the Work done by Consultant						1	1						
Poor Communication/Flow of information among Parties		1											
Poor documentation Procedure Practiced											1		
Deliberate delay for some benefits													
Major defect in Construction Work/Rework	1												
Local Culture/Attitude of late Payment													
Wrongly Calculated Claims					1		1						
Poor Quality of Work					1								1
Conflict in the work involve									1				

FACTORS \ BIM FEATURES	3d Parametric Modeling	Collaboration/Communication / Sharing of Information	Design Productivity and Competitiveness	On Site Design Changes	Design Coordination	Better Visualization of on-site Construction	Quantity Takeoff (5D BIM)	Site Situation Awareness of Construction	Integrated Modeling	Smart Contracts	Effective/Unambiguous Documentation, Drawings	Interoperability	Qualitative Work
Difficulties in reaching settlement between parties									1				
Non-BOQ Work done					1								
Perception that late Certification is acceptable for few days													
Involvement of too many parties for Certification												1	
Work done doesn't reach IPC limit/Slow Pace					1			1					
Elongated Payment terms in Contract													
Poor Economic /Market Conditions of Client													
Inexperience Project Personnel								1					
Breach of any Contract term by the Contractor									1				
Complex Contractual Provisions										1			
Short of Current Year Projects													
Scarcity of Capital to finance Project													
Clients assume that Contractor will finance the Project													
Failure to understand Contract Agreement										1			

FACTORS \ BIM FEATURES	3d Parametric Modeling	Collaboration/Communication / Sharing of Information	Design Productivity and Competitiveness	On Site Design Changes	Design Coordination	Better Visualization of on-site Construction	Quantity Takeoff (5D BIM)	Site Situation Awareness of Construction	Integrated Modeling	Smart Contracts	Effective/Unambiguous Documentation, Drawings	Interoperability	Qualitative Work
Client's lack of trust on Consultant Valuation		1											
Inequality of Contractual bargaining power													

CHAPTER 3: RESEARCH METHODOLOGY

This chapter will discuss 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 the review of inefficiencies present in Preparation and Certification of IPC pointed out by different researchers and to validate these inefficiencies by industry experts.

After review, a feature – factor matrix will be developed to identify those key factors of delay in processing of IPC which can be resolved using adequate feature of Building Information Modeling (BIM) and then a framework will be developed for efficient preparation & Certification of IPC by nullifying the inefficiencies. That framework would then be validated by applying a case study.

3.1 Research Design

Figure 3-1 demonstrates the research design for this study. A systematic review of literature studies was carried out to identify the inefficiencies present in preparation and Certification of IPC, which is our first objective of the study. Those inefficiencies were discussed in detail in previous chapter Those inefficiencies were then validated from construction industry. The results are discussed ahead in this chapter.

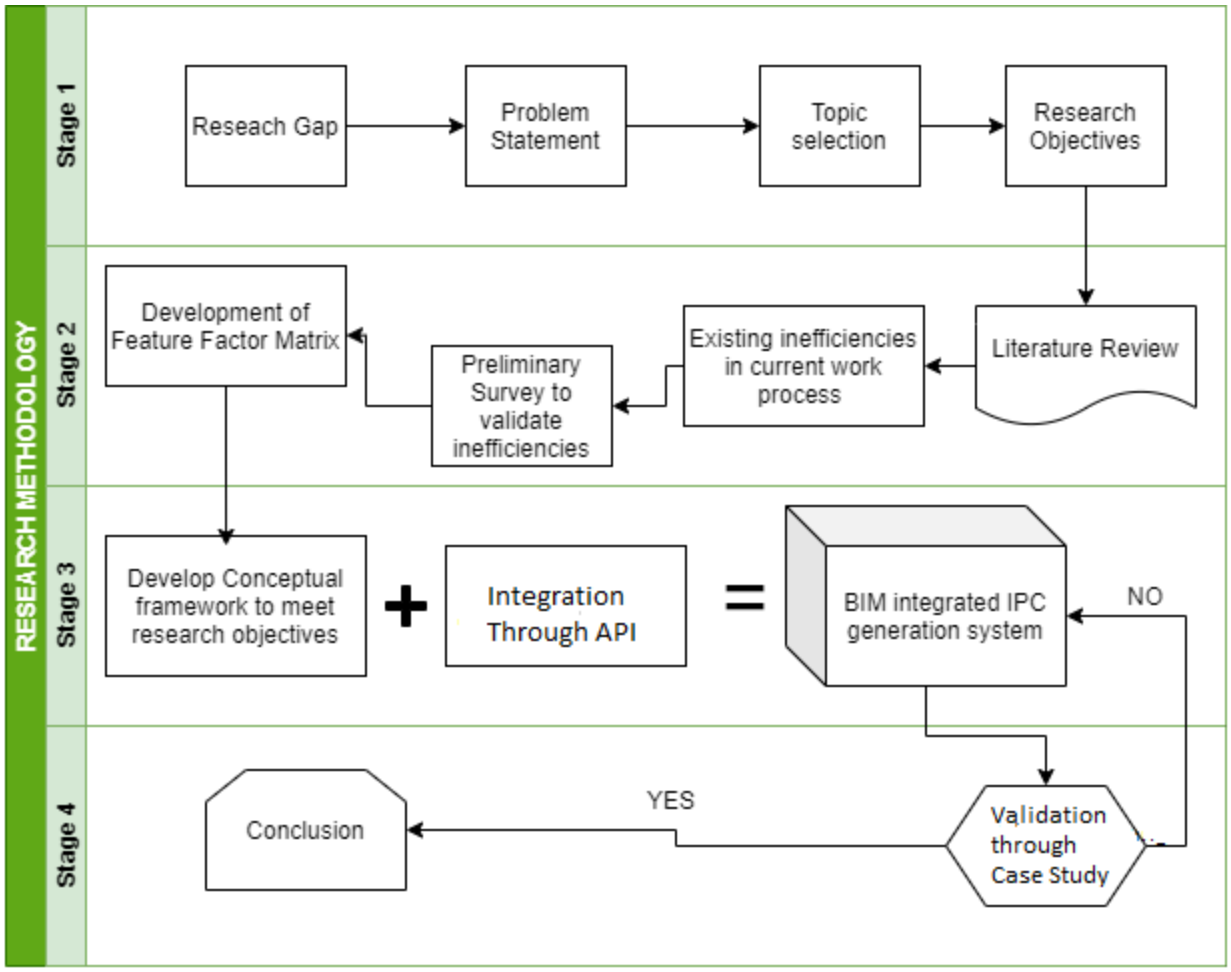


Figure 3-1 Research Design

In the second part of stage 2 of research, a Feature – factor matrix is developed to identify those key factors of delay in processing of IPC which can be resolved using adequate feature of Building Information Modeling (BIM) and basis on that, a framework would be developed for efficient Preparation and Certification of IPC. Making of the conceptual framework was our second objective. This conceptual framework elaborates the workflow of data in prototype built. The workflow will be discussed later in the chapter. In the last stage, that developed framework would then be validated using a case study to check its effectiveness.

3.2 Validation of Inefficiencies present in Preparation and Certification of IPC

Following literature review, a questionnaire was developed, and responses were collected to identify the existence of same issues in the industry. Data was collected from 35 respondents out which 5 responses were rejected because their experience was less than 5 years. Experts from the field included from all nature of parties of contract which are clients, contractors, consultants, Architects and sub-contractors. The field experts have vast knowledge of construction and specifically related to Interim Payments. Most of the respondents were somehow linked with Payment related matters in their representative organization. Their experience and major expertise are shown in Figure 3-2-1 & Figure 3-2-2 respectively. Most of the respondents are from Contractor & Consultant side as both the stakeholders are more involve in preparation and Certification of IPC. Field Experts were also asked if there were any additional inefficiency, they were no additional inefficiencies founded due to their merging nature with existing inefficiencies. These inefficiencies were then ranked in order based on their field score & literature score with 60F-40L ratio. The final inefficiencies are then presented in Table 3-1.

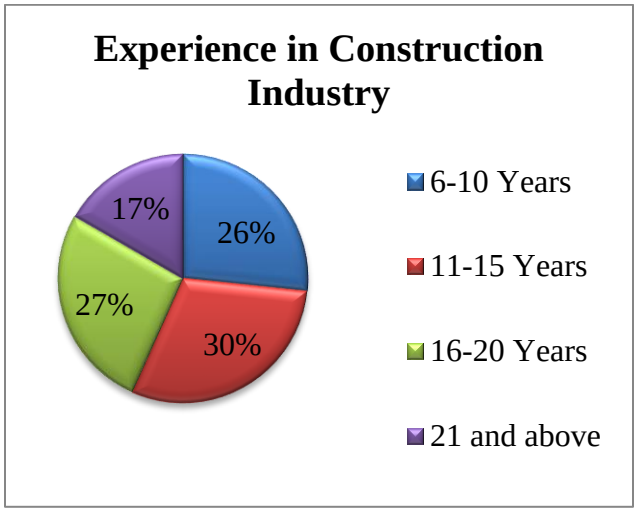


Figure 3-2-1 Experience in Construction Industry

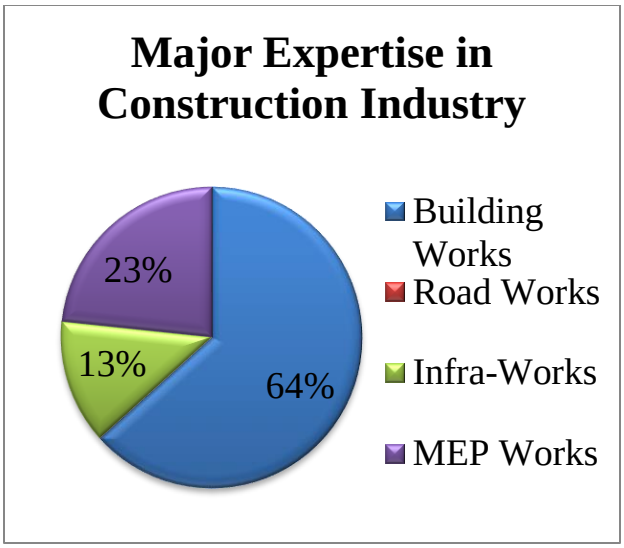


Figure 3-2-2 Major Expertise in Construction Industry

Table 3-1: Finalized Inefficiencies

Rank	Factors Causing Delay	Field Score	Literature Score	60F-40L Analysis
1	Poor Financial Management by Client	0.046	0.120	0.076
2	Disagreement on Valuation of Work done	0.046	0.087	0.062
3	Insufficient/ambiguous Information Provided for Certification	0.046	0.073	0.057
4	Slow Process of Approving Variations	0.037	0.067	0.049
5	Disputed Work	0.046	0.046	0.046
6	Failure to value & certify the work done by Consultant	0.037	0.048	0.041
7	Poor Communication / Flow of Information among parties	0.046	0.033	0.041
8	Poor documentation procedure practiced	0.037	0.046	0.040
9	Deliberate delay for some benefits	0.037	0.044	0.039
10	Major defects in Construction work	0.037	0.040	0.038
11	Local Culture/Attitude of late payment	0.037	0.040	0.037
12	Wrongly Calculated Claims	0.046	0.020	0.035
13	Poor quality of work	0.037	0.033	0.035

Rank	Factors Causing Delay	Field Score	Literature Score	60F-40L Analysis
14	Conflict among the parties involve	0.037	0.032	0.035
15	Difficulties in reaching a settlement between parties	0.037	0.032	0.035
16	Non-BOQ Work done	0.046	0.013	0.033
17	Perception that late certification is acceptable for few days	0.027	0.040	0.032
18	Involvement of too many parties for certification of payment	0.037	0.024	0.031
19	Work done doesn't reach the limit of IPC	0.046	0.006	0.030
20	Elongated Payment terms in Contracts	0.037	0.020	0.030
21	Poor Economic & Market Conditions	0.027	0.028	0.027
22	Inexperience Project Personnel	0.037	0.006	0.024
23	Breach of any Contract term of project by the Contractor	0.018	0.032	0.023
24	Complex Contractual Provision	0.027	0.010	0.020
25	Short of Current Year's Project	0.018	0.016	0.017
26	Scarcity of Capital to Finance Project	0.018	0.012	0.015
27	Clients' assumption that Contractor will finance the project	0.018	0.005	0.013
28	Failure to Understand Contract Agreement	0.009	0.008	0.008
29	Client's Lack of Trust on Consultants Valuation	0.009	0.008	0.008
30	Inequality of Contractual bargaining Power	0.009	0.001	0.006

3.3 Conceptual Framework

The figure shows conceptual framework for development of prototype. It indicates that our BIM MODEL needs to be launched in BIM Platform. After that the developed plug-in will need to import Bill of Quantity and basis on that Work Check Request (WCR) will be generated. The Consultant will then check the quality of work physically on site and basis on that WCR will be "Accepted" or "Rejected". The Rejected WCR will have to be rectified and then re-submit again while based on accepted Check Request, Measurement sheet will get updated. The quantity of

approved WCR will be processed and after multiplying with the provided rates cost summary will be updated. After reaching the limit of IPC provided in the Contract, the Contractor will be able to generate the Bill and the Client will have to clear the liability within 07 days. The system will be able to enlist the details of all the costs and their summary for printing purposes.

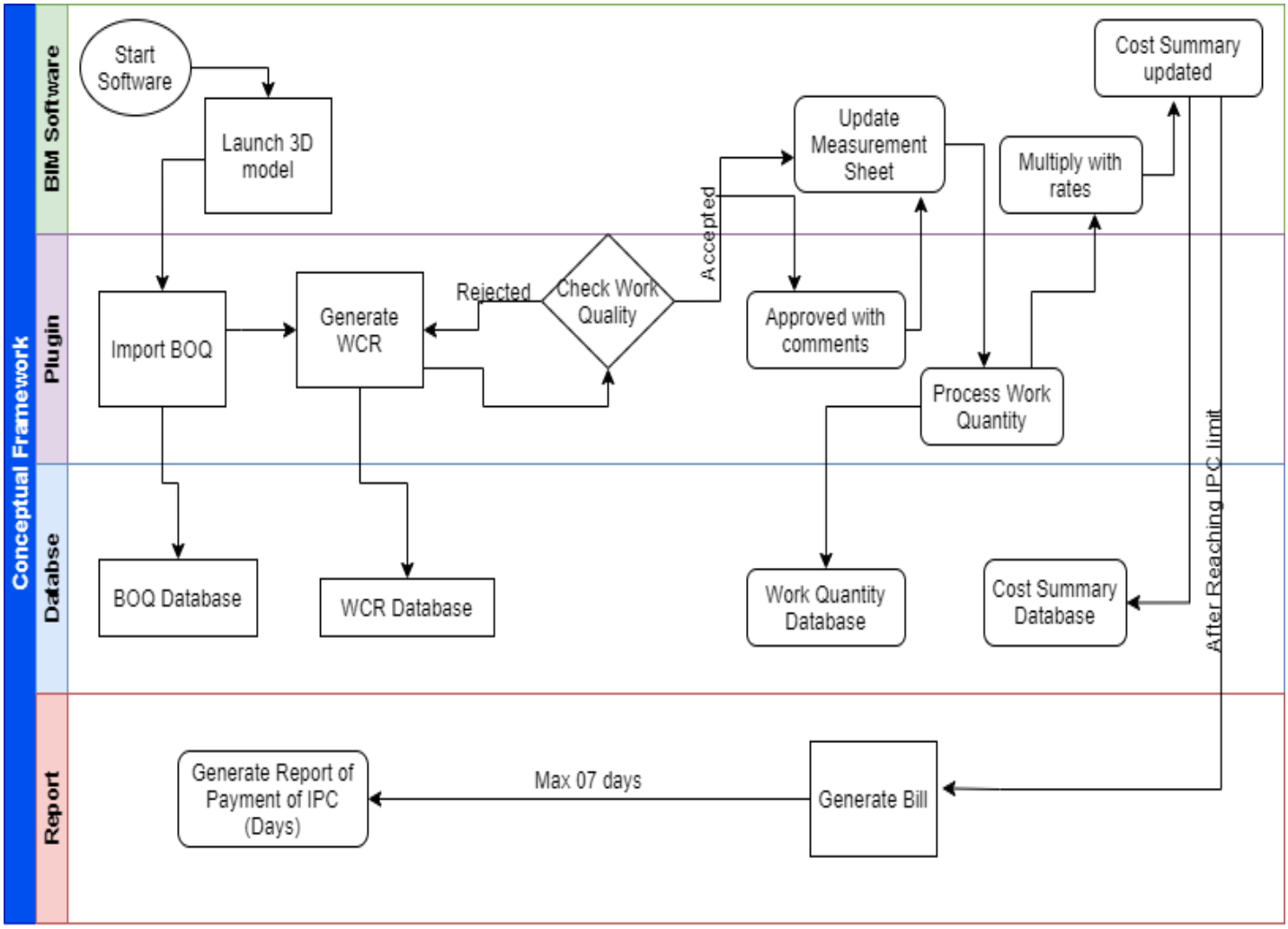


Figure 3-3: Conceptual Framework

3.4 Prototype Development

In this phase, prototype will be created which will aim to solve the matters recognized in the initial phase. At first, some standards traditional contracts were studied which are being used all along the world and the time duration for the payment of Interim payments to the Contractor provided

in these Contracts were reviewed. The Contracts that have been studied were of Consensus Docs, Engineers Joint Contract documents committee (EJCDC), International Federation of Consulting Engineer (FIDIC), the New Engineering Contracts (NEC), American Institute of Architects (AIA), and Pakistan Engineering Council (PEC). It was done to have a lucid knowledge about payment terms and durations and complexities in them which will help to develop a prototype to address all the shortcomings or inefficiencies present in them. Also, in this phase of research, Building Information Modeling software API functioning is studied, and a plugin will be developed for Digitization of Interim Payments. Most BIM software provide API to extend their functionalities (Akinade et al., 2016). The workflow used for the development is as followed: Autodesk Revit Architecture (BIM Software); Dynamo for visual coding, python software for backend coding for scripts, Microsoft Excel for Database management. Autodesk Revit is used because of its high quality and friendly user interface and its ease of connectivity with external database. The reason for selecting Autodesk Revit as a BIM platform for the plug-in development is that it is widely used and it provides a rich API platform (Akinade, 2017).

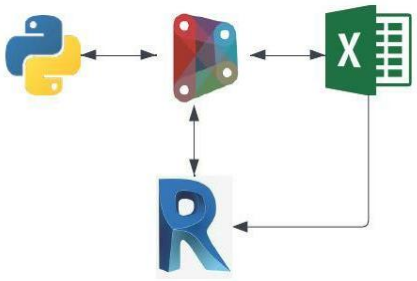


Figure 3-4: Data Workflow

3.5 Prototype Evaluation

The system developed was checked and evaluated by the field experts. Field experts were carefully selected based on their working experience and expertise in the relative field of Quantity surveying, Payment terms and conditions, Building Information and Modelling (BIM). Overall,

fifteen (15) of the field experts were chosen for this purpose. Some of the experts were selected based on their experience. Others were approached for during preliminary survey. Among selected experts, 07 were Quantity Surveyor, 05 were having expertise in Contracts and 03 were BIM experts. All these experts were given background of the topic and issues identified in the literature. After that, experts were presented with the working of the tool to let them decide how well the developed system can handle the identified issue.

A house project at its under-construction stage was selected for the purpose of case study. This project was targeted due to its ease in demonstration to small construction enterprise (SCE) professionals (Sebastian et al., 2009) and also because of the complete knowledge of this project. BIM Model of the selected house project is shown as Figure 3-5. The Bill of Quantity (BOQ) of the project was developed in Microsoft Excel and quantity of each item was calculated for the generation of Interim Payment. First two Interim payments were already produced and payments against each of them were released. For case study purpose, third IPC was calculated and generated using BIM based IPC generation system. Then the generated IPC was processed further for release of payment to the Contractor once it fulfills the payment limit set by the client for generation of IPC.

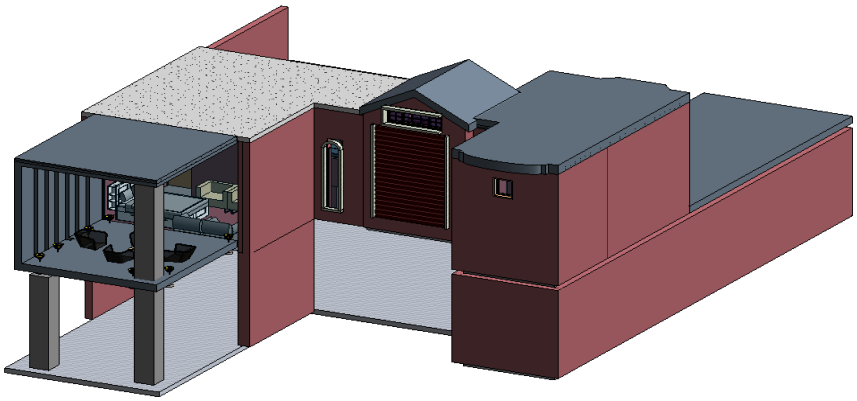


Figure 3-5: BIM Model

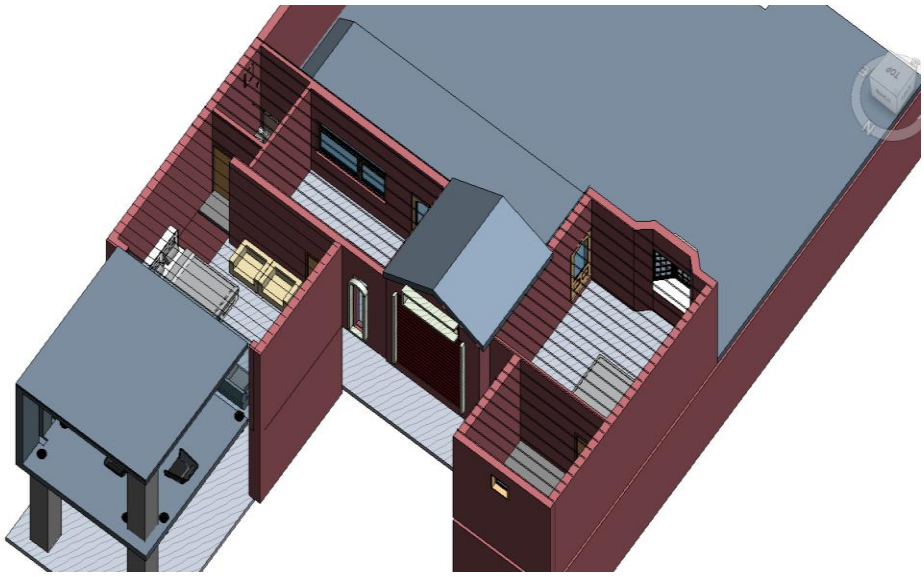


Figure 3-6: BIM Model

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

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

Where W = weight given to each factor by the respondents; A =highest weight, i.e., 5 in this case; and N = total number of respondents. N=15 for this specific case.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Preamble

This chapter will discuss in depth the architecture of BIM based knowledge management system for the development of BIM – IPC for Contractor and for consultants and further its evaluation / validation from the field experts.

The conceptual framework developed has already been discussed in chapter as figure 3-3 which becomes the basis for development of BIM-IPC.

4.2 BIM-IPC Template Architecture

The templates were developed for the contractor and consultants separately. The prototype was developed on basis of recommendation by SCL (2017). Dataflow for this prototype requires visual coding in Dynamo, a plugin in Autodesk Revit 2021. The data workflow is shown in previous chapter as figure 3-2. The developed protype was introduced in Revit in both tabs of BIM-IPC (contractor) and BIM-IPC (Consultant) as part of Revit Ribbon bar. The tabs have been developed separately for the Contractor and Consultants and each of the stakeholder has access to its own tab. The tab for BIM-IPC (contractor) has single main panel of Generate IPA.

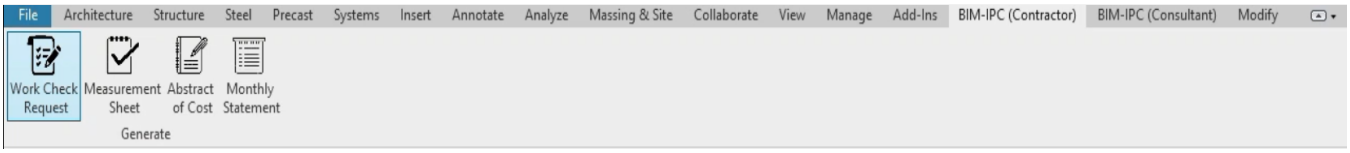
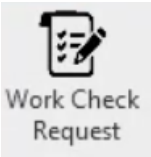


Figure 4-1: BIM IPC (Contractor) Ribbon

The panel further contains buttons for their respective tasks. Functions of each button are demonstrated in following sections.

Table 4-1: Generate Panel buttons and their Functions

Button Name	Icon	Button Function
Work Check Request		This button allows the contractor to generate the Check Request against the work done
Measurement sheet		This button allows the user to generate Measurement sheet based on approved check requests
Abstract of cost		After development of measurement sheet, the abstract can be generated in this tab.
Monthly statement		This button allows users to generate its Monthly statement or bill for approval.

While the tab of BIM-IPC (Consultant) also has a single main panel of Approval.

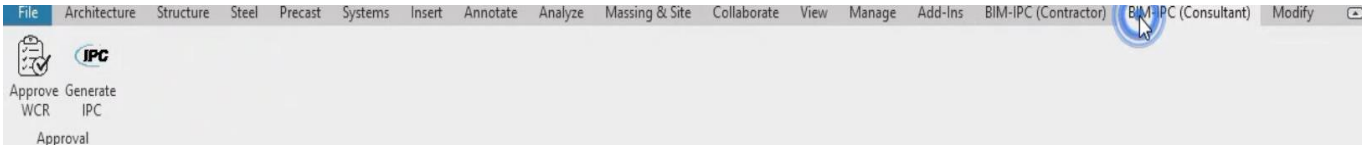


Figure 4-2: BIM IPC (Consultant) Ribbon

The panel further contains buttons for their respective tasks. Functions of each button are demonstrated in following sections.

Table 4-2: Approval Panel buttons and their Functions

Button Name	Icon	Button Function
Approve WCR		This button allows the Consultant to approve or reject the WCR generated by Contractor.
Generate IPC		This button allows the user to check the IPC submitted by the Contractor based on WCRs.

Let's further discuss how this process will work step by step with the help of both tabs.

4.2.1 Work Check Request Button

The user will select element from the prototype for generating Work Check Request (WCR) which will form the basis of IPA. The user must select that whether the element is continuous or completed as in most of the construction projects the activities are completed in parts. So, to give clarity whether the element activity is completed or not as shown in figure 4-3

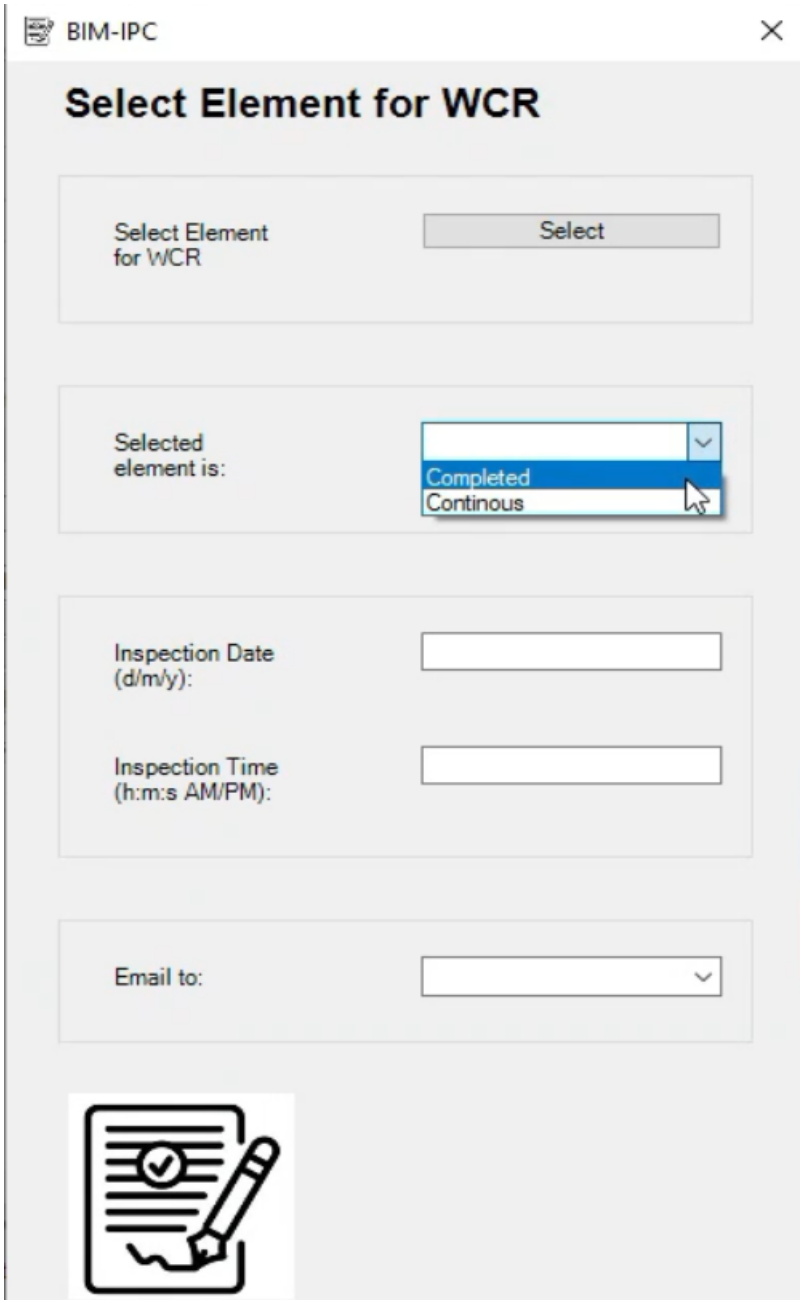


Figure 4-3: Element Select

Once all the requirements are completed of Inspection date and Inspection time of the selected element, an email will be sent to concerned staff of Consultant and Contractor as shown in figure 4-4

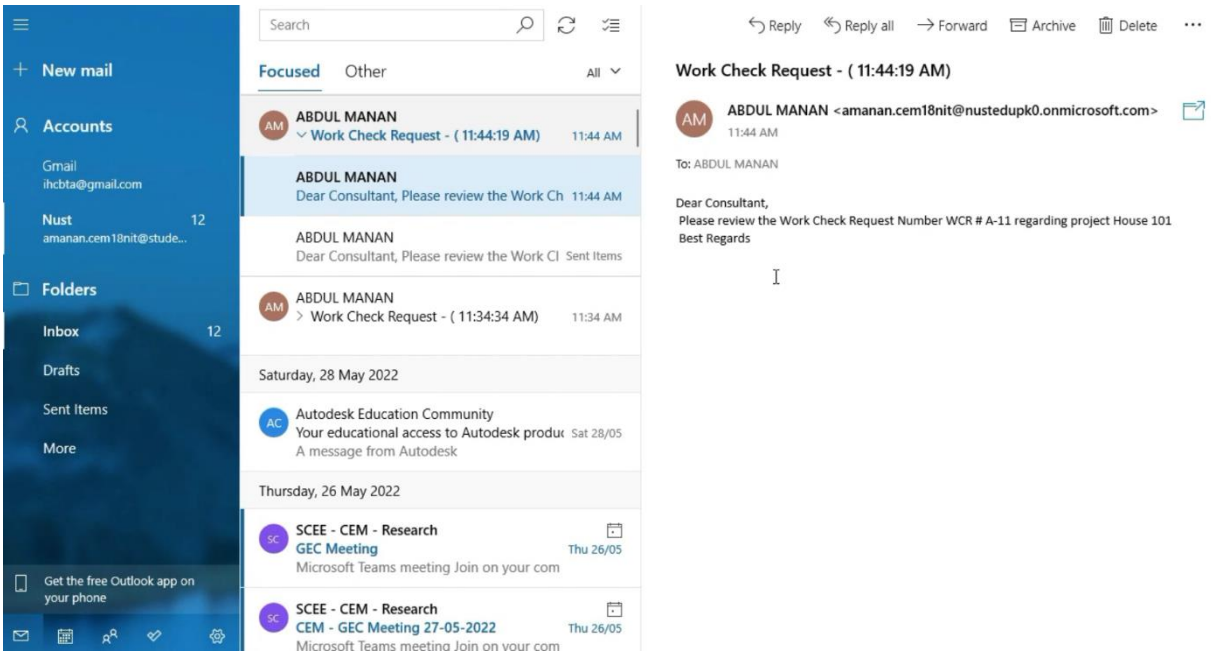


Figure 4-4: Email sent

4.2.2 Approve WCR (Work Check Request) Button

After receiving the email for approval of Work Check Request, the Consultant staff will then physically verify the status of that details that has been shared by the Contractor as shown in figure 4-5.

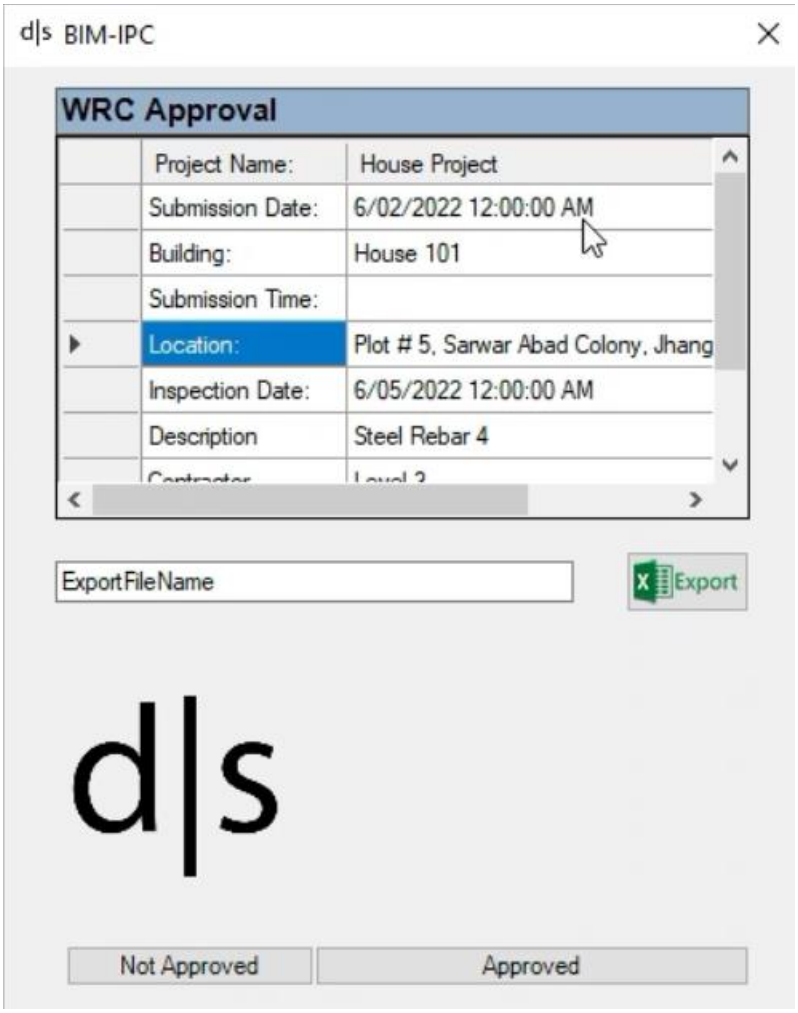
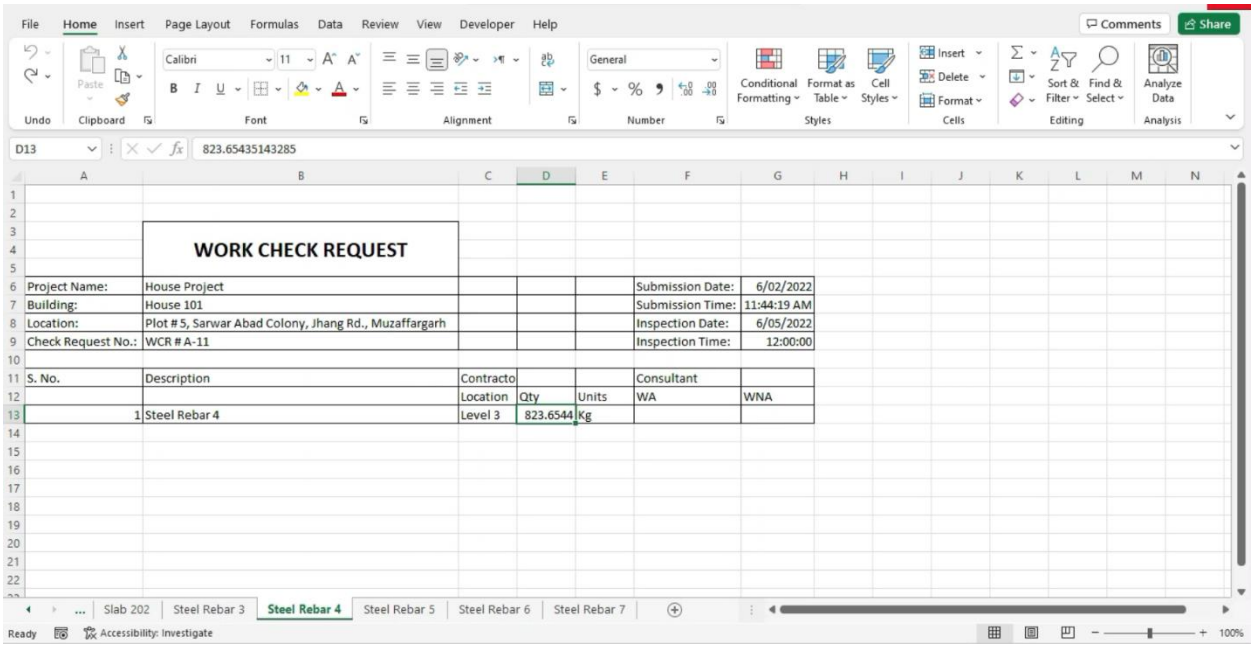


Figure 4-5: Approve WCR

Consultant has the authority to accept the check request or reject it. In both the cases, WCRs will be updated whether accepted or rejected at time of approval/rejection will be shown in respective column as shown in figure 4-6



WORK CHECK REQUEST

Project Name:	House Project				Submission Date:	6/02/2022
Building:	House 101				Submission Time:	11:44:19 AM
Location:	Plot # 5, Sarwar Abad Colony, Jhang Rd., Muzaffargarh				Inspection Date:	6/05/2022
Check Request No.:	WCR # A-11				Inspection Time:	12:00:00

S. No.	Description	Contracto			Consultant	
		Location	Qty	Units	WA	WNA
1	Steel Rebar 4	Level 3	823.6544	Kg		

Figure 4-6: WCR Sheet

The rejected work will be rectified by the Contractor and again the Check for same element will be floated following the same pattern.

4.2.3 Measurement Sheet Button

Once the Work Check Request has been approved by the Consultant then the Contractor must update Measurement sheets. Contractor must prepare measurement sheets for all the elements individually. For example, there should be separate measurement sheet for all the WCRs related to steel fixing, Concreting, Brick Work etc. respectively. Let's demonstrate the measurement sheet for steel here as shown in figure 4-7:

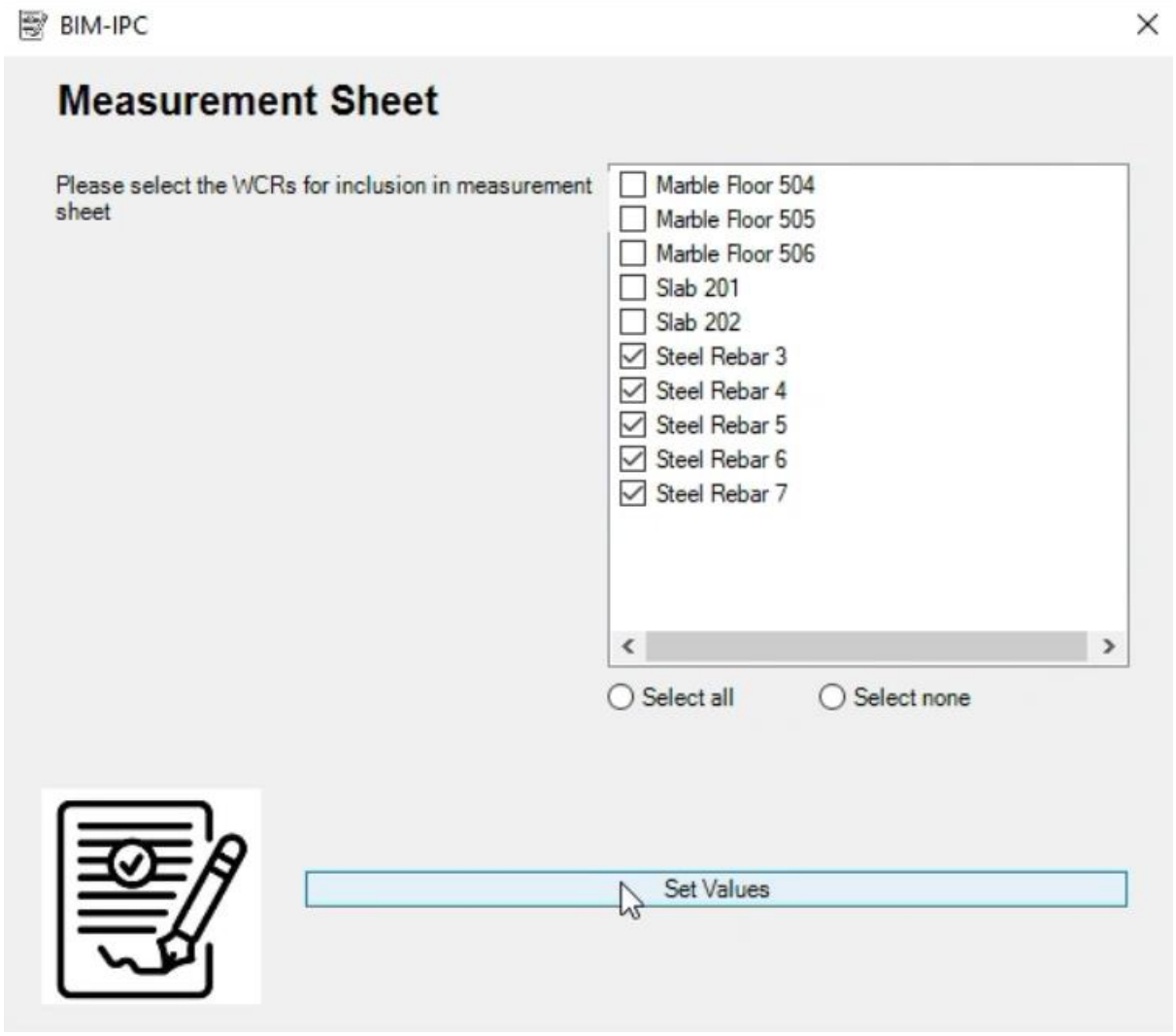
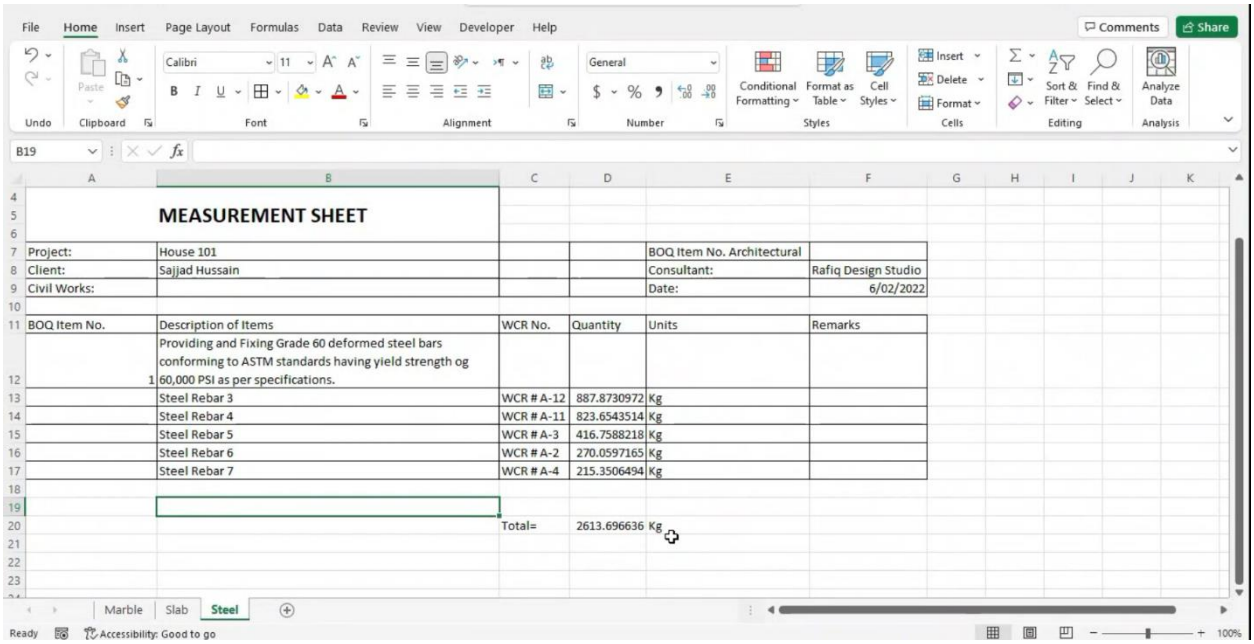


Figure 4-7: Measurement Button

Contractor must select the WCRs which needs to be included in measurement sheet. As the value is set, the measurement sheet will be updated as shown in figure 4-8.



MEASUREMENT SHEET

Project:	House 101			BOQ Item No. Architectural	
Client:	Sajjad Hussain			Consultant:	Rafiq Design Studio
Civil Works:				Date:	6/02/2022
BOQ Item No.	Description of Items	WCR No.	Quantity	Units	Remarks
1	Providing and Fixing Grade 60 deformed steel bars conforming to ASTM standards having yield strength og 60,000 PSI as per specifications.				
	Steel Rebar 3	WCR # A-12	887.8730972	Kg	
	Steel Rebar 4	WCR # A-11	823.6543514	Kg	
	Steel Rebar 5	WCR # A-3	416.7588218	Kg	
	Steel Rebar 6	WCR # A-2	270.0597165	Kg	
	Steel Rebar 7	WCR # A-4	215.3506494	Kg	
		Total=	2613.696636	Kg	

Figure 4-8: Measurement Sheet

This shows the description of items and the reference of WCRs against which the work has been approved by the Consultant and the quantity of work approved in that WCR. It is worth mentioning that the rejected WCRs couldn't be included for updating measurement sheet and if selected the system will generate error as shown in figure 4-9.

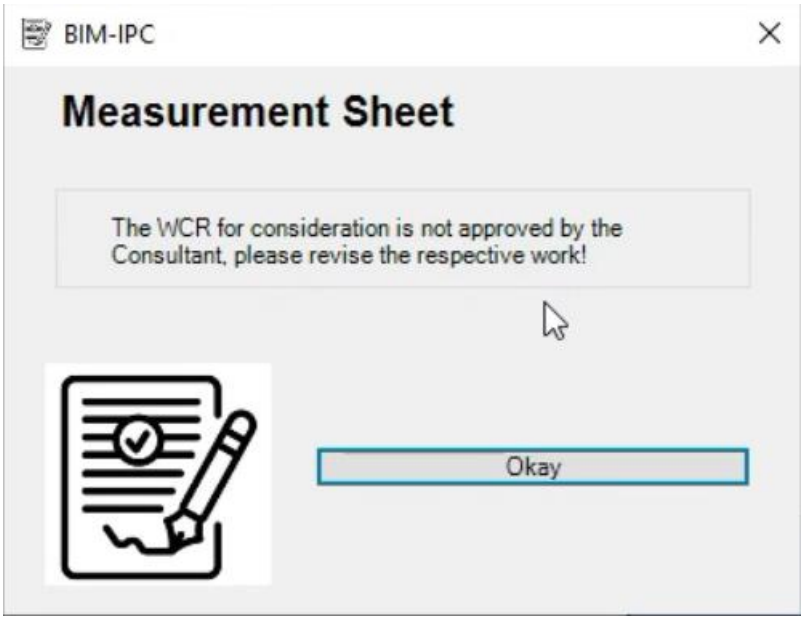


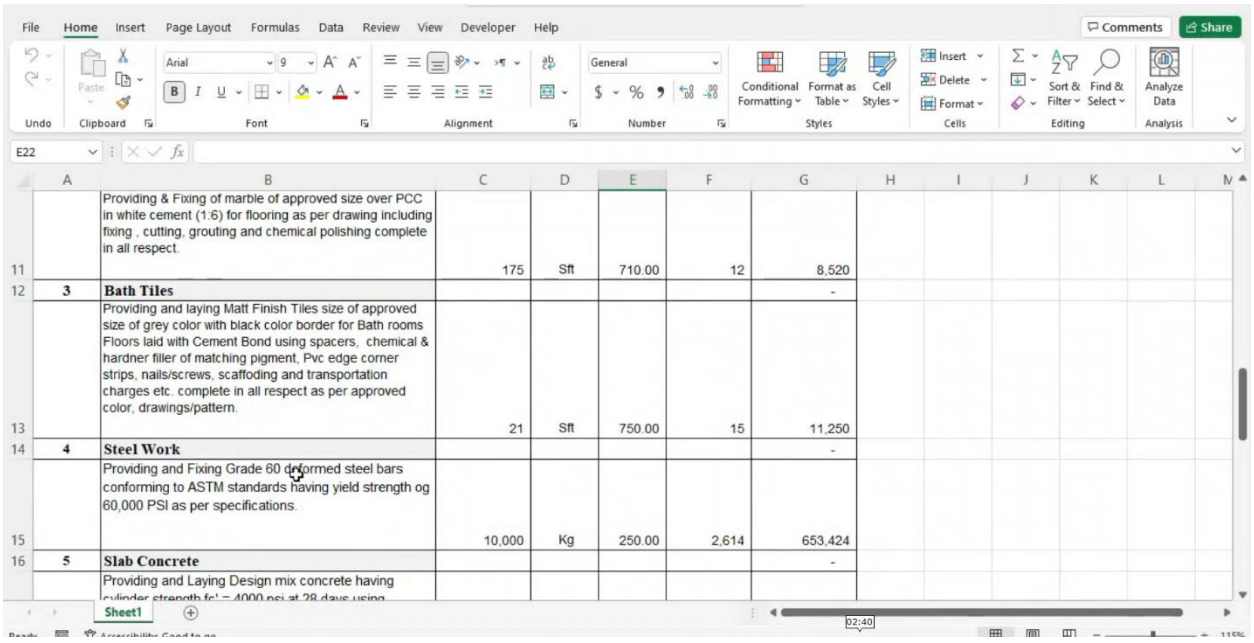
Figure 4-9: Rejected WCRs

4.2.4 Abstract of Cost Button

This button will help to generate the total quantity of work done by the Contractor and multiply that with the approved rates, we will get the amount of work done against each head. The Contractor needs to select each head against which work has been done as shown in figure 4-10.

Figure 4-10: Abstract of Cost

It shows only those activities against which work has been done thus far. The user should select activities to update Abstract of Cost sheet. Those values then multiply with approved rates to get the exact amount of work done as shown in figure 4-11.



11		Providing & Fixing of marble of approved size over PCC in white cement (1:6) for flooring as per drawing including fixing , cutting, grouting and chemical polishing complete in all respect.	175	Sft	710.00	12	8,520
12	3	**Bath Tiles**					-
13		Providing and laying Matt Finish Tiles size of approved size of grey color with black color border for Bath rooms Floors laid with Cement Bond using spacers, chemical & hardner filler of matching pigment, Pvc edge corner strips, nails/screws, scaffoding and transportation charges etc. complete in all respect as per approved color, drawings/pattern.	21	Sft	750.00	15	11,250
14	4	**Steel Work**					-
15		Providing and Fixing Grade 60 deformed steel bars conforming to ASTM standards having yield strength og 60,000 PSI as per specifications.	10,000	Kg	250.00	2,614	653,424
16	5	**Slab Concrete**					-
		Providing and Laying Design mix concrete having					

Figure 4-11: Abstract of Cost Sheet

4.2.5 Monthly Statement Button

This will finalize the task of generating of IPC from Contractors' end. After abstract of cost total gross amount will be generated upon that there will be some deductions such as deduction of Mobilization Advance, Retention money, Income tax and others if any as shown in figure 4-12.

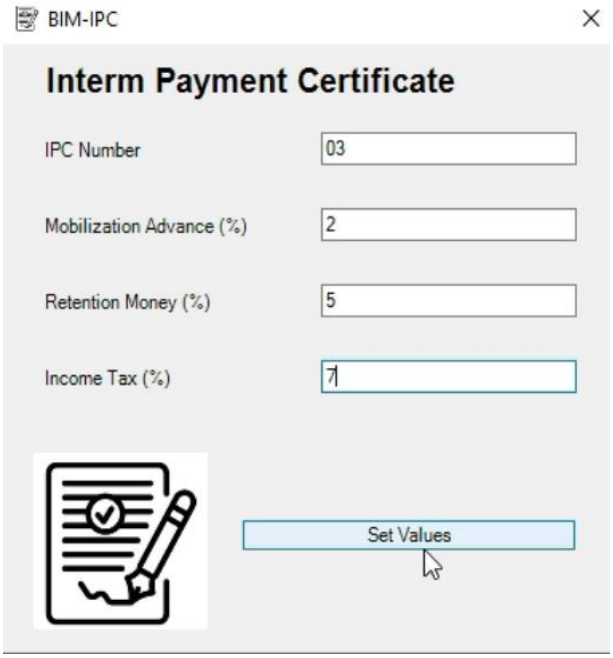
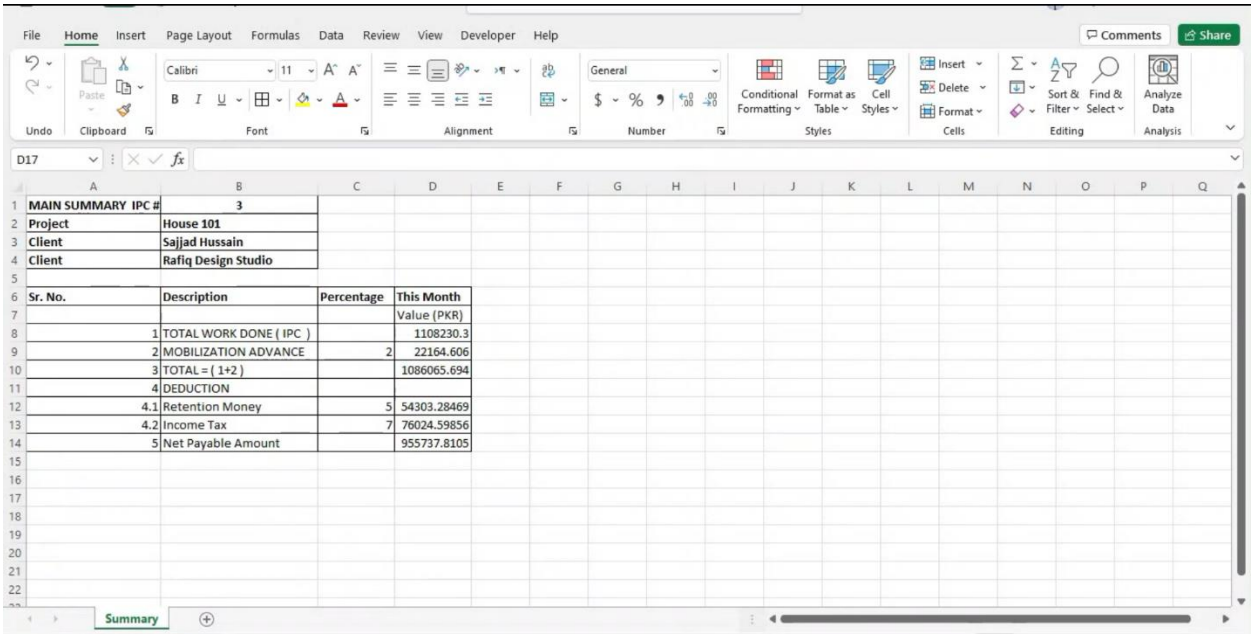


Figure 4-12: Monthly statement

After these deductions the total sum occur will be the amount that should be payable to the Contractor by the Client as shown in figure 4-13.



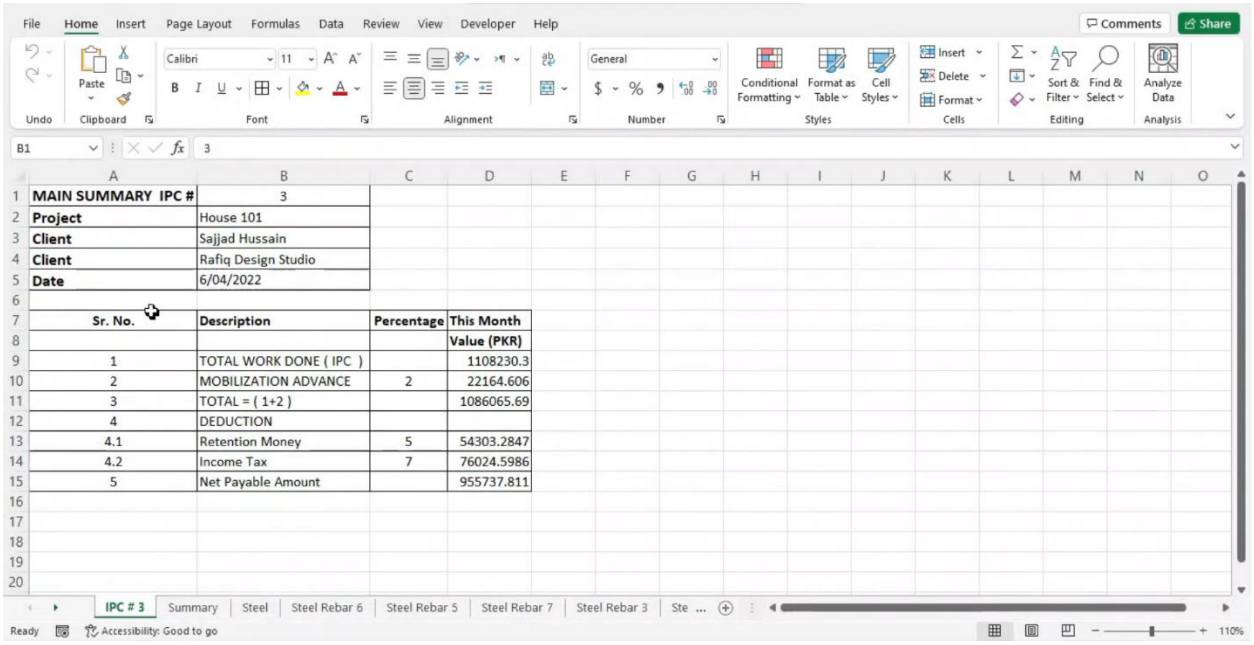
MAIN SUMMARY IPC #	3			
Project	House 101			
Client	Sajjad Hussain			
Client	Rafiq Design Studio			
Sr. No.	Description	Percentage	This Month	
			Value (PKR)	
1	TOTAL WORK DONE (IPC)		1108230.3	
2	MOBILIZATION ADVANCE	2	22164.606	
3	TOTAL = (1+2)		1086065.694	
4	DEDUCTION			
4.1	Retention Money	5	54303.28469	
4.2	Income Tax	7	76024.59856	
5	Net Payable Amount		955737.8105	

Figure 4-13: Summary sheet

Contractor will then send this to the Consultant along with Covering letter for further validation

4.2.6 Generate IPC Button

This button will only be accessible to the Consultant as he is the authority on the project to approve or reject the Contractor bills. After all the process involve, the Consultant will again verify the whole IPC including WCRs, Measurement sheets, Abstract of Cost generated by the Contractor with the approval of Consultant. Consultant will have the whole record of IPC as shown in figure 4-14



MAIN SUMMARY IPC #	3			
Project	House 101			
Client	Sajjad Hussain			
Client	Rafiq Design Studio			
Date	6/04/2022			
Sr. No.	**Description**	**Percentage**	**This Month**	
			Value (PKR)	
1	TOTAL WORK DONE (IPC)		1108230.3	
2	MOBILIZATION ADVANCE	2	22164.606	
3	TOTAL = (1+2)		1086065.69	
4	DEDUCTION			
4.1	Retention Money	5	54303.2847	
4.2	Income Tax	7	76024.5986	
5	Net Payable Amount		955737.811	

Figure 4-14: Generate IPC

Consultant will then send the whole IPC to the Client along with its recommendation that the bill has been verified and payment for this bill should be released to the Contractor.

4.3 Significance of DYNAMO:

The use of Dynamo plugin for visual coding plays pivotal role in frontend scripting for the prototype. Due to its vast variety of nodes and acceptance of packages for script making, enhances its potential to use within BIM platforms. It has very dynamic compatibility range with Revit, Python and Excel in terms of data inputs and outputs. Dyno browser was used to read the script from DYNAMO atmosphere and make buttons and respective panels in the Revit Interface. Script behind every button runs in DYNAMO atmosphere. Users need to input the data through Revit or Excel format and DYNAMO will sort that information based on its nodes' nature. It polished the work in terms of final Presentation of IPC. The data flow or script flow in dynamo starts from left side, all the nodes and strings will be pushing scripts in right direction and ends on right side. For example, Figure 4-15 Shows script developed in dynamo environment for Work Check Request. Figure 4-16 shows dynamo script for calculation of checked quantity of that activity and got approved from the Consultant. These scripts will extract necessary data from database and logics will be applied in form of visual coding. Users will get results in the form of tables as shown.

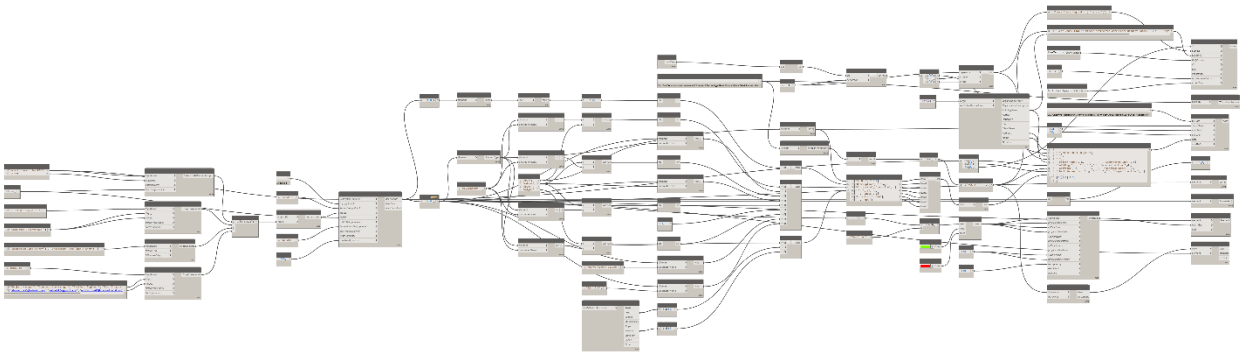


Figure 4-15 Dynamo Script for Work Check Request

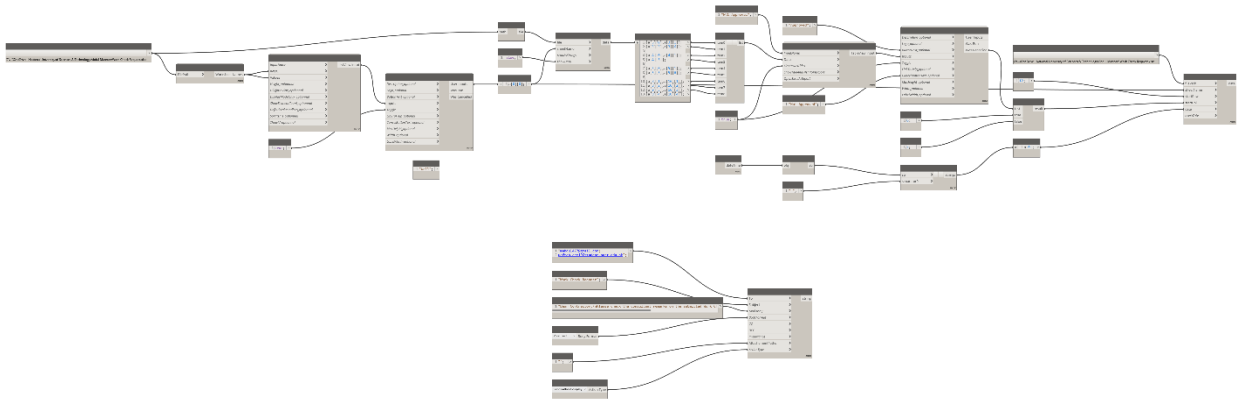


Figure 4-16 Dynamo Script of Approve/Reject WCR

Similarly, Figure 4-31 shows script developed for calculation of Measurement sheet basis on approved Work Check Requests. Contractor needs to select those Work Check Requests which got approval from the Consultant otherwise, Measurement sheet will not be formed.

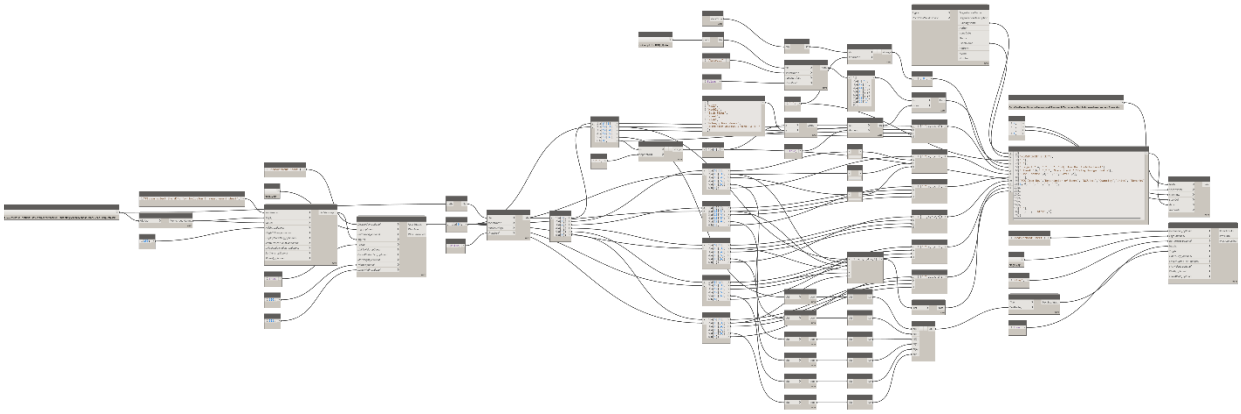


Figure 4-17 Dynamo Script for Measurement sheet

Now, Abstract of Cost will be formed by taking in account all the measurement sheets of separate activity heads as shown in figure 4-18. Basis on that Abstract of Cost, Monthly statement will be generated. All the taxes and advance payments will be deducted from Monthly statement after the approval of Consultant as shown in figure 4-19.

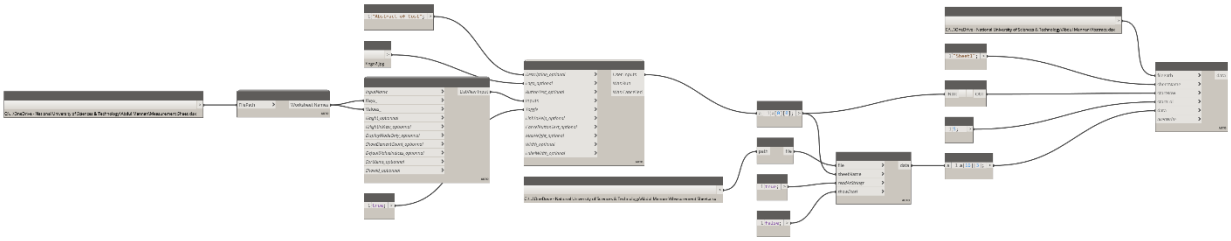


Figure 4-18 Dynamo Script for Abstract of Cost

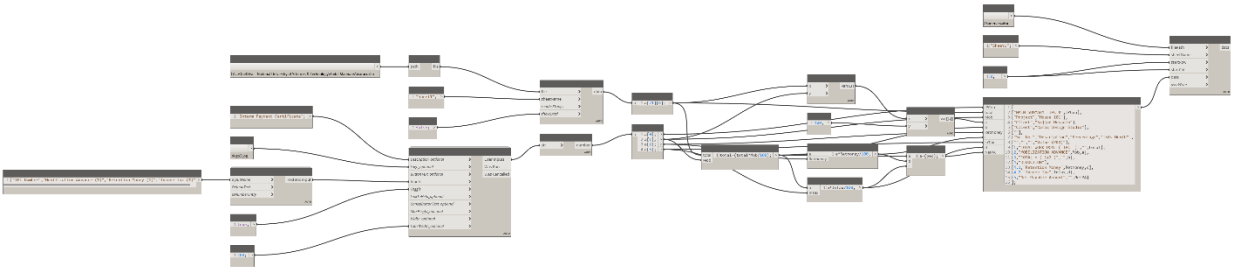


Figure 4-19 Dynamo Script for Monthly Statement

Once, all the formalities have been completed from Contractor side the whole IPC including Work Check Requests, Measurement Sheets, Abstract of Cost and Summary will be sent to the Consultant for further re-verification and approval shown in figure 4-20. The Consultant will approve this IPC and sent it to the Client for release of payment to the Contractor.

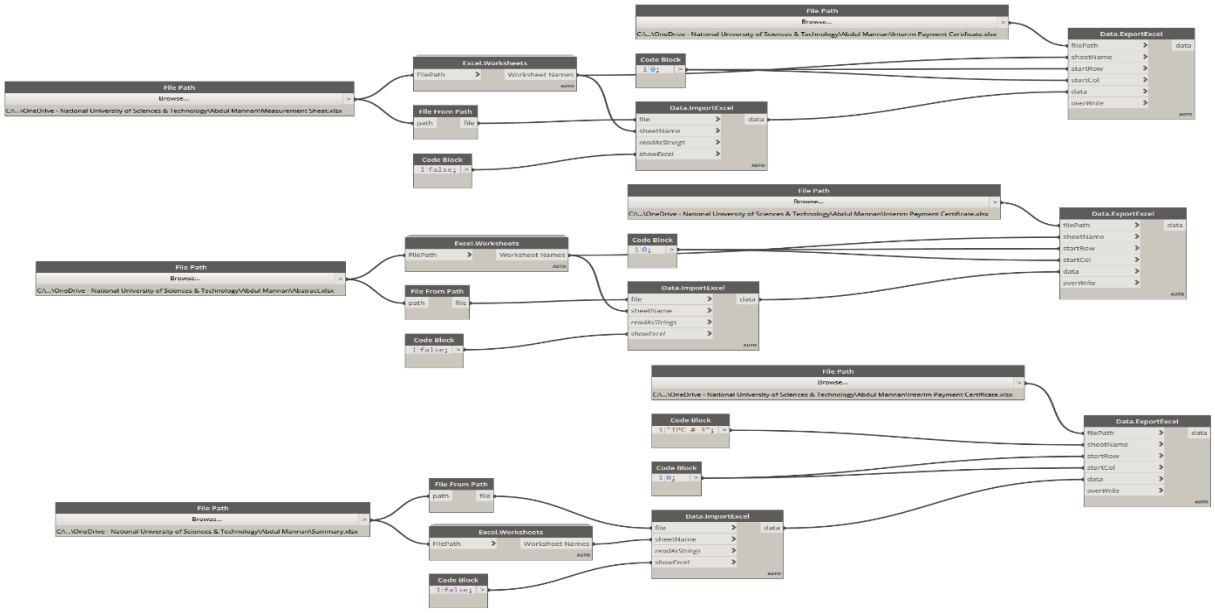


Figure 4-20 Dynamo Script of IPC

4.4 Evaluation Results

Experts were asked about the need of the system in construction. Figure 4-21 shows the results of respondents. 67% of experts strongly agreed and 33% of experts agreed. None of the experts disagreed to need of BIM-IPC.

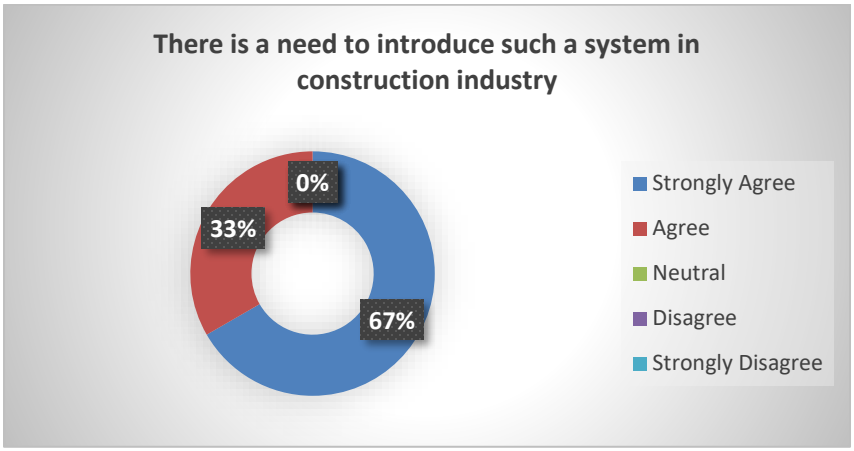


Figure 4-21 Need of BIM-IPC in construction Industry

We also asked from experts about usability of the system; results are shown in Figure 4-22. 67% of the experts said that the system was easy to understand and use so they strongly agreed to ease of system. While 33% agreed to system usage and its easiness.

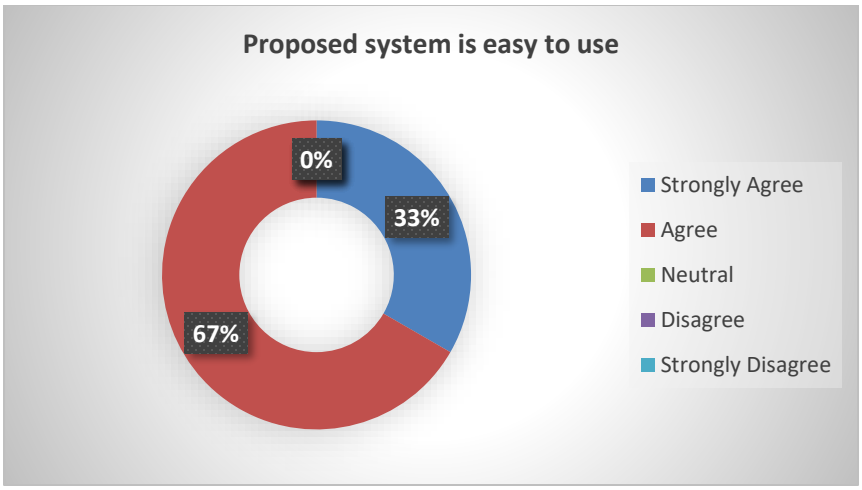


Figure 4-22 Usability of BIM-IPC

Experts were asked if the system is implementable in construction industry. 46% of experts strongly agreed and 47% agreed that system is implementable. There were 7% of the respondents who neither agreed or disagreed to question asked. Surprisingly there was no one to disagree (Figure 4-23).

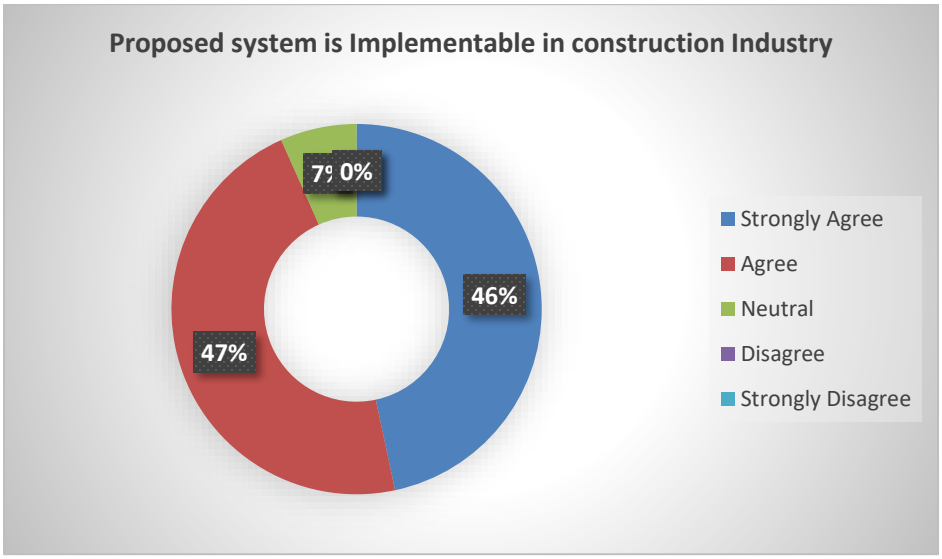


Figure 4-23 BIM-IPC implementation in Construction Industry

Figure 4-24 shows overall effectiveness of the system in management of cost claims. 64% strongly agreed and 36% agreed to the question asked. No expert disagreed to effectiveness of the system.

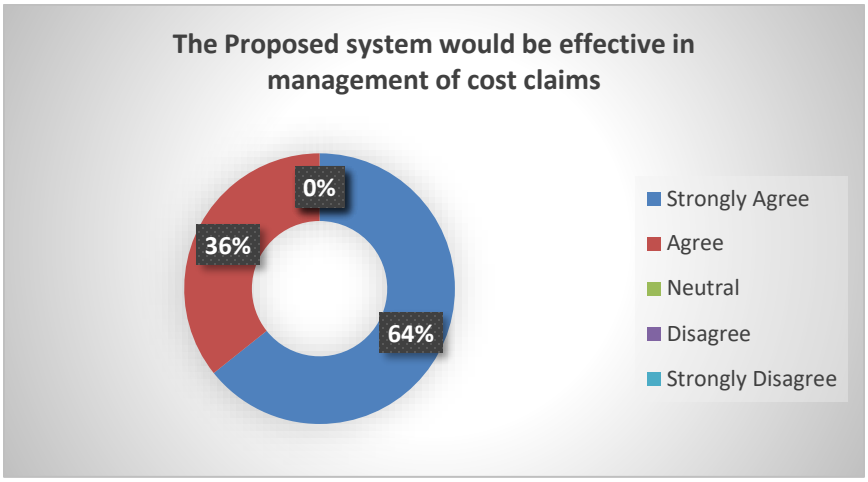


Figure 4-24 Overall Effectiveness of BIM-IPC

The Table shows the effectiveness of developed system to resolve the issues related to IPC. These values were given rankings on their respective RII values.

Table 4-3: semi-structured interview-based evaluation

Sr. No	Inefficiencies	Mean	Sum	RII	Ranking
1	Poor Financial Management by Client	2.267	34	0.567	25
2	Disagreement on Valuation of Work done	3.800	57	0.760	5
3	Insufficient/ambiguous Information Provided for Certification	4.000	60	0.800	3
4	Slow Process of Approving Variations	2.333	35	0.583	24
5	Disputed Work	3.267	49	0.653	18
6	Failure to value & certify the work done by consultant	4.400	66	0.880	1
7	Poor Communication / Flow of Information among parties	3.200	48	0.640	21
8	Poor documentation procedure practiced	3.533	53	0.707	8
9	Deliberate delay for some benefits	1.667	25	0.556	26

Sr. No	Inefficiencies	Mean	Sum	RII	Ranking
10	Major defects in Construction work	3.400	51	0.680	15
11	Local Culture/Attitude of late payment	3.467	52	0.693	13
12	Wrongly Calculated Claims	3.533	53	0.707	9
13	Poor quality of work	4.200	63	0.840	2
14	Conflict among the parties involve	3.533	53	0.707	10
15	Difficulties in reaching a settlement between parties	3.600	54	0.720	6
16	Non-BOQ Work done	3.267	49	0.653	19
17	Perception that late certification is acceptable for few days	3.200	48	0.640	22
18	Involvement of too many parties for certification of payment	3.333	50	0.667	16
19	Work done doesn’t reach the limit of IPC	3.600	54	0.720	7
20	Elongated Payment terms in Contracts	2.800	42	0.700	12
21	Poor Economic & Market Conditions	1.800	27	0.450	30
22	Inexperience Project Personnel	3.533	53	0.707	11
23	Breach of any Contract term of project by the Contractor	2.733	41	0.683	14
24	Complex Contractual Provision	2.467	37	0.617	23
25	Short of Current Year's Project	2.067	31	0.517	27
26	Scarcity of Capital to Finance Project	2.667	40	0.667	17
27	Clients’ assumption that Contractor will finance the project	1.800	27	0.467	28
28	Failure to Understand Contract Agreement	2.600	39	0.650	20
29	Client's Lack of Trust on Consultants Valuation	3.867	58	0.773	4
30	Inequality of Contractual bargaining Power	1.667	25	0.467	29

Developed system could handle the issue of Certification of IPCs by the Consultant having RII value 88%. Also, it can handle the issue of poor quality of work and ambiguous information provided for Certification with RII value 84% and 80% respectively. However, field experts

believe that it cannot handle poor economic and market conditions and inequality of contractual bargaining power which are one of the reasons for delay in process of IPCs.

4.5 Feedback for System from Experts

Experts were asked if there were any barriers to implement this system in construction industry. Table 4-2 shows some key barriers and their key comments.

Table 4-4: Barriers in implementing BIM-IPC

Barriers	**Key Comments**
Knowledge	Construction industry needs to improve its experience in using new technology. Most of the experts provided with the information that many of construction firms are still in 2D. 3D is being used for rendering purposes only.
Cost	Proper Trainings and seminars should be done to which will bring extra costs with them.
Data Input	Data Coming from other software which are not BIM can make results less realistic.
Contract	Contractors and other parties should know contracts enough to work within 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 are recorded in Table 4-3.

Table 4-5: Future Improvements Recommended by Experts

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

CHAPTER 5: CONCLUSIONS

Construction Projects are complex in nature. Size, location and number of parties involved in a project add complexity in a project. These complex projects need modern solutions to avoid loss actively or reactively. BIM is one of the widely used platform 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 solution to all the problems. Modern Information and Communication Technology (ICT) systems have facilitated in construction industry. BIM was used to achieve our goals through this research.

Based on systematic and action-based nature of the research, both were used partly in methodology. Issues in conventional processing of IPC system has been identified through vast literature review and those issues were then ranked in order and verified from the field experts. As BIM cannot solve all the issues identified on its own therefore, we had to develop BIM-IPC tool. This tool was developed using scripts developed in Dynamo environment. Dynamo has a huge involvement in decision making for calculation of costs. SQL server database can be connected to Dynamo through nodes packages to store the data in database. Excel data which were imported from BOQs was used in the system. A sample for processing of IPC was also generated in the end based on actual site conditions and terms used. Un resolved issues found from the literature were aimed to be resolved. For validation of the developed tool, a real time IPC is generated of a construction project and all the protocols have been followed which are in use in the construction industry. The generated IPC from the tool and the working of developed tool is then shown to the industry experts for their review and further improvements. The results of the validation from industry experts shows that it is are shown in the previous chapter. A prototype is then developed

for the validation of developed tool. Their percentage of resolution is discussed in previous chapter.

The developed tool helps the AEC industry to digitize the whole payment system however, it doesn't resolve main inefficiency of the system of poor financial management by Client. It indirectly aware the client about stage of IPC but there is no such BIM feature which directly counter that inefficiency. The tool heavily depends upon formation of drawings in Revit with the unique name for every element in order to generate Work Check Requests. It is somehow feasible for small scale projects, but it is not possible for projects involving hundreds of elements and activities. This system doesn't include price escalation which is integral for calculation of IPCs.

5.1 FUTURE RESEARCH RECOMMENDATION(S)

The size of the sample project was small, and it should be tested on large and complex projects. The system should develop and show price escalation and variation orders within the environment. It should be applied from the start of the project to visualize the impact of processing of IPCs. It should also cover dayworks as well.

There are other systems in construction industry to calculate Monthly bills. A reliable study should be made to assess and manage the risk in using such developed systems. The system is applied to project with lumpsum cost. It should be applied to projects which includes per unit cost method and other Contract types as well.

References

(Civil Works) Available on PEC website (www.pec.org.pk) and PPRA website (www.ppra.org.pk) ISLAMABAD. (2007).

A.A., O. (2015). A quantitative assessment of the cost and time impact of variation orders on construction projects. *Journal of Engineering Design and Technology*, *5*(1), 35–48.

a Framework for Combating Payment-Related Issues (Pri) in the a Framework for Combating Payment-Related Issues (Pri) in the Malaysian Construction Industry. (2021). *May 2017*.

Abdul-Rahman, H., Kho, M., & Wang, C. (2014). Late payment and nonpayment encountered by contracting firms in a fast-developing economy. *Journal of Professional Issues in Engineering Education and Practice*, *140*(2). https://doi.org/10.1061/(ASCE)EI.1943-5541.0000189

Abdul-Rahman, H., Takim, R., & Min, W. S. (2009). Financial-related causes contributing to project delays. *Journal of Retail and Leisure Property*, *8*(3), 225–238. https://doi.org/10.1057/rlp.2009.11

Abdul-Rahman, H., Wang, C., Takim, R., & Wong, S. (2011). Project schedule influenced by financial issues: Evidence in construction industry. *Scientific Research and Essays*, *6*(1), 205–212. https://doi.org/10.5897/SRE10.989

Abotaleb, I. S., & El-adaway, I. H. (2017). Administering Employers' Payment Obligations under National and International Design–Build Standard Forms of Contract. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *9*(2), 04517003. https://doi.org/10.1061/(asce)la.1943-4170.0000213

Agyei-kumi, S. (2017). Critical Causes and Effects of Payment Delays in the

Execution of Public Construction Projects in Ghana : Fresh Evidence from the Brong-Ahafo Region. *Developing Country Studies*, *7*(5), 12–24.

Akinade, O. O. (2017). BIM-BASED SOFTWARE FOR CONSTRUCTION WASTE ANALYTICS USING ARTIFICIAL By. *BIM-Based Software for Constuction Waste Analytics Using Aritifical Intelligence Hybrid Models*.

Akinade, O. O., Oyedele, L. O., Munir, K., Bilal, M., Ajayi, S. O., Owolabi, H. A., Alaka, H. A., & Bello, S. A. (2016). Evaluation criteria for construction waste management tools: Towards a holistic BIM framework. *International Journal of Sustainable Building Technology and Urban Development*, *7*(1), 3–21. https://doi.org/10.1080/2093761X.2016.1152203

Ali, B. (2018). *BIM - Based Claims Management System : A Centralized Visual Information Repository for Extension of Time Claims Babar Ali BIM - Based Claims Management System : A Centralized Visual Submitted by Babar Ali*. *00000105768*.

Ali, B., Zahoor, H., Mazher, K. M., & Maqsoom, A. (2018a). BIM Implementation in Public Sector of Pakistan Construction Industry. *ICCREM 2018: Innovative Technology and Intelligent Construction - Proceedings of the International Conference on Construction and Real Estate Management 2018*, *1*, 42–51. https://doi.org/10.1061/9780784481721.005

Ali, B., Zahoor, H., Mazher, K. M., & Maqsoom, A. (2018b). *BIM Implementation in Public Sector of Pakistan Construction Industry*. *August*, 42–51. https://doi.org/10.1061/9780784481721.005

Ali, B., Zahoor, H., Nasir, A. R., Maqsoom, A., Khan, R. W. A., & Mazher, K. M. (2020). BIM-based claims management system: A centralized information repository for extension of time claims. *Automation in Construction*,

110(December 2018). https://doi.org/10.1016/j.autcon.2019.102937

Ansah, S. K. (2011). Causes and Effects of Delayed Payments By Clients on Construction Projects in Ghana. *Journal of Construction Project Management and Innovation*, *1*(1), 27–45.

Arditi, D., & Chotibhongs, R. (2005). Issues in Subcontracting Practice. *Journal of Construction Engineering and Management*, *131*(8), 866–876. https://doi.org/10.1061/(asce)0733-9364(2005)131:8(866)

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and Management in Engineering*, *11*(3), 241–252. https://doi.org/10.1061/(ASCE)LM.1943-5630.0000127

Azhar, S. (2013). Research Impact Principles and Framework. *General Information*, *1*.

Babar, S., Thaheem, M. J., & Ayub, B. (2017). Estimated Cost at Completion: Integrating Risk into Earned Value Management. *Journal of Construction Engineering and Management*, *143*(3), 04016104. https://doi.org/10.1061/(asce)co.1943-7862.0001245

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). *International Journal of Project Management*, *31*(7), 971–980. https://doi.org/10.1016/j.ijproman.2012.12.001

Bynum, P., Issa, R. R. A., & Olbina, S. (2013). Building Information Modeling in Support of Sustainable Design and Construction. *Journal of Construction Engineering and Management*, *139*(1), 24–34. https://doi.org/10.1061/(asce)co.1943-7862.0000560

Cerovsek, T. (2011). A review and outlook for a “Building Information Model”

(BIM): A multi-standpoint framework for technological development. *Advanced Engineering Informatics*, *25*(2), 224–244. https://doi.org/10.1016/j.aei.2010.06.003

Chen, Z., Agapiou, A., & Li, H. (2020). A Benefits Prioritization Analysis on Adopting BIM Systems Against Major Challenges in Megaproject Delivery. *Frontiers in Built Environment*, *6*(April). https://doi.org/10.3389/fbuil.2020.00026

Chiu, W. Y. B., & Lai, J. H. K. (2020). Building information modelling for building services engineering: benefits, barriers and conducive measures. *Engineering, Construction and Architectural Management*, *27*(9), 2221–2252. https://doi.org/10.1108/ECAM-10-2018-0460

Chou, H. Y., & Chen, P. Y. (2017). Benefit Evaluation of Implementing BIM in Construction Projects. *IOP Conference Series: Materials Science and Engineering*, *245*(6). https://doi.org/10.1088/1757-899X/245/6/062049

Chou, H. Y., & Yang, J. Bin. (2017). Preliminary Evaluation of BIM-based Approaches for Schedule Delay Analysis. *IOP Conference Series: Materials Science and Engineering*, *245*(6). https://doi.org/10.1088/1757-899X/245/6/062048

Construction Industry Council. (2018). *Building Information Modeling (BIM) protocol second edition*. 1–15.

Davidson, J., Fowler, J., Pantazis, C., Sannino, M., Walker, J., Sheikhkhoshkar, M., & Rahimian, F. P. (2019). Integration of VR with BIM to facilitate real-time creation of bill of quantities during the design phase: a proof of concept study. *Frontiers of Engineering Management*. https://doi.org/10.1007/s42524-019-0039-y

Demachkieh, F. S., & Abdul-Malak, M. A. U. (2019). Administration of Construction Contract Interim Payments Based on Earned-Value Reduction Techniques. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *11*(4), 1–14. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000309

Doumbouya, L., Gao, G., & Guan, C. (2016). Adoption of the Building Information Modeling (BIM) for Construction Project Effectiveness: The Review of BIM Benefits. *American Journal of Civil Engineering and Architecture*, *4*(3), 74–79. https://doi.org/10.12691/ajcea-4-3-1

El-adaway, I. H., Fawzy, S. A., Cody, K., Fast, S., Spencer, G., Bond, D., Cushman, D., & Stieffel, T. (2014). Contract Administration Guidelines for Contractors Working under AIA A201-2007 Contract for Construction. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *6*(1), 03013002. https://doi.org/10.1061/(asce)la.1943-4170.0000131

Getachew, Z. (n.d.). *FEDERATION INTERNATIONALE DES INGENIEURS-CONSEILS PART II CONDITIONS OF PARTICULAR APPLICATION WITH GUIDELINES FOR WORKS OF CIVIL*.

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., & Raahemifar, K. (2017). Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. *Renewable and Sustainable Energy Reviews*, *75*(September 2016), 1046–1053. https://doi.org/10.1016/j.rser.2016.11.083

Gibbs, D.-J., Lord, W., Emmitt, S., & Ruikar, K. (2017). Interactive Exhibit to Assist with Understanding Project Delays. *Journal of Legal Affairs and*

Dispute Resolution in Engineering and Construction, *9*(1), 04516008. https://doi.org/10.1061/(asce)la.1943-4170.0000198

Hergunsel, M. F. (2011). Benefits of Building Information Modeling. *Benefits of Building Information Modeling*, *May*, 1136–1145. http://www.wpi.edu/Pubs/ETD/Available/etd-042011-135239/unrestricted/MHergunsel_Thesis_BIM.pdf

Hill, C. M. (2015). *The Business Value of BIM in Europe*.

Hooper, M., & Widén, K. (2015). BIM Inertia: Contracts and Behaviours. *Building Information Modeling*, *46*(0), 107–134. https://doi.org/10.1061/9780784413982.ch05

Hudson, N., Biscomb, J., Jarosz, C., Stephens, D., Marsh, S., Beardsley, S., Sharif, T., Holmes, K., Olbrich, L., Johnson, C., Buckley-Thorp, A., Siddiqui, R., Thompson, S., Greant, M., Redmond, K., Graham, S., & Phillips, J. (2017). Closed BIM Versus open BIM. *BIM Journal*, *1*(1), 54.

Ibrahim, M., Mohammad, M., Nekooie, A., Binti, N., & Kamaruddin, C. (2012). The Adequacy of Contractual Provisions in Managing Construction Failure in Malaysia. *European Journal of Business and Management*, *4*(1), 22–38. http://www.iiste.org/Journals/index.php/EJBM/article/view/1023/943

Jin, R., Hancock, C. M., Tang, L., & Wanatowski, D. (2017). BIM Investment, Returns, and Risks in China's AEC Industries. *Journal of Construction Engineering and Management*, *143*(12), 04017089. https://doi.org/10.1061/(asce)co.1943-7862.0001408

Kartam, N. A., & Kartam, S. A. (2001). Risk and its management in the Kuwaiti construction industry: A contractors' perspective. *International Journal of Project Management*, *19*(6), 325–335. https://doi.org/10.1016/S0263-

7863(00)00014-4

Kenyatta, M. O. (2016a). Causes of Payment Defaults in the Construction Industry of Kenya: Small and Medium Sized Contractor's Perspective. *International Journal of Emerging Science and Engineering*, *4*(4), 1–8.

Kenyatta, M. O. (2016b). Exploring Into the Factors That Cause Payment Defaults : a Perspective of the Payment Dispute Cases in the Kenyan Construction Industry. *International Journal of Innovative Technology and Exploring Engineering*, *9*, 2278–3075. https://www.researchgate.net/profile/Mark_Kenyatta2/publication/320426495_Exploring_Into_the_Factors_That_Cause_Payment_Defaults_a_Perspective_of_the_Payment_Dispute_Cases_in_the_Kenyan_Construction_Industry/links/59e4c8f1458515393d611e17/Exploring-Into-t

Latiffi, A. A., Mohd, S., Kasim, N., & Fathi, M. S. (2013). *Building Information Modeling (BIM) Application in Malaysian Construction Industry*. *2*(June), 1–6. https://doi.org/10.5923/s.ijcem.201309.01

M. E. Che Munaaim, M. (2012). Is Late Or Non-Payment A Significant Problem To Malaysian Contractors? *Journal of Design and Built Environment*, *Volume 3*(Issue 1).

Mara, T. (2011). *Munich Personal RePEc Archive The adequacy of Malaysian security of payment legislation for sub-contractors in construction industry Supardi , Azizan and Adnan , Hamimah and Mohammad ,. 34013*.

Mason, J. (2017). Intelligent Contracts and the Construction Industry. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *9*(3), 04517012. https://doi.org/10.1061/(asce)la.1943-4170.0000233

Moayeri, V., Moselhi, O., & Zhu, Z. (2016). Design Change Time Ripple Effect

Analysis Using a BIM-Based Quantification Model. *Construction Research Congress 2016: Old and New Construction Technologies Converge in Historic San Juan - Proceedings of the 2016 Construction Research Congress, CRC 2016*, 28–36. https://doi.org/10.1061/9780784479827.004

Muthi, S. A. G. (2019). *Payment Regularity : a Study of Building*. *August*, 160.

NEC. (2013). *use BIM with NEC3 contracts - An NEC document*. *April*.

Nisbet, N., & Dinesen, B. (2010). International Alliance for Interoperability; Constructing the business case, Building information modelling. *British Standards Institution*, 20. http://shop.bsigroup.com/Browse-by-Sector/Building--Construction/Building-Information-Modelling/

Nor, M., Azman, A., Dzulkalnine, N., Hamid, Z. A., & Bing, K. W. (2014). Jurnal Teknologi Full paper Payment Issue in Malaysian Construction Industry : Contractors ’. *Quarterly Journal of Economics*, *1*, 57–63. http://books.google.com/books?id=FTaNfk6Z_xMC&pgis=1

Odeh, A. M., & Battaineh, H. T. (2002). Causes of construction delay: Traditional contracts. *International Journal of Project Management*, *20*(1), 67–73. https://doi.org/10.1016/S0263-7863(00)00037-5

Odenigbo, O. G., Odusami, K. T., Okolie, K. C., & Okafor, V. C. (2020). Causes of Delayed Payment in Construction Project in Nigeria. *European Journal of Engineering Research and Science*, *5*(9), 1049–1053. https://doi.org/10.24018/ejers.2020.5.9.2066

Odeyinka, H. A., Lowe, J., & Kaka, A. (2008). An evaluation of risk factors impacting construction cash flow forecast. *Journal of Financial Management of Property and Construction*, *13*(1), 5–17. https://doi.org/10.1108/13664380810882048

Onososen, A. (2019). *Unilorin Environmental Sciences Conference 2019 ICES i* (Issue September).

Osman, Z., Omran, A., & Foo, C. K. (2009). The Potential Effects of Variation Orders in Construction Projects. *Annals of the Faculty of Engineering Hunedoara – Journal of Engineering*, *Tome VII*(Fascicule 2), 141–152.

Oyewobi, L. O., Jimoh, R., Ganiyu, B. O., & Shittu, A. A. (2016). Analysis of causes and impact of variation order on educational building projects. *Journal of Facilities Management*, *14*(2), 139–164. https://doi.org/10.1108/JFM-01-2015-0001

Peters, E., Subar, K., & Martin, H. (2019). Late Payment and Nonpayment within the Construction Industry: Causes, Effects, and Solutions. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *11*(3), 04519013. https://doi.org/10.1061/(asce)la.1943-4170.0000314

Ramachandra, T., Rotimi, J., & Hyde, K. (2015). *Causes of payment delays and losses in the construction industry*. *15*(1), 43–55.

Ramachandra, T., & Rotimi, J. O. B. (2015). Mitigating Payment Problems in the Construction Industry through Analysis of Construction Payment Disputes. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *7*(1). https://doi.org/10.1061/(asce)la.1943-4170.0000156

Raman, S. A., Zakaria, R., & Mohandes, S. R. (2016). *L ATE P AYMENT P RACTICES I N T HE M ALAYSIAN C ONSTRUCTION Mohd Khairul Anas Mohd Badroldin , Abdul Rahim Abdul Hamid *,*. *162*(3), 149–162.

Scholnick, B., Massoud, N., & Saunders, A. (2013). The impact of wealth on financial mistakes: Evidence from credit card non-payment. *Journal of Financial Stability*, *9*(1), 26–37. https://doi.org/10.1016/j.jfs.2012.11.005

Sebastian, R., Haak, W., & Vos, E. (2009). BIM application for integrated design and engineering in small-scale housing development: a pilot project in The Netherlands. *Proceedings of International …*, *November*, 2–3.

Senarathne, E., Bandara, G., & Dissanayake, K. (2020). *Significant Causes behind Payment Delays in Public Sector Building Construction Projects in North Western Province of Sri Lanka*.

Song, M. H., Fischer, M., & Theis, P. (2017). Field Study on the Connection between BIM and Daily Work Orders. *Journal of Construction Engineering and Management*, *143*(5), 3–6. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001267

Sopihia, T. S. H., Majid, M. A., & Ahamad, N. H. (2016). A study on the constraints encountered by Quantity Surveyors in the process of preparation of Interim Payment. *INTI Journal Special Edition -Built Environment*, 3–5.

Stanley, R., & Thurnell, D. (2014). The benefits of, and barriers to, implementation of 5D BIM for quantity surveying in New Zealand. *Australasian Journal of Construction Economics and Building*, *14*(1), 105–117. https://doi.org/10.5130/ajceb.v14i1.3786

Suhaidah Sahab, S., & Ismail, Z. (2011). Construction industry payment and adjudication Act; Enhancing security of payment in the malaysian construction industry. *ICBEIA 2011 - 2011 International Conference on Business, Engineering and Industrial Applications*, 153–159. https://doi.org/10.1109/ICBEIA.2011.5994231

Tang, S., Shelden, D. R., Eastman, C. M., Pishdad-Bozorgi, P., & Gao, X. (2020). BIM assisted Building Automation System information exchange using BACnet and IFC. *Automation in Construction*, *110*(November 2019), 103049.

https://doi.org/10.1016/j.autcon.2019.103049

Touran, A., Atgun, M., & Bhurisith, I. (2004). Analysis of the United States Department of Transportation Prompt Pay Provisions. *Journal of Construction Engineering and Management*, *130*(5), 719–725. https://doi.org/10.1061/(asce)0733-9364(2004)130:5(719)

Tulubas Gokuc, Y., & Arditi, D. (2017). Adoption of BIM in architectural design firms. *Architectural Science Review*, *60*(6), 483–492. https://doi.org/10.1080/00038628.2017.1383228

Tun, U., Onn, H., & Said, I. (2021). *Issues of Late and Non-Payment Among Contractors in Malaysia*. *January*.

Volk, R., Stengel, J., & Schultmann, F. (2014). Building Information Modeling (BIM) for existing buildings - Literature review and future needs. *Automation in Construction*, *38*, 109–127. https://doi.org/10.1016/j.autcon.2013.10.023

Wong, J. T. Y., & Hui, E. C. M. (2006). Construction project risks: Further considerations for constructors' pricing in Hong Kong. *Construction Management and Economics*, *24*(4), 425–438. https://doi.org/10.1080/01446190600601602

Wong, K. din, & Fan, Q. (2013). Building information modelling (BIM) for sustainable building design. *Facilities*, *31*(3), 138–157. https://doi.org/10.1108/02632771311299412

Wu, J., Kumaraswamy, M., & Soo, G. (2008). Payment problems and regulatory responses in the construction industry: Mainland China perspective. *Journal of Professional Issues in Engineering Education and Practice*, *134*(4), 399–407. https://doi.org/10.1061/(ASCE)1052-3928(2008)134:4(399)

Ye, K. M., & Rahman, H. A. (2010). Risk of late payment in the Malaysian

construction industry. *World Academy of Science, Engineering and Technology*, *65*(5), 538–546. https://doi.org/10.5281/zenodo.1329721

Yunianto, I., & Rarasati, A. D. (2021). Development of Contract Management Strategy to Control Late Payment in Building Projects. *Journal of International Conference Proceedings*, *3*(4), 10–23. https://doi.org/10.32535/jicp.v3i4.1005

Zhang, S., Teizer, J., Lee, J. K., Eastman, C. M., & Venugopal, M. (2013). Building Information Modeling (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules. *Automation in Construction*, *29*, 183–195. https://doi.org/10.1016/j.autcon.2012.05.006

APPENDIX-A

Evaluation of DIGITIZED IPC SYSTEM from Industry Experts

This exercise is carried out to evaluate the BIM based Digitization of Interim Payment System for monthly payments in construction industry, 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 for monthly bills.

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 written formats. Experts may answer depending on their preferable mode.

Thank You for your Cooperation.

Abdul Manan,

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)

1) There is a need to introduce such a system of IPC generation in Construction industry.

1	2	3	4	5

2) The proposed system would be easy to use.

1	2	3	4	5

3) The proposed system is implementable.

1	2	3	4	5

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

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

6) 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	**Likert Scale**				
Poor Financial Management by Client	1	2	3	4	5
Disagreement on Valuation of Work done	1	2	3	4	5
Insufficient/ambiguous Information Provided for Certification	1	2	3	4	5
Slow Process of Approving Variations	1	2	3	4	5
Disputed Work	1	2	3	4	5
Failure to value & certify the work done by Consultant	1	2	3	4	5
Poor Communication / Flow of Information among parties	1	2	3	4	5
Poor documentation procedure practiced	1	2	3	4	5
Deliberate delay for some benefits	1	2	3	4	5
Major defects in Construction work	1	2	3	4	5
Local Culture/Attitude of late payment	1	2	3	4	5
Wrongly Calculated Claims	1	2	3	4	5
Poor quality of work	1	2	3	4	5
Conflict among the parties involve	1	2	3	4	5

Difficulties in reaching a settlement between parties	1	2	3	4	5
Non-BOQ Work done	1	2	3	4	5
Perception that late certification is acceptable for few days	1	2	3	4	5
Involvement of too many parties for certification of payment	1	2	3	4	5
Work done doesn't reach the limit of IPC	1	2	3	4	5
Elongated Payment terms in Contracts	1	2	3	4	5
Poor Economic & Market Conditions	1	2	3	4	5
Inexperience Project Personnel	1	2	3	4	5
Breach of any Contract term of project by the Contractor	1	2	3	4	5
Complex Contractual Provision	1	2	3	4	5
Short of Current Year's Project	1	2	3	4	5
Scarcity of Capital to Finance Project	1	2	3	4	5
Clients assumption that Contractor will finance the project	1	2	3	4	5
Failure to Understand Contract Agreement	1	2	3	4	5
Client's Lack of Trust on Consultants Valuation	1	2	3	4	5
Poor Financial Management by Client	1	2	3	4	5
Inequality of Contractual bargaining Power					

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

8) Overall, the proposed system would be effective in improving the process of Interim Payments in Construction Industry.

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

1	2	3	4	5