

ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING



**Computer Aided Management of Construction
Payment: For Clients with Multiple Building
Projects**

**A Thesis Submitted to School of Civil and Environmental Engineering of
Addis Ababa University in Partial Fulfillment of the Requirements for the
Degree of Master of Science in Civil Engineering
(Construction Technology and Management)**

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**March, 2022
Addis Ababa**

DECLARATION

I, the under signed, declare that this thesis work titled “**Computer Aided Management of Construction Payment: For Clients with Multiple Building Projects**” is my original work and it has not been presented for a degree in any other university. All sources of materials used for the thesis have been duly acknowledged.

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Computer Aided Management of Construction Payment: For Clients with Multiple Building Projects

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ABSTRACT

Regular and on-time payment is critical for the successful completion of a construction project. However, the construction industry suffers from delayed payments due to an inefficient payment certification process. Payment delays affect material delivery, labor productivity, and project progress and induce financial and subsequent time claims. This study proposed the breakdown of contract conditions into a logic that can be converted into executable codes called smart contracts that are executed on a web-based application. The system uses a centralized database to store contract data and BOQ and a backend developed using PHP that integrates smart contracts to automate and control payment management. The web-based application was then tested using the data from three building projects and was found to be accurate, effective, and efficient. Aside from creating automated payment certificates the web-based application can check bill of quantities, update advance payment and performance guarantee amount and expiry dates, identify various contract limits, and provide documentation tools. The result of the study has shown that the use of smart contracts and web-based application facilitate automation, control, and follow-up of the payment management process for clients with multiple building projects.

Keywords: Web-based Application; Construction Payment Management; Payment Certificate; Smart contract

LIST OF ABBREVIATIONS

CSS:	Cascading Style Sheets
GCC:	General conditions of contract
HTML:	Hypertext Markup Language
SCC:	Special Conditions of Contract
SQL:	Structured query language
PHP:	Hypertext preprocessor
WAMP:	Windows, Apache, MySQL and PHP

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CHAPTER 1. INTRODUCTION

1.1 Background of the Study

Payment is the transfer of money or its equivalent in exchange for a product or service. Payments are critical in any industry, especially in the construction industry where the performance period is long, the work is complex, significant capital and large scale manpower are required, and the risks involved are high (Ameer-Ali, 2006).

The construction industry is a major player in the growth of any country and this is true for the Ethiopian construction industry. Clients being the most important party in any construction industry play a significant role. However, clients are faced with adverse problems in managing their projects because of various issues one of which is difficulty in managing payment.

The common types of payment problems are categorized into three namely late payment, partial payment, and non-payment. However, based on the research by Fitehawok (2018) late payment has the highest occurrence in public building construction projects in Addis Ababa City. Hence, the study focuses on late payment as the primary payment problem affecting the construction industry.

Several pieces of research have demonstrated the effect of late payment on the construction industry. These include the impact on contractor's cash flow Odeyinka et al. (2008), low labor productivity rates Durdyev & Mbachu (2011), stress on contractors leading to interruption of the program of works Amoako (2011), time overrun and cost overrun Abdul-Rahman et al. (2011) obstruct material delivery, decrease in labor productivity, insolvency, and ultimately the survival of the industry is affected (Cheng, et al., 2009).

A study by Worku (2020) found that late payment can lead to project delays, negatively affect the construction supply chain, and fuel disputes among parties. Additionally, a study by Fitehawok (2018) indicated that payment delay results in project cost overrun, the bankruptcy of contractors, and a decrease in quality of work.

Based on the research conducted by Fitehawok (2018) the number one issue causing payment delay is the bureaucratic payment system of the employer. It involves several people looking at a single certificate in a fragmented manner increasing the time without reducing the errors.

Furthermore, the hierarchical structure of the employer and contractual framework is not transparent and is susceptible to poor payment practices (Pettigrew, 2005). Another cause of payment delay is frequent variation order than doesn't account for the variation limit and its consequence on the capacity of the employer to finance the project (Fitehawok, 2018). Clients' delay in payment certification and poor financial management are some of the causes identified by Ansah (2011).

However, the client's current payment management system is characterized by negligence and repetitive errors (Fitehawok, 2018), late certification of payment Abdul-Rahman et al. (2008), and poor documentation that leads to delays in the processing of variations (Euginie, 2006). Furthermore, the current payment management relies on manual supervision of contractual limits, prerequisites, and guarantees. Negligence on the part of the Client's engineers' could lead to payments that exceed contractual limits and payments without valid guarantees. Furthermore, compiling reports on various items in the payment certificate like exceeding quantity will require significant effort. Furthermore, due to the sheer amount of paperwork involved it's practically very difficult to trace each payment or transaction.

For clients managing multiple building projects considering the above problems of the current payment management problem and the increasing complexity of the construction projects, the task has become daunting.

Several studies were done by various researchers to automate the payment management process and incorporate contractual conditions as a follow-up and control mechanism (Hamledari & Fischer, 2020). The most promising study is done by Luo et al. (2019) where they used a blockchain framework that uses the smart contract as the base. However, it uses a decentralized system hence; privacy and security become the primary issues.

Furthermore, this will strip the contractual position that the client has and limit his rights. Additionally, the concept and the technology that support it are at their earliest stage which would inhibit its applicability in the construction industry. Consequently, this study aims to address the problems in the current payment management system used by clients for managing multiple building projects.

1.2 Statement of the problem

Payment is an integral part of the construction industry as the activities of contractors, subcontractors, and suppliers are dependent on the consistency of cash flow from the construction projects. Some researchers even argue that payment can be considered the lifeblood of the construction industry (Supardi et al., 2011). Consequently, the impact of payment problems on the construction industry is significant, to say the least (Durdyev & Mbachu, 2011; Amoako, 2011; Odeyinka et al., 2008; Cheng, et al., 2009).

Payment problems include late payment, partial payment, and non-payment with late payment having the highest occurrence Fitehawok (2018). A study by Worku (2020) found that late payment can lead to project delays, negatively affect the construction supply chain, and fuel disputes among parties. Additionally, a study by Fitehawok (2018) indicated that payment delay results in project cost overrun, the bankruptcy of contractors, and a decrease in quality of work.

The payment problems observed in the construction industry could be attributed to the bureaucratic payment system of the employer Fitehawok (2018), poor payment practices (Pettigrew, 2005), delay in payment certification, and poor payment management Ansah (2011). The current payment management system is characterized by negligence and repetitive errors (Fitehawok, 2018), mechanical and arithmetic errors Panko (2005), late certification of payment Abdul-Rahman et al. (2008), and poor documentation that leads to delays in the processing of variations (Eugenie, 2006), and lack of transparency.

Furthermore, clients that manage multiple building projects have to effect and administer payments arising out of the design and construction of these projects increasing the difficulty of payment management which exacerbated the payment problems (Tadele, 2017).

A review of previous studies shows that solutions available to mitigate payment management problems vary due to the nature of the problem, the structure and unique aspects of each construction industry, technological advancement, and other characteristics. Most studies aimed at mitigating the problems of construction payment management systems have been done (Hamledari & Fischer, 2020). However, each of them has its limitations including lack of automation and contractual control Alemneh et al. (2010 E.C), and privacy and security issues Luo et al. (2019).

This research aims at developing a computer-aided construction payment management that is focused on clients managing multiple building projects to address the limitation of the current payment management system.

1.3 Objective of the study

1.3.1 General Objective

Develop a computer-aided construction payment management system for clients with multiple building projects that will: -

- Reduce time, error, and paperwork required in the payment certification process
- Creates a transparent payment certification process
- Aid payment related claim management process

1.3.2 Specific Objective

The following outlines the specific objectives developed in the current study to achieve the above general objectives

- To create an automated payment certification system for multiple projects.
- To create a payment follow up system that keeps accurate track of payment transaction/certification and manages the whole process
- To create a payment reporting system
- To create a secure database with hierarchical clearance
- To create an Integrated Project Interface

1.4 Scope and Limitations of the study

The research title is Computer-Aided Management of Construction Payment: For Clients with Multiple Building Projects. Consequently, the scope of the research is limited to clients managing multiple building projects. Furthermore, the projects managed by the clients should be re-measurement (unit price) type contract and governed by the Public Procurement Act 2011 (PPA 2011).

This delineation of scope is needed because different conditions of the contract have different parameters and in the future, the system could be extended to include other standard conditions

of the contract. Furthermore, currently, the system is designed to handle unit price-based contract BOQs only. The projects chosen will consist of those which are in progress to fully demonstrate the capability of the system being developed. However, the system can be used to prepare final payment for completed projects.

The results of this study should be interpreted with caution while considering the following limitations. The study has focused on payment management from the perspective of the client consequently activities like on-site measurement or valuation of work executed were not addressed.

Furthermore, due to the time limitation the web-based application developed to manage payment doesn't include price adjustment analysis, however, the option of adjusting the contract price manually and submitting the revised BOQ is incorporated.

Due to cost limitation, open-source PHP framework is used which is limited in capacity and functionality. Large scale implementation of the study output should be done taking this into consideration.

Due to constrain of time and logistical problems the study was implemented on three building projects only hence caution should be taken when generalizing the results of this paper.

1.5 Significance of the Study

This study aims to develop an automated construction payment management system that will help clients manage multiple building projects by incorporating contractual conditions as system parameters and creating a secure database.

The clients will have real-time payment management that can be seen by contractors and consultants. This will enhance communication and collaboration between project stakeholders. Furthermore, this will address transparency issues and aid payment-related claim management through proper payment documentation and tracking. The system can create several reports concerning the progress of exceeding quantity, variations, liquidated damage, and guarantees which will provide quantifiable data for further studies.

CHAPTER 2. LITERATURE REVIEW

2.1 Construction Contract

2.1.1 Introduction

A construction contract is a foundation for any construction project. It serves as the basis for administering and managing construction projects. However, before discussing a construction contract, the contract has to be defined. There are several definitions of a contract but all of them start by identifying a contract as an agreement.

A contract is an agreement between two or more parties that is enforceable by law (Hinze, 2011). This definition closely resembles the definition given in the Civil Code of Ethiopia. Based on article 1675, of the civil code of Ethiopia (1960), "a contract is an agreement whereby two or more persons as between themselves create, vary or extinguish obligations of a proprietary nature."

The above two definitions contain various key points that need to be raised. The first key point is that a contract is an agreement that is made between two or more persons. No contract can be made without an agreement however not all agreements are contracts. The next key point is the existence of obligations that have been set out by the parties. The agreement made could be to create, vary or extinguish these obligations of proprietary nature.

A construction contract fulfils all the above requirements and is tailored to suit the specific need of construction projects. Additionally, article 3019, of the Civil Code of Ethiopia states that the contract shall be considered complete where the parties have agreed on the work to be done and on the price. Agreement on the price of the work is seen as criteria for the validity of the contract. The scope of work for which the contract is being drawn should also be defined (Hinze, 2011).

2.1.2 Elements of a contract

There are basic elements that all contracts need to have to become valid. The construction contract is a legally binding agreement, therefore; it should adhere to the legal criteria set out by the civil laws. A construction contract contains the essential elements including offer, acceptance, and consideration (Nunnally, 2007).

An offer is a proposal submitted by one party to show his willingness to enter into a legally binding contract. The offer should be unconditional and communicated to the other party.

The offer should be accepted without any reservation by the other party otherwise, it will be defective based on article 1694, of the Civil Code of Ethiopia. Both offer and acceptance can be made orally or in writing. However, construction contracts are made in writing since the contract document is used as proof. The client sends a notice of award as a form of acceptance. Furthermore, according to article 1678 of the Civil Code of Ethiopia, No valid contract shall exist unless

- The contracting parties are capable
- The object of the contract is sufficiently defined and is possible and lawful and;
- The contract is made in the form prescribed by the law if any.

2.1.3 The contract document

The contract document is a special document prepared to address specific topics. A construction contract should identify the main parties in a construction project and define their rights and obligations. The project may be defined descriptively, along with specific reference to documents such as the construction drawings and specifications (Hinze, 2011).

The contract document contains multiple documents that address various issues related to the construction project. These documents should be coherent, complementary, and free from conflicts however, the contract agreement shall declare the order of precedence in the event of a conflict. According to PPA clause 7(2011), the documents forming the Contract shall be interpreted in the following order of precedence in the event of any conflict between the documents comprising this Contract Agreement, including all appendices;

- 1) Letter of Acceptance by the Employer to the Contractor;
- 2) The Special (Particular) Conditions of Contract,
- 3) The General Conditions of Contract,
- 4) Bid Submission Sheet with Annexes;
- 5) Specifications (Special/Particular and General);
- 6) Technical proposal with technical specification;
- 7) The design documentation (drawings);
- 8) For Unit-Price Contracts: -The Bill of Quantities and Price Schedule(after correction of arithmetical corrections)

For Lump-Sum Contracts: -the breakdown of the Lump-Sum price (after correction of arithmetical corrections)

The contract document is prepared by the involvement of various professionals including the project manager, design team members, contract administration staff, and others with each contributing certain elements to the total package. These professionals are responsible for the quality and proper functioning of the contract document.

2.1.4 The role of the main participants in contracts

A construction contract is based on a legally binding agreement between the employer and the contractor. The contract defines the rights and obligations of the employer and the contractor. Introducing a third person to successfully manage the construction activities and administer the contract is an option.

Depending on the chosen standard conditions of the contract, the third person has varying powers under the contract. The third person is commonly designated 'the Engineer' under the contract but it can also be designated as 'Employer's Representative' or 'the Project manager'. Each designation carries a unique position and corresponding duties. Consequently, the third person rights or obligations as derived rather than direct legal rights or obligations.

2.1.4.1 Role of the Employer

Clause 1 of PPA (2011), defines Employer as, “Means Employer, which has the powers and duties to conclude a Contract for the supply of Works, as specified in the SCC.”Based on the standard conditions of contract used the role of the Employer varies. This is because the Engineer will take on the role of supervision and contract administration. The PPA has limited to the role of the Employer to assist and supply documents, provide access to the site, and make payment in the manner stipulated in the contract.

Based on Clause 30 of PPA (2011), the Employer's Role in the assistance and supply of documents includes providing copies of laws, regulations, and necessary permits. Additionally, the Employer is required to provide a copy of drawings, specifications, and other contract documents. These documents are used for the sole purpose of completing the project and may not be communicated to a third person without the consent of the Employer.

Furthermore, the Employer is required to provide access to the site within the given time stipulated in the contract document. Failure to provide the above documents or access to the site

will deem the Employer responsible for delaying the project. The Contractor should allow the Employer or the Employer's representative access to the site.

Another important role of the Employer is making payments for the work done by the Contractor. The amount and timing of payments made shall be stipulated in the contract. If the employer failed to make the required payment promptly, it would have delayed the project's completion (Ansah, 2011). Therefore, a proper manager of payment is vital for the healthy progress of any construction project.

2.1.4.2 Role of the contractor

Under clause 1 of PPA(2011), Contractor “means a natural or juridical person under contract with an Employer to supply works;”

The contractor is obligated to execute works and remedy defects in the works. The contractor will be responsible for the site, materials, personnel, equipment, and other items required for the work. The contractor should make sure that the work executed conforms to the specifications set out in the contract.

The contractor will depend on its expertise, specifications, various quality tests, and other documents to ensure the quality of work. The contractor is obligated to perform all the work set out in the contract regardless of difficulties that may be encountered. He is responsible for all work done by his sub-contractors and suppliers, and any design work the contract requires him to undertake (Gordon, 2004).

The contractor is required to submit various documents per the contract. These documents may be related to material or work approval, variation or time extension, etc. In addition, the contractor is required to submit guarantees in the form prescribed in the contract. If the guarantees expire before completion of the project or before full repayment the contractor is obligated to renew the guarantee or furnish a new one.

2.1.4.3 Role of the Consultant/Engineer

According to clause 1(n) of PPA (2011), Engineer “Means a person named in the Special Conditions of Contract or appointed as such by the Employer and notified in writing to the Contractor to act as the representative of the Employer to supervise and inspect works and to test

and examine the materials employed and the quality of workmanship, including any authorized representative of such person;”

According to the FIDIC condition of contract for building construction (2017), the engineer has a specific role independent of the Employer and Contractor. The main responsibilities of the Engineer include design and documentation, supervision, and contract administration. The Engineer should act as a skilled professional and make decisions without bias. The engineer is an experienced and qualified professional (Gordon, 2004). The engineer's knowledge and standing should be sufficient to assure both employer and contractor that the decisions made are likely to be satisfactory, and given independently and impartially (Gordon, 2004).

One of the critical roles of the Engineer is to check measurements of work done. Along with this, the Engineer has to check and certify interim and final payment certificates and make any deductions necessary. When found necessary the engineer shall determine and issue additional payment as per the contract agreement.

2.1.5 Types of Construction Contracts

Depending on the contract payments are made in various ways. Contracts will state the frequency of payment, mode of payments, and prerequisite of payments. Payment could be made on monthly basis or for smaller projects it could be made in one or two installments. According to clause 60 PPA (2011), the contractor may be given an agreed sum before construction begins which is called advance payment.

Multiple arrangements could be made regarding payment. These arrangements will be the key aspects that classify the types of construction contracts. The nature of the project and the specific needs of the owner will determine the form that is most suited for the project (Hinze, 2011). The most common types of construction contracts are re-measurement contracts, lump-sum contracts, cost-reimbursement contracts, and target contracts.

2.1.5.1 Re-Measurement Contracts

In this category of contract, the employer accepts the risk of variation in the quantities originally estimated and in some of the rates and prices tendered (Bunni, 2005). This type of contract is suited for projects that are well defined and estimated actual quantities are possible with a certain

degree of accuracy. The unit prices of each work item are determined using cost breakdown and become the basis of the contract.

During bidding, contractors set unit bid prices and the winning bid will be used as a means to establish the contract and payment to be made to the contractor. However, the total project cost will be different than the agreed price which is based on the offer by the contractor with lowest bid (Hinze, 2011).

2.1.5.2 Lump Sum Contracts

Lumps sum contract is another type of contract used in the construction industry where the contract price is fixed. This will present a low financial risk to the owner, and the required investment level can be established at an early date (Benator & Thumann, 2003). It will also provide an opportunity for the contractor to increase returns by working efficiently.

The contract essentially states that the contractor will produce the project as designed for a stated specific sum (Hinze, 2011). The lump-sum contract is a suitable contract agreement if the required work is well-defined and construction drawings are completed. In this type of contract, the owner's risk is reduced and the contractor has greater control over profit expectations. The time required to award this type of contract is shorter and change orders are minimized during construction.

2.1.5.3 Cost Reimbursement Contracts

Cost reimbursement contracts are commonly used types of contracts for projects with unforeseeable kinds of work. These types of contracts may contain lump sum items or daily or hourly rates considering all associated costs. The major advantage of this type of contract is that a contract can be signed during the earlier stages of the project (Benator & Thumann, 2003).

This type of contract requires a competent contractor since the majority of the risk will be covered by him. Where the works can be reasonably well defined, it may be best to use a measurement type of contract with a contingency sum allowed for any changes found necessary (Gordon, 2004). However, the main disadvantage of this type of contract is that the owner will not be able to know the final cost which makes budgeting very difficult.

2.1.5.4 Target Contracts

Target contracts can be seen as a special type of cost-reimbursement contract. The major difference is that there is an estimated target cost for the works and a fixed or percentage fee for the contractor's overheads and profit. Target contracts are intended to provide a strong financial incentive for the contractor to complete the work at minimum cost and time (Benator & Thumann, 2003).

Based on the design the contractor prepares cost estimates if they are approved to become the target cost. After the completion of the project, the target cost will be compared with the contractor's expenditure. If the total cost for the project is less than the target cost the contractor will get the difference as a bonus. Thus there is a financial incentive to the contractor to be efficient and save costs (Gordon, 2004).

Basically, the owner and contractor agree on the share of savings made by the contractor (Hendrickson & Au, 2008). This would push the contractor to find more efficient methods of construction and cost saving practices.

2.2 Contract Conditions Used in Building Projects

Contract conditions are terms used to describe the relationship between the client and contractor. They describe the rights and obligations of each party and the detailed conditions under which the work is to be carried out. They are a fundamental block for any construction contract and therefore, should be prepared with care.

These conditions bind both the Contractor and Employer to an obligation of performance. Clause 19 of PPA (2011) set out ways of penalizing a party in breach of the Contract. Generally, there are two types of construction contract conditions; General Conditions of Contract (GCC) and Special Conditions of Contract (SCC).

2.2.1 General Conditions

The General Conditions of Contract set out the legal/contractual arrangements that will apply to the Contract. The use of standard conditions of contract helps in allocating risks fairly between parties (Hughes et al., 2015). Analyzing each risk and properly allocating these risks is very difficult especially when dealing with complex projects. Consequently, the use of standard

conditions of contract will simplify and formalize this process however, this is not without its limits.

The General Conditions of Contract are used without any modifications to the terms or wording of the conditions. These conditions stipulate definitions of various terms, obligations of each party, method and forms of payment, guarantees, and other specific issues.

The use of standard general conditions of a contract will increase the successful completion of a contract because the contractor will be more familiar with the conditions that will apply under the contract. This will also help the contractor to plan for the project and assess the risks involved in the work.

2.2.2 Special Conditions

The Special Conditions of Contract (SCC) shall supplement the General Conditions of Contract (GCC) by specifying details relevant to an individual contract document such as its amount of liquidated damages, amount of retention money, percentage to apply to the value of the work not completed, etc. The Employer should include conditions from the GCC that need to be amended or augmented to meet the specific requirements (Hinze, 2011).

The SCC will have the same numbering as the corresponding GCC clause and the SCC should be prepared by the Employer to be issued with the Bidding document so that bidders will know of their commitments and other required information regarding the particular contract. Whenever there is a conflict between these documents, the provisions herein shall prevail over those in the GCC.

2.2.3 Ministry of Works and Urban Development Standard Conditions of Contract

The Ministry of Works and Urban Development Standard Conditions of Contract (MoWUD) Conditions of Contract known as “Standard conditions of contract for construction of civil work projects” are important local conditions of contract. The current one is valid since 1994 and contains 75 clauses. This condition of the contract has a similar structure and content with the FIIDC standard condition of contract. The project delivery system adopted is that of design-bid-build. The type of contract is based on a bill of quantities or BOQ, which is an admeasurement contract. It applies to civil engineering works.

2.2.4 Public Procurement Agency (PPA) General Conditions of Contract

The PPA Conditions of Contract are a recent one. They have been issued in January 2006 and later in 2011. They apply to all possible sorts of public procurement. The PPA, under its legal

mandate provided under The Public Procurement Proclamation, has prepared & issued certain standard tender & contract documents for public procurement.

The types of contracts treated in these conditions of contract are bill of quantities (BOQ) and lump sum. Additionally, it is based on a design-bid-build project delivery system. It applies to the procurements of the federal government.

The procurement activities include:-

- Consultancy Services;
- Non-consultancy Services;
- Works;
- Goods;

The main content includes general provisions, the contract, obligations of the Employer, obligations of the Contractor, payment to the Contractor, performance of the Contractor, and acceptance and defect liability. All the conditions in the GCC are expected to be correlative, complementary, and mutually explanatory.

Moreover, it deeply explains subcontracting, modification by change orders, change in laws and regulations, force majeure, breach of contract, suspension, termination, payment upon termination, settlement of disputes, and liquidated damages. It also states the obligations of the employer. Assistance and supply of documents to the contractor, providing access to the site, payment, and issues related to delayed payments to the contractor's staff are also briefly explained as the employer's obligation.

2.2.5 FIDIC Forms of Contract

These conditions of contract are prepared by the International Federation of Consulting Engineers (FIDIC) in association with the European International Federation of Construction (FEIC). FIDIC has published various conditions of contract including the Red Book (Conditions of Contract for Construction for Building and Engineering Works Designed by the Employer); Silver Book (Conditions of Contract for EPC/Turnkey Projects); Yellow Book (Conditions of Contract for Plant and Design-Build); Green Book (short form of contract); and Multilateral Development Bank (MDB) Harmonized Edition (Conditions of Contract for Construction).

FIDIC conditions of contract contain provisions for payments, an extension of time, nomination of subcontractors, liquidated damages, and other complexities that are dealt with by other standard conditions of contract. Furthermore, FIDIC has two distinct parts with specific roles. Part I of the conditions is of general applicability and Part II contains optional clauses specific to each project (Hughes et al., 2015).

2.3 Payment in a Construction Contract

2.3.1 Introduction

Payment can be defined in various ways but it's generally understood as the sum of money paid to someone in return for work done or goods delivered. In the construction industry, payment is the sum of money paid to contractors after the work for certain projects has been completed (Ansah, 2011). Payment in a construction contract should be made for work completed and materials delivered to the worksite. However, payments could be made upfront before the work is executed this is called an advance payment (Amoako, 2011; Mohd-Nazir, 2006). Based on Clause 60 of PPA (2011), advance payment is made to the contractor for mobilization expenses and implementation of the work.

The contract document contains various provisions related to how the contractor is to be paid. The primary obligation of the employer is to pay the contractor the sum of money which forms the consideration for the contract (Hughes et al., 2015). This is further supported by article 3029 of the Civil Code of Ethiopia which states that payment of the price; shall raise the presumption that the work has been examined and accepted by the client.

The contractor should submit copies of invoices and other supporting documents. According to PPA clause 59, failure to provide these documents will entitle the Employer to delay payments until such information is provided. Following FIDIC, these documents shall include the following items, as applicable, which shall be expressed in the various currencies in which the Contract Price is payable, in the sequence listed:

- The estimated contract value of the Construction Documents produced and the Works executed up to the end of the month (including Variations but excluding items described below.
- Any amount to be deducted for retention,

- Any amounts to be added and deducted for the advance repayments
- Addition or deduction for Plants and Materials used
- Any other additions or deductions which may have become due per the Contract and
- Any amounts to be added for Provisional Sums as per the contract
- Amount to be added when retention money is released
- Any amounts to be added for the release of Retention Money
- Deduction for previously paid interim payment certificates

2.4 The Contract Price

The contract price is the amount of money payable to the contractor for the execution of the work as stated in the contract. Under PPA general condition of contract sub-clause 1.2, contract price means the contract amount stated in the Employer's letter of acceptance. This amount could be the initial estimated amount or the final amount calculated after the completion of all works. Based on the contract type the final amount paid maybe different than the initial estimated amount.

The contract price could be fixed using an estimated price or by way of a lump sum. The employer has the right to fix the price by way of a lump sum or base the price on the estimated cost. But the important thing is that the contract price should be set since it's an issue of the validity of a contract. Once the parties agree on the rate for each work the employer should make payment accordingly.

2.5 Time of Payment

The contract document containing the standard conditions of the contract stipulates the general outlines regarding the timing and manner of payments to contractors for work done. The client can specify a specific frequency for an interim payment. Otherwise, per PPA sub-clause 64.7, the frequency shall be one interim payment per month. This is also supported by FIDIC 14.3, denoting that if a specific frequency for interim payment is not stated then the contractor shall submit a payment request at the end of each month.

The timing of payment should make sure that a contractor gets paid at regular intervals and shortage of cash is minimized. The contractor will be responsible for how he manages his cash flow however; the frequency of payment should not be an obstacle to achieving an optimal cash

flow. The FIDIC Red Book (2017), condition of the contract provides a typical sequence of payment for interim and final payments as presented in the figure below.

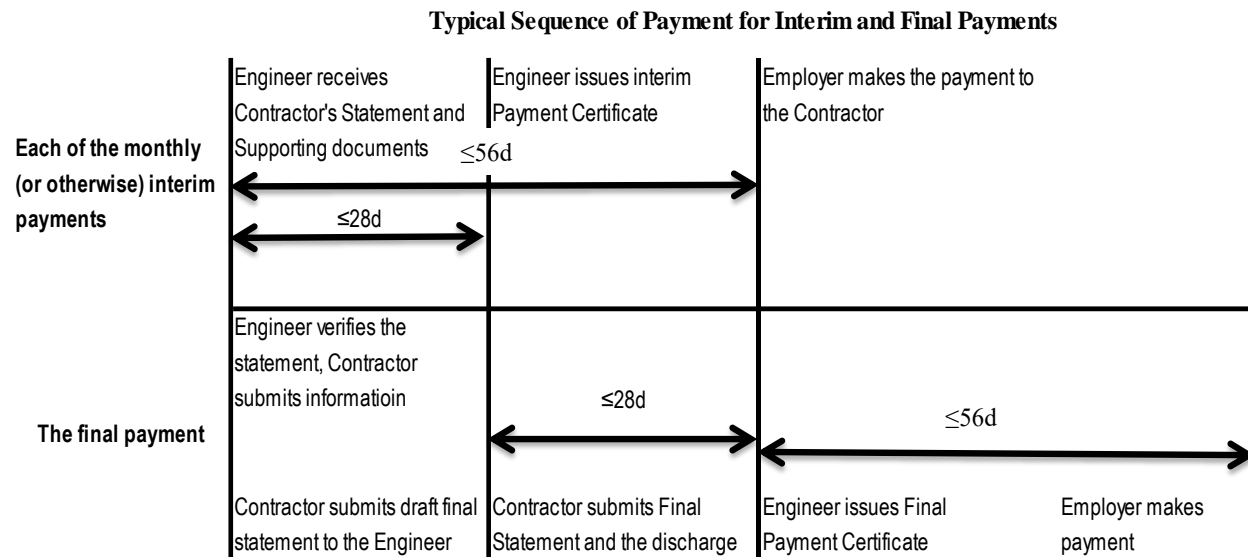


Figure 1 Typical Sequence of Payment for Interim and Final Payments

2.6 Types of payment in construction contract

There are many types of payments in construction contracts. But advance payment, interim payments, final payment, and retentions release are discussed as follows.

2.6.1 Advance Payment

Most conditions of the contract contain provisions for advance payment to be paid as an interest-free loan. The main purpose of implementing this scheme is to assist the contractor to start working without having to resort to unnecessary and costly external borrowings (Ansah, 2011).

Based on PPA (2011) sub-clause 60.1; the advance payment is made to the contractor to meet expenditures that are connected to the commencement of work. These might include the purchase of materials, plants, equipment, and other necessary expenses. Furthermore, the contractor is required to submit a guarantee in an amount equal to the advance payment.

The PPA states the limits and other considerations relating to advance payment. Other standard conditions of contracts like FIDIC Red Book (2017) also provide similar clauses however, the total advance payment, the number and timing of installments (if more than one), and the applicable currencies and proportions, are not stated explicitly.

2.6.2 Interim Payment

Interim payments are payments made at different intervals before the completion of the project. Interim certificates are simply a mechanism for confirming that an installment of the contract sum is due to the contractor (Hughes et al., 2015). The frequency of interim payment could be different for a different project.

These payments are important to create a healthy cash flow for the contractor. Based on the PPA conditions of contract, the contractor is entitled to one interim payment per month unless the SCC provides otherwise. According to Nunnally (2007) interim payments are commonly made monthly or after a certain milestone.

Based on article 3030 of the Civil Code of Ethiopia it is notified that where it has been agreed that the work would be carried out by stages and the work can be examined and delivered in stages. And the contractor may require that part of the price corresponding to the work completed he paid to him on completion of each of such stages.

Furthermore, based on PPA clause 64, the contractor is required to submit monthly statements which include the following items applicable:

- a) The estimated contract value of the permanent works implemented up to the end of the period in question;
- b) An amount reflecting any price adjustment under GCC Clause 62;
- c) An retention sum under GCC Clause 61;
- d) Material on-site
- e) An amount to be deducted on account of the advance payment repayment under the provisions of GCC Clause 60; and
- f) Any other sum to which the Contractor may be entitled under the Contract

Both PPA and FIDIC provide authority to the engineer to make corrections or modifications to previous certificates issued by him if he believes the works or any part thereof is not being carried out to his satisfaction.

2.6.3 Final Payment

Once the project achieved substantial completion the contractor submits the final payment certificate. Then the engineer will assess previous payments and completed works and determine the final amount due under the contract. Based on FIDIC Red Book (2017), the engineer after receiving the final statement shall issue to the employer, with a copy to the contractor, the final payment certificate.

The employer should make regular interim payments otherwise the final payment will be considerably large. The employer must also be prepared to shoulder this burden as well as be in a position to source and impact payment ultimately of a sizeable lump sum amount upon the taking over of the works (Amoako, 2011).

2.6.4 Retention Release

Retention money can be seen as security held by the employer in regards to the contractor fulfilling his obligations in respect of defects. It could also be understood as a small proportion of payments that are withheld from the contractor until the work has been completed satisfactorily (Hughes et al., 2015).

Based on sub-clause 61.1 of PPA (2011), “Retention money is the sum which shall be retained from interim payments by way of guarantee to meet the Contractor's obligations during the Defects Liability Period, and the detailed rules governing that guarantee shall be stipulated in the SCC, provided that it shall, in no case, exceed 10% of the contract price.”

The retention money shall be released as laid out in the contract agreement on the date specified thereof. Based on FIDIC (2017), the employer shall release half of the retention money upon issuance of taking-over certificate and the other half shall be released upon the expiration of the defects liability period for the works. The specific conditions surrounding this could be stipulated by the employer in SCC.

2.7 Payment Certificate

A payment certificate is a statement of evidence that the work has been completed and was verified by the engineer for a construction project. The resident engineer will check all items of

work that have been stated to be completed and verified. Once all the calculations are done and checked the payment certificate will be approved and issued.

The contractor is required to submit a payment request and any other supporting document needed for evaluation and approval. Based on FIDIC (2017), the engineer shall issue an interim payment certificate (IPC) to the employer within 28 days of receiving a statement and supporting documents. The certificate should contain the amount the engineer considers due to the contractor and any addition or deduction that has been set in the contract document.

The PPA (2011) conditions of contract stipulate certain conditions that should be met by the contractor to process the payment. These conditions include the submission of valid guarantees and invoices. The invoices should include the date of issuance, serial number, contractor's bank information, and other relevant information. Failure to provide such information will entitle the Employer to delay payment until such information is provided.

For unit-price contracts, the executed work to date will be the summation of all works done till the date this payment is requested. The quantities used will be the actual executed quantities for each item which may be less than or greater than the original quantity. However, the unit rate should not be altered. The engineer will check if the actual quantities match those reported by the contractor and verify the result or make modification and notifies the contractor.

Based on clause 14.6 of FIDIC Red Book (2017), the engineer is entitled to make corrections or modifications to the previous payment certificate when required. If the engineer found that the previous payment certificate has errors or missed items he shall make changes as per the contract document. The correction or modification shall be applied in the next payment certificate.

Based on clause 14.6 of FIDIC Red Book (2017), the contractor is also entitled to inform the engineer of any amount that he believes should not be included in the payment certificate. The engineer shall then make any corrections to be applied to the next payment certificate. On the other hand, if there is any amount that the contractor believes should have been included in the payment certificate he should notify the engineer, and a similar procedure as the above shall be followed.

2.7.1 Current Payment Certification Process

The current payment certification process lacks automation, follow-up, control, reporting, and a secure database. Automation in this study means the ability of the system to check the payment BOQ against the contract BOQ, identify all errors, and prepare payment certifications based on the corrected BOQ without any supervision. Follow-up means the ability of the system to oversee the payment certification process based on the contract and project information and then provide the necessary notice and advice.

Control means the ability of the system to manage the payment certification, approval, or rejection based on contractual limits and prerequisites. Reporting includes the preparation and display of automated reports including payment certificates, payment errors, payment history, and current status. A secured database means a database that can store and retrieve information easily and efficiently while avoiding any tampering by its users purposely or by accident.

The current payment certification process relies on manual checking and the use of Microsoft Excel. The payment BOQ will be checked manually against the contract BOQ for unit rate error or if there are any items not included in the contract. Then subtotal values, total value, and the payment certificate will be prepared and checked using Microsoft Excel. This process has its limitations and issues.

Manual checking requires a long time to correctly inspect every item especially when the project is large. Additionally, many arithmetic errors are not easily identified. Research has been done that validates that many spreadsheets have errors (Panko, 2005). These errors come from errors in the cells of the spreadsheet itself and the improper use of a spreadsheet.

Based on the research by Panko and Halverson (1996), they classified spreadsheet errors into quantitative and qualitative errors. Quantitative errors include mechanical, logic, and omission errors. Mechanical errors include typing or pointing errors while logic errors include the use of incorrect functions or formulas. Omission errors include data left out or misinterpreted.

Qualitative errors are related to errors in the Excel file itself. These include errors from using a different version of Microsoft Excel, use of long formulas, linking multiple sheets, and poor physical layout. Based on the study by Panko (2005), there's an average of 5.2% cell error rate.

This will affect the accuracy of payment certification especially considering the incremental nature of the payment certification process.

The use of formulas to substitute the manual checking will only complicate the payment certification problem. This is because the process will require lengthy formulas, linking multiple sheets, and thousands of cells. A study by Lerch (1988) found that when equations contained references to cells located at different columns and different rows from the cell containing the formula the mechanical error rates will increase dramatically.

The manual checking process will not be able to find and correct a significant number of errors. This is supported by research that humans are oblivious to most errors hence, they substantially underestimate the difficulty of detecting and correcting errors. This is commonly called "error blindness". Consequently, a payment BOQ could be checked multiple times to yield errors that were not found the previous time.

As discussed above, Clause 14.6 of FIDIC Red Book (2017), standard conditions of contract entitles the engineer to make any correction or modification to a previous payment certificate. The same concept is also found in the PPA standard conditions of contract. Interim payment certificates are not conclusive and are open to reevaluation. They are a confirmation that an installment of the contract sum is due to the contractor.

The final payment certificate is the only conclusive payment certificate in the construction industry. The only obligation of the employer is to make sure payments are made within the stated time. Since failure to make such payment is regarded as a breach of contract. Due to this fact, the lack of attention when preparing interim payment certificates results in negligence and repetitive errors (Fitehawok, 2018). This may create a situation where the contractor is paid the wrong amount because of errors in evaluation, arithmetic errors, erroneous calculation of deductions, and other reasons.

Because of the repetitive errors, the IPC has to go back and forth which results in a longer period for certification and approval. Errors overlooked during interim payment certification will be very difficult to trace. Consequently, the accumulated errors found in IPCs' take a longer time to correct which leads longer time for interim or final payment certification and in some cases a negative final payment. In this case, Clause 65.2 of PPA (2011), instructs the difference to be

paid back to the Employer by the Contractor however, tracing the exact source of the errors is very difficult.

Documentation of payment certificates and corresponding BOQs is difficult using Microsoft Excel. The reason is that for a single certificate multiple excel files are sent back and forth before final certification and approval. These excel files including their data and formulas could easily be manipulated because of a lack of knowledge and negligence. Finding the final account of the excel file and the corrections made at each exchange of payment certificates is difficult. Lack of proper documentation will lead to a delay in processing variations (Eugenie, 2006).

Furthermore, the current payment certification process relies on manual supervision of contractual limits, prerequisites, and guarantees. Negligence on the part of the Client's engineers' could lead to payments that exceed contractual limits and payments without valid guarantees. Furthermore, compiling reports on various items in the payment certificate like exceeding quantity will require significant effort.

All these issues will make it harder than necessary to use manual checking and spreadsheets productively in managing construction payments. The need for an alternate payment certification system that will solve the above issues is clear.

2.8 Construction Payment Claims

2.8.1 Introduction

As noted before, regular payment is critical to any construction project. Construction payment problems will affect project cost, time, and relationships among project stakeholders. Construction payment problems are caused by the employer, contractor, or even consultant. And if not dealt with on time they will lead to claims by the grieved party.

2.8.2 Payment Problems

Payment delays are affecting the construction industry in various ways. The impact of payment delays on the construction industry has been studied by several researchers (Watts and Scrivener, 1993). There are three types of payment problems: -

- a) Delayed payment: where the time taken to make payment is beyond the contracted payment period is due to the usual practice of late payment of invoices.)

- b) Partial payment: invoices where payment is withheld for any reason
- c) Non –payment: where the Client or Employer has refused to make any payment for various reasons.

Delayed payment is a condition where payment is not made to main contractors or sub-contractors per the time schedules agreed on the signed contract. On the other hand, non-payment implies that the contractor has not received any form of payment in relation to the work.

Payments have been a cause of disputes within Australia's construction industry Watts and Scrinvener (1993) found, that delayed payment as the second-highest operational risk, after financial failure, which causes project delays. The nature and the various types of contractual payments that could be delayed or defaulted by the employer may further be classified as interim, stage or milestone, advance payments, payment of retention monies, and final payments (Ansah, 2011).

Based on research, conducted by Fitehawok (2018) the results showed that Payment delay had the highest occurrences followed by partial payment in public building construction projects in the Addis Ababa city. Non-payment of sums due had the lowest incidence. Consequently, it was not considered a major problem.

2.8.2.1 Causes of payment problems

The construction industry is a complex but mostly fragmented industry that requires the involvement of multiple parties. The failure of each party to fulfill its obligation will create a significant problem for the functioning of the other parties and the industry likewise. As payment is vital for any construction project delays in payment certification will undoubtedly affect the success of the project.

Based on the research conducted by Fitehawok (2018), the number one issue causing payment delay is the bureaucratic payment system of the employer. The bureaucratic system contains a hierarchical and multi-tiered structure. Consequently, the payment certification process involves several people looking at a single certificate in a fragmented manner increasing the time without reducing the errors.

Furthermore, the hierarchical structure of the employer and contractual framework is not transparent and is susceptible to poor payment practices (Pettigrew, 2005). Another cause of

payment delay is frequent variation order than doesn't account for the variation limit and its consequence on the capacity of the employer to finance the project (Fitehawok, 2018).

Clients' delay in payment certification and poor financial management are some of the causes identified by Ansah (2011). This issue becomes more challenging because the construction industry is highly competitive and contractors that are not paid in time could lose profits and may even face insolvency (Hughes et al. 2015). Payment delays have a significant impact on project completion as it affects labor productivity, material delivery, and the financial stability of the contractor.

The current construction payment management, which is characterized by poor documentation with incomplete or unavailable payment information leads to delays in processing variation and final payment (Eugenie, 2006). Based on the study by Abdul-Rahman et al. (2008) in the Malaysian construction industry delays in late certification of the payment claim by client despite the correctness of the claim is owing to poor payment management.

It should be noted that construction payment problems arise not only from employers' sides. But consultant/engineer also contributes to some defaults for the payment problems in the construction industry. Based on the research by Tadele (2017) and (Fitehawok, 2018), favoring the employer or bias is one of the major causes of payment delay that is attributed to the consultant. Other causes include mistakes in the valuation of variations, weakness in deciding on issues arising in the course of construction, and absence of continuous supervision of the work (Tadele, 2017).

Mohamed Nor Azhari Azmana (2014) indicated that delays in certification by consultants also contributed to the late and non-payment in the Malaysian construction industry. Other reasons for payment delay include the contractor's lack of progress, conflict among parties involved in the contract, suspension of work, and submitting a request that exceeds the executed work (Ansah, 2011 & Fitehawok, 2018). Based on the arguments above it is important not to underestimate the effect of the client's poor payment management and payment certification delay on payment problems.

2.8.3 Payment Claims

A claim is an assertion to a right. A construction claim is an assertion of a contractual right by one party for the damage incurred to him by the other party. It can also be defined as a request by either party to the contract for compensation for damage resulted from the failure of the other party in fulfilling his contractual obligations (Abhishek Shah et al., 2014).

Contract conditions dictate how these claims should be submitted, handled, process, and decided. Payment claims are claims that are related to the amount, timing, or manner of payment. The most common construction payment claims are claims for delayed payment and claim for additional payment. In both cases, the contractor has to show evidence that the claim emanated from the contract and was due to the fault of the employer. The employer has to show that the cause was due to the contractor's failure to perform his obligations.

2.8.3.1 Claims for Delayed Payments

As discussed above various reasons contribute to payment delays. When the time elapsed to certify a payment exceeds the expiry of the payment deadline the contractor can claim for delayed payment plus later payment interest. Standard conditions of the contract describe the procedure to handle delayed payments. Claims for delayed payments are acceptable only on the condition that the contractor has fulfilled all his obligations including submitting required documents and invoices.

According to sub-clause 67.1 of PPA 2011 “Once the time-limit referred to in GCC Clause 59.3 has expired, the Contractor has submitted within two months of receiving late payment, be entitled to late payment interest at the rediscount rate applied by the National bank of Ethiopia on the first day of the month in which the time-limit expired, plus three and a half percentage points. The interest shall be payable for the time elapsed between the expiry of the payment deadline and the date on which the Employer’s account is debited.”

Under sub-clause 67.2 of PPA 2011 it is marked that “Any default in payment of more than 120 days from the expiry of the period laid down in GCC Clause 67.1 shall entitle the Contractor either not to perform the Contract or to terminate it.”

2.8.4 Claims for Additional Payment

The contractor has the right to make claims for additional payment if he believes that the amount stated in the payment certificate doesn't reflect the work executed by him under the contract document or any additional written work orders given to him by the engineer.

In accordance to sub-clause 69.1 of PPA 2011 when the circumstances allow for the contract to claim additional payment he has to give written intention to claim within 15 days after the said circumstances become known to him. Then submit a detailed particular of the claims within 60 days after the date of such notice unless otherwise agreed by the Engineer.

After receiving the full and detailed particulars of the contractor's claim that he requires, the engineer shall consult with the employer and the contractor to determine whether the contractor deserves additional payment. It should be kept in mind that the engineer may reject any claim for additional payment if the request does not comply with the requirements of the General Conditions Contract

It is agreed upon that payment is vital for the construction process and in the meantime, it is the source or cause of disputes arising between the employer and the contractor. Not being able to pay the contractor according to the planned schedule would be forcing the contractor not to go along with the speed expected to complete the project on time.

If material suppliers are not paid on time they may increase their quotations which in turn increase total project cost. This would adversely affect the owner and his capacity to finance the project. Therefore, payment delays should be minimized by increasing the efficiency of payment certification process.

2.9 Impact of Payment Problems on International Projects

A study by Kenny (2007), found that the construction industry is estimated to be a \$1.7 trillion industry worldwide. This is close to 7% of GDP in most countries which accounts for a major part of the country's economy. The sector's role in economic development is undeniable – housing, roads, utility networks, schools, and clinics are all built assets.” The survival of the construction industry and the success of projects are dependent on the cash flow of contractors (Cheng et al. 2009). Because most contractors are heavily reliant on cash flow from projects the

disruption in cash flow will affect the whole construction supply chain (Ye & Abdul-Rahman, 2010).

Delay in payment and delay in the release of retention monies have a significant impact on cash flow in turn impacting the construction industry (Odeyinka et al., 2008). Another major impact of delayed payment is construction disputes. Several studies have shown that payment problems are the main causes of construction disputes affecting the industry (Kennedy, 2005). Construction disputes may arise due to delays of interim payments from clients, non-payment for sub-contractors by the main contractor, failure to comply with payment provisions, non-payment for certified sums, an argument about the amount to be paid, and variations claims by contractors (Kumaraswamy, 1997 and Sheridan, 2003).

In addition, construction delays can occur as a result of delayed payment. If the delayed payment is prolonged for no reason, the contractor can terminate the contract. This in turn results in the reduction of productivity of the construction. In this sense, the efficiency and development of the whole industry will be affected. Moreover, cash flow problems might occur due to delayed payments. And the contractor is the main victim that will be facing cash flow problems. Furthermore, construction payment delay might result in a lower quality standard of work which in turn facilitates the negative public image of the contractor.

It should not be forgotten that a failure of the contractor in getting regular and timely payment could result in project delay, reduced profitability, and in the extreme case, the company may go into liquidation. As discussed before, the failure of clients to pay the main contractors on time will have a knock-on effect on the entire construction industry (Mohamed Nor Azhari Azman, 2014).

Ramachandra (2013) states that construction payment problems have been a significant obstacle to the construction industry in the United Kingdom since 1964 as supported by various studies. Furthermore, it is reported that due to the prevalence of payment issues in the United States and Canada Mechanics' lien through the Miller (Little Miller) Act was introduced requiring payment guarantee to be submitted to protect contractors, sub-contractors, and suppliers against payment risk (Ramachandra, 2013).

This issue is also being seen in Africa as Fugar & Agyakwah-Baah (2010) also indicated that Payment delays in the execution of public projects in Ghana have been identified as the most

critical obstacle for the construction industry in Ghana. Kartam and Kartam (2001) reported that “Delayed payment is the second-highest operational risk, after financial failure that causes project delays.” This could accumulate into bigger problems and may end up undermining the success of construction project, and in turn affect the survival of the construction industry (Cheng, et al., 2009).

A similar effect was seen in China due to late and eventual non-payment along with lack of security (Cheng et al., 2009). These problems even aggravated to the point where the construction parties were at risk of insolvency. A study done in New Zealand showed that delayed payments hurt on-site conditions leading to low labor productivity rates (Durdyev & Mbachu, 2011).

Research by Ramachandra (2013) mentioned that; under the five years (2006-2010) considered in the study; there were 40 cases related to construction payment disputes filed in the High Court of New Zealand. She also strongly argued that claimants were refused progress, final, and other payments (retention and costs incurred in court proceedings) because of the validity of progress claims, incomplete or defective work, and non-issuance of payment schedules.

Another impact of delayed payment is a delay in project progress, subcontractors' refusal to continue work, and negative relationships among parties in the contract (Ansah, 2011). Subcontractors' failure to continue work delays the project's progress and creates conflicts among the parties which leads to further claims. The research goes on to show that low quality of work, delay in project progress, and extension of project time are the main impacts identified by clients.

According to survey results of Amoako (2011) in Ghana, the five effects of late payment were: result in cash flow problems, making it difficult to procure material and services, creation of enormous stress on contractors, leading to interruption of the program of works and likely suspension and resulting in disputes e.g. litigation/ arbitration.

As Abdul-Rahman et al. (2011) suggested that payment delays lead to time overruns and cost overruns. They opined that when interim payment certificates are not honored and works are suspended it often leads to an extension of previously agreed time (Time Overrun). They also indicated that the volatile nature of economic indices affects the purchasing power of the

previously agreed sum (even when adjusted for inflation) rendering the funds insufficient and the need for additions to be made (Cost Overrun).

Mohd Khairul et al. (2018), analyzed the report published by the Master Builders Association of Malaysia (MBAM). Based on their survey involving contractors and subcontractors 80.3% of them indicated that they had encountered slow progress payment similarly in government and private sector projects. The contractors are facing delays in payment for more than 91 days and up to 12 months compared to the contractual date.

As mentioned above, payment delays will lead to adversarial working relationships among different stakeholders. This coupled with the complexity and uncertainty of the construction environment in Hong Kong construction projects, the outstanding payment amount was reported to be over HK\$20 billion in 2015 (Luo et al., 2019).

In summary, payment delays in the construction industry affect contractors' cash flow (Odeyinka et al., 2008), causes disputes (Kennedy, 2005), obstruct material delivery, decrease labor productivity, and insolvency (Cheng, et al., 2009), and affect the working relationship of different stakeholders (Luo et al., 2019).

2.9.1 Impact of Payment Problems in Ethiopia

The construction payment problem is dominantly affecting the construction industry of Ethiopia. Researches and studies have been conducted regarding this topic at a national level and some of them are discussed under this section. Worku (2020) In his studies conducted on Gondar city stated, that among different impacts of delayed payment he studied; “occurrence of construction delays, creation of negative chain impact on other parties, a rise of disputes among parties and reduced employment in construction projects are the top five impacts of payment delays.”

Shimekit (2015) and Fitehawok (2018) indicated that consequences of the payment problems in public building projects of Addis Ababa include “Delay of project completion time, project cost overrun, bankruptcy of contractors, a dispute between the parties in the contract and poor/lower quality work are impacts of payment problems in Addis Ababa. Consequently, delay in payment will not just affect the construction project progress but may result in abandonment of the construction project.

2.10 Previously Proposed Potential Solutions

Research is presented below that attempt to provide solutions for the issues arising in construction payment management. The biggest issue in construction payment management is a delay in payment certification which affects the contractor's cash flow and others down the supply chain. The current payment certification process that relies on the combined effort of manual checking and Microsoft excel has several problems as discussed previously. The problems include difficulty in tracing and correcting errors, taking considerable time, lack of proper documentation, lack of control mechanism, and not transparency.

Consequently, the focus of the majority of research was to automate the operation and encode the contractual conditions to enable control and follow-up. However, some researchers like Agyei-Kumi et al. (2017) have recommended management solutions including diligence on the side of clients to ensure effective and proactive financial management and planning for projects. In addition, he stated that contractual provisions should be clearly defined between all parties to the projects to avoid disputes when the time is due for interim and actual payment certificates to be honored.

He added that regular communication between parties to aid the smooth flow of information helps to establish the realistic duration and total cost of the project. This is crucial since the current payment certification doesn't allow multiple parties to work in real-time and collaborate. This is one of the main aspects that this study aims to address.

Alemneh et al. (2010 E.C) proposed a software application that will help contractors prepare BOQ and payment certificates. He argued that the use of software, particularly on quantification of the work executed increases efficiency. Furthermore, Alemneh et al. (2010 E.C) argue that the use of payment software will help avoid arithmetic errors and save the time required to calculate the payment manually. Ease of data processing and handling are also the benefits of using construction payment software.

However, the software developed doesn't support automation since the manual entry of data is required which is a cause of errors even if it can minimize arithmetic errors. Additionally, contractual conditions are not integrated into the software hence the payment management

process will be manual. These include following up on contractual limits and providing necessary notices to the client.

One of the significant steps was taken by SYNERGY Software Solutions, a local software developer, which developed a system useful for cost estimation, planning of materials quantity, man-hours, equipment hours, and related budgetary cost; takeoff sheet and payment certificate preparation; and cost controlling of a project called ConMIS (Conmis Engineering and Construction plc., 2016). However, this software has also a similar limitation to the one proposed by Alemneh et al. (2010 E.C).

Luo et al. (2019) proposed a methodology to automate construction payments by formalizing them into smart contracts and executing them on a decentralized permission Blockchain-based framework. As stated by Luo et al. (2019) blockchain was selected for the proposed framework because it possesses characteristics of information sharing among multiple parties, information updating among multiple parties, and verification/approval at several levels.

This proposal solves many of the challenges of the current payment certification problems. However, it uses a decentralized system hence; privacy and security become the primary issues. Furthermore, this will strip the contractual position that the client has and limit his rights. Additionally, the technology that supports it is at its earliest stage which would inhibit its applicability in the construction industry.

As mentioned before several efforts have been made to digitalize payment management allowing the parties to the contract to make payment certification without the use of paper. This is believed to reduce the payment processing effort by a significant margin (Hamledari & Fischer, 2020). However, fully automated payment certification has not been achieved yet. This is attributed to the fact that most of these technologies are dependent on manual and intermediate workflows that are paper-based.

The alternative option proposed is the use of smart contract-based payments. As reported by Hamledari & Fischer (2020) smart contract-based payments are still in the early stages of development and far from mass adoption. Further study and investigation are required before they are implemented in the construction industry to replace the paper-based alternative.

Consequently, each of these proposals wasn't able to achieve automation, follow-up, control, and reporting of payment certification and management in a secured way. The limitation of each research proposal is an indication of why the current payment certification has continued relying on manual operation and the use of software like Microsoft Excel despite the aforementioned challenges of these methods.

CHAPTER 3. METHODOLOGY

3.1 General

This study aims to develop a computer-aided payment management system to address various issues in processing construction payments for clients with multiple building projects. The study strives to develop a web-based application that manages construction payment for clients with multiple building projects.

3.2 Research Design

The study begins with a detailed study of literature to gain a thorough understanding of the current construction payment process. This will be essential in the development process to identify all the variables and relations that should be analyzed. The study uses an analytical approach by collecting quantitative data and creating relations and automating the whole payment management process to minimize time, reduce error and create a secure and easily accessible database system.

The approach to the solution for the problem statement is systematically tracked based on literature reviews of local and international researches to design a payment management system that will address the limitation and challenges of current payment management system.

The study proposes a framework to automate payment management in building construction projects by converting construction contracts into smart contracts. For this study, smart contracts are defined as a collection of formal logic that is derived from standard conditions of contract and converted into executable codes, and managed by a single party in the contract namely the client. The contract is executed on a web-based centralized framework that supports decision-making and control based on the conditions of the smart contract. This process will be divided into two parts namely contract formalization and contract execution.

Contract Formalization

Here, the methodology for converting construction contracts into a smart contract for payment management will be presented. Construction contracts specifically PPA 2011, was studied to identify the main concepts of construction contracts concerning payment management. These concepts include the parties, activities, and the logic relating to them. Based on this extensive

study, a representation of smart contract and the formalization of logic were modeled. The methodology for contract formalization is as follows:

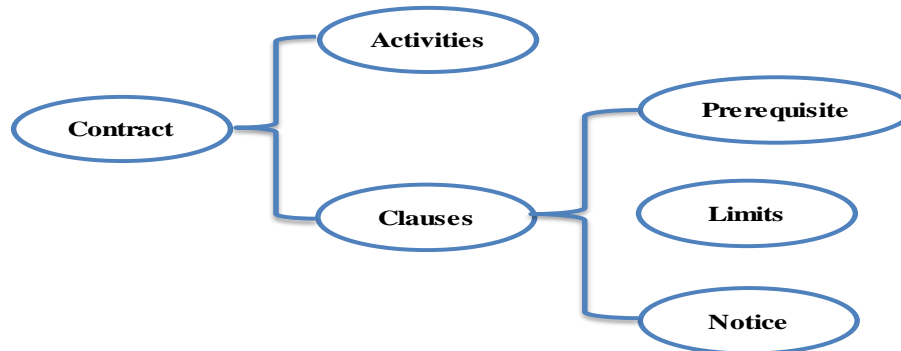


Figure 2 Structure of Smart Contract

As shown in Figure 2, the structure of a smart construction contract is developed. The only party involved in the direct management of the system will be the client and the contractor and consultant will be able to follow up on the process. Hence, the figure above doesn't include representation of contract parties. Contract clauses that are related to payment management were extracted and broken down into prerequisites, limits, and notice. Then the logic that enables the smart contract to execute was established. The logic connects the activities performed during payment management and the conditions set out in the contract. Furthermore, it outlines the sequence of activities and the preconditions for executing each activity.

Finally, if the payment request satisfies the contract conditions and no errors are found interim payment will be triggered. The logic that automates and controls the process is converted into pseudocode first and then into executable code using PHP. This is the basic building block of the system and is referred to above as a smart contract. As mentioned above, several prerequisites and limits are derived from the contract conditions that are checked before executing a payment.

The process of formalization and representation of a smart contract for a single contract condition (PPA 2011, sub-clause 15.8) is presented in the figure below. A similar procedure is followed for each condition of contract and activity which forms a complex network of logic that automates, controls, follow-up, and reports the payment process.

Step 1

Contract Condition	The total value of the works resulting from a change order shall not exceed 30% of the total value of the initial contract price.
Limit	Variation amount \leq 30% of Contract amount

Step 2

Activity	Interim Payment
Limit	Variation amount \leq 30% of Contract amount
Action	Make Payment
Resultant event	Certify Payment

Step 3

```

if (Variation <= (Project total * 0.3)) {
    Variation is within Limit;
    Certify payment
else
    return error
    error = "Project variation amount has exceeded the
    Contract Limit";
}
    
```

Figure 3 Formalization and representation of smart contract

Contract Execution

The smart contract will be executed on the web-based application that has pre-defined conditions of the smart contract and input from the authorized stakeholder who is the client. The data will be stored in the database prepared using phpMyAdmin in two parts - one is for storing the contract information at the initiation of the project and the second is for checking and keeping payment transactions. The database uses a centralized framework hence, all the stakeholders will be able to see and follow the same payment information and make informed decisions.

The first part will be the backbone of the system where the majority of information will not be modifiable and is used for checking the second part which is the payment transaction. As presented in the above figure when payment is requested the smart contract is executed automatically to check the pre-defined condition including prerequisites, limits, and notices. The process starts with the client submitting the contract and project information followed by Contract BOQ. The payment BOQ will be submitted to initiate the interim and final payment certification process. The payment request, BOQ checking, payment certificate preparation,

guarantee, and another prerequisite checking, final approval, and reporting process will follow the following sequence.

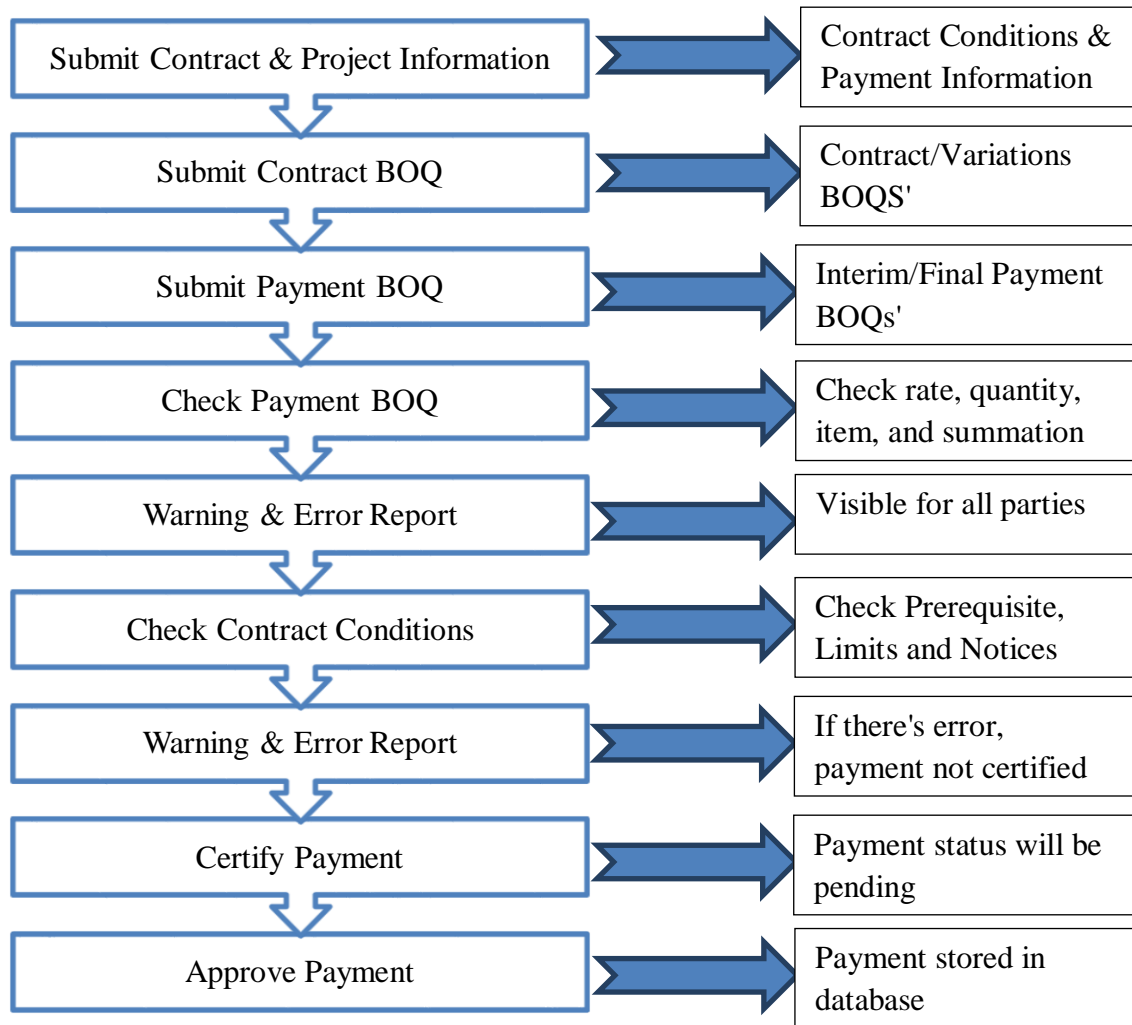


Figure 4 Sequence of activities and respective events

These pre-defined conditions check the validity of the payment request and assess the information including unit rate, the quantity of material, and item specification match with the information submitted above. Furthermore, the smart contract updates its values as the information in the first part is updated. For instance, if the client submits a variation BOQ then the system will be updating the total contract amount, and total variation amount and will use this new information to track the variation limit.

After all the necessary checks have been done then the payment request will be prepared and certified. Once the client approves the payment it will be added to the database and the follow-up

and reporting subsystems are updated. The details of each subsystem and its function are presented below in the data analysis section. The approved payment will have a time stamp and the users that approve the payment will be recorded. Even if the payment request is rejected the system will still save the payment BOQ and respective warning and error report for the auditing and claim management process.

3.3 System Development

The system development consists of two components which are designing the system architecture and developing the system components. The system architecture will outline the dependencies between system components in this case are the database, backend, and frontend (Perry and Wolf, 1992). Furthermore, it provides structural model for the final system. The system components contain the five subsystems that enable the web-based application to function. The details of these components will be discussed below.

3.3.1 System Architecture

The software will be a web-based application that has both backend and frontend. The reason for choosing a web-based application is that it allows users access to the system from anywhere and at any time. Additionally, users can share their work and real-time update is possible. Front-end refers to the user interface where users interact with the software. Back-end refers to the server that provides data to the user when requested. The core concern of back-end development is creating applications that can find and deliver data to the front end.

The front end is built to be user-friendly and interactive. The languages used are Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), and JavaScript. The server and database communicate with each other through the back-end developed. Notepad++ is used to write and edit the codes into the backend.

The system will be developed using PHP, and the reasons for these are:

- It is reliable, stable, and mature
- Easier to learn
- Can manage large projects
- Creates a secure system

The database will be built and administered using phpMyAdmin. This will allow create and manipulation of the database without writing MySQL code. The database will contain all the tables needed for the system. The contract and payment BOQs will be uploaded here. Wamp server, which is a windows web environment, is used since it's free and easy to manage.

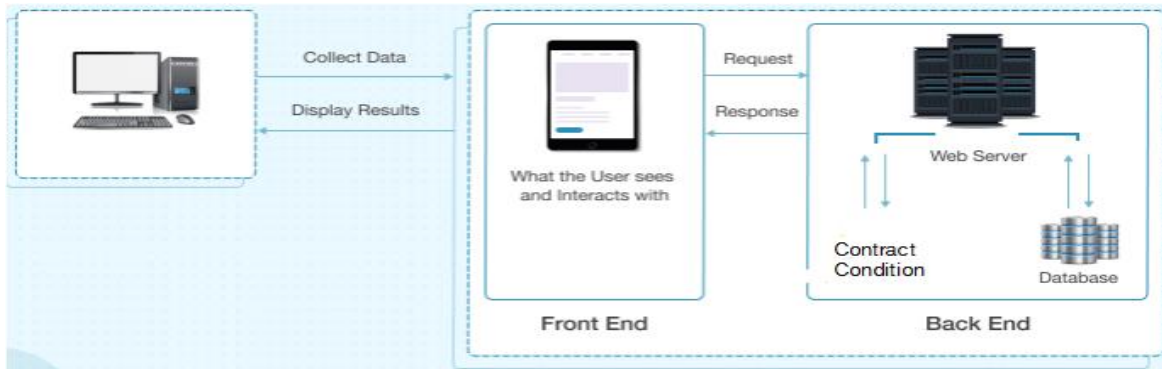


Figure 5 Web-based Application Architecture

As shown above, the frontend will interact with the user and sends a request to the backend. The backend will retrieve the data from the database and use the contract conditions in the smart contract to prepare the payment certificate. The backend will use the smart contract to certify, control, and follow up on the payment certificates. Every transaction of payment will be recorded in the payment and will be available for the user on the front end.

3.3.2 The System Components

The system development process consists of creating five subsystems namely: - the Payment Data-processing subsystem, Payment follow-up subsystem, Payment-Reporting subsystem, Security subsystem, and Project Interface.

Payment Data Processing Subsystem

These subsystems create a standard payment certificate automatically and with no errors. The first step is to create standard templates using Microsoft Excel to be used as a template when developing the web-based application. Then data, formulas, and relations will be recorded and manipulated. The system should be able to create and check payment certificates automatically. The templates, formulas, and relations created using Microsoft Excel are used in developing the

system. The payment processing will not be accessible to any users as it's done in the backend hence, it will be secure and no tampering can be done.

Payment Control and Follow-up Subsystem

These subsystems will greatly aid the client by keeping track of all information related to the payment process and giving notifications and advice. Here all data will be time-stamped and categorized. Furthermore, the client will be given the option of setting contractual particulars (based on GCC and SCC) and notification options.

The status of each payment will be tracked and notified to all the users created by the client. Each payment certificate will be recorded and available later to handle claim disputes or for management decisions. The client can specify a deadline for payment certification and approval. The notifications are shown on the project interface.

Payment Reporting Subsystem

The report content, format, and schedule of reporting will be defined ahead of time after discussion with the client and consultant. The reporting system will be integrated with the other subsystem to create a standard, relevant and timely report of payment history, notifications, and advice.

Security Subsystem

The database should be secure enough to prevent contractual matters from being exposed to a third party. Consequently, a security system that follows a contractual and organizational hierarchy will be adopted. The users will have a username and password to access the database. Security measures like use of hash encryption, separate servers, and regularly updating the database will be followed. The accessibility will be for view only for some users and with the ability to modify and certify for others. The system will provide an option to lock a payment after it's certified by the privileged user.

Project Interface

This is the final subsystem that will be developed using JavaScript and it will allow the users to create, update, add, delete, view the status of projects and get notifications and advice in real-time. These will be integrated with the security subsystem to make it secure and harmonious.

Finally, all these subsystems will be integrated and tested with multiple projects and scenarios. Errors in the system that could potentially occur and feedback from users collected. Based on the error reports and feedback from users the integrated system will be reassessed and once all bugs are fixed and fully functional a final run of the system will take place on selected projects.

3.4 Validation and Verification

The web-based application will be piloted on three building projects owned by the Commercial Bank of Ethiopia. The data used for validation purposes for this study will be gathered using a desk study. The projects are selected based on specific merits they exhibit that are necessary for the implementation and validation of the study. These merits include: -

- The projects should be on-going
- The availability of projects' financial documents in softcopy
- Completeness of the project information
- Projects that use Unit priced contract (re-measurement contract)
- The project's document meets all quality requirements

The data gathered through desk study includes the Contract document, Payment certificate, Variation documents, Guarantee information, Supplementary documents if any, and other useful financial information. The Consultants' will be contacted and consulted through the whole process and any vital information missed from the Client's data will be compensated.

The first step was to create the checklist for data collection and validation. The data collection checklist will list all the required data and the data quality attribute. The checklist is prepared based on the system requirements and data categories. Most of the data collected are mandatory and missing this data will make the project not viable for the study. Some of the data are marked as 'If Present' to show that they may not appear in all projects. Other data values are marked as 'If Applicable' to show that those limits may not be defined in the contract document.

Table 1 Checklist for Data Collection

Type of Document	Data Category	Data Required	Data Relevance
Contract Document	Project Information	Project Name	Mandatory
		Project Location	
		Client Name	
		Contractor Name	
		Consultant Name	
		Contract No.	
	Time Information	Signing Date	Mandatory
		Mobilization Period	
		Contract Period	
	Contract Limit	Variation Limit	Mandatory
		Minimum Interim Amount	
		Minimum Interim Period	
		Advance Payment Limit	
		Retention Amount Limit	
		Liquidated Amount Limit	
	Basic Payment Data	Contract Amount	Mandatory
		Rebate %	
		Retention %	
	BOQ Information	Contract BOQ	Mandatory
	Advance Information	Advance Payment %	Mandatory
Advance Instalments'			
Advance Repayment			
Start Repay Advance %		If Applicable	
Fully Repay Advance %			
Invoice Detail	Contractor's Bank Name	Mandatory	
	Account Number		
	VAT Registration No.		
	Payment Signed by		

		Consultant Representative	
		Currency	
Variation Document	BOQ Information	Variation BOQ	Mandatory
	Basic Payment Data	Variation Amount	Mandatory
		Rebate %	
		Retention %	
Supplementary Document	BOQ Information	Supplementary BOQ	If Present
	Basic Payment Data	Supplementary Amount	
		Rebate %	
		Retention %	
Guarantee Letters	Guarantee Information	Guarantee Type	Mandatory
		Guarantee Expiry Date	
		Guarantee Amount	
		Guarantee Renewal Date	
Payment Certificate	Advance Payment	Advance Amount	Mandatory
		Payment Date	
		VAT Paid	
	Interim Payment	Payment BOQ	Mandatory
		Executed Work to Date	
		Material on Site	
		Rebate Amount	
		Retention Amount	
		Previously Paid Amount	
		Net Payment	
		Retention VAT	
		Net Payment VAT	
Total Payment including VAT			

The data gathered through desk study was checked for consistency, completeness, accuracy, orderliness, time record, uniqueness, and auditable. A detailed document analysis was performed to identify, evaluate, and approve the data. All softcopy data has to meet the following quality attributes presented in the table 2 below.

Table 2 Data Quality Attributes

Quality Attribute	Details of Attribute
Consistency	Corresponding hardcopy file exist
	All softcopy data match with the hardcopy file
	Contains name of authorizer, authorized signature, date of signature
	Name and signature of witnesses
Completeness	All data categories included
	Complete checklist record
	No missing data value
Accuracy	Manually crosschecking input data
	Arithmetic check
	Observation
Orderliness	Follow System's format
	Check data structure
Uniqueness	No duplicate documents
Time Record	Time-Stamped documents
Auditable	Data is accessible
	Changes can be traced

Firstly, the softcopy data is manually checked for any contradiction with the hardcopy data. Then the softcopy data for each project is cross-checked with the other for consistency. For instance, the payment amount shown in payment certificate no. 1 will be checked with the amount shown as the previous payment in payment certificate no. 2. The list of documents that are required for each project is prepared ahead and checked with the data gathered to identify any missed information.

The accuracy of data gathered is manually checked by arithmetic analysis and observation. Additionally, since the system requires data to be submitted in a standard format the orderliness of the data will be checked. Data entry into the system is done in an automated manner and a

time-stamp is given to control data version and prevent duplicates. Each payment certificate will be checked to see if it's the final version of that specific interim payment. The contract and variations documents are checked to see if they're signed and approved. The system stores all information which provides access for auditing purposes. Any discrepancy found during this process will be reported to the Client team for clarification.

The above process shows how the data quality is validated using manual procedures. Additionally, the system has its internal data quality check mechanism. This mechanism is dependent on specified data quality attributes coded into the system. The quality attributes and their detail is presented in table 3 below. The system checks all data as the user enters them based on this mechanism and displays errors if it does not correspond to its standard.

Table 3 System Data Quality Attributes

Quality Attribute	Details of Attribute
Data Type	Integer, float, string
Data Format	Fixed format like date format (DD-MM-YYYY)
Range	Specified range (below 100)
Uniqueness	Unique entries
Consistent Expressions	Sequence between data
No Null Value	All fields are filled

The validation process will comply with established standards for software validation like IEEE SA - P1012. The validation process follows common procedure that will make sure that the software developed performs as per the intended use. The first step is developing a validation plan. This will outline the purpose of validation as presented above. It answers question as who, what and where of the validation process. The validation will be done at the client office by the author with the collaboration of the client's project teams' of the respective projects.

Secondly, the system requirements and conditions are outlined. The system is designed to run on any web browsers including Microsoft Edge, Google Chrome, Mozilla Firefox, and Opera. Multiple users will be created with unique username and password to test the capacity of the project interface to allow real-time collaboration and integration.

The validation process will try to re-create different scenarios to check the capacity and viability of the system based on the objectives of the study. The subsystems mentioned above and their specific function will be tested. The payment data processing will be tested by checking the system output with manually prepared payment certificates. Based on the contract conditions and project information provided by the client the payment control and follow-up subsystem are checked. The system's data processing speed, accuracy, and error reporting will be thoroughly checked. Each process is repeated for each payment certificate and the result is documented. This process is designed to uncover errors or limitation of the system. Based on this a conclusion can be drawn.

CHAPTER 4. RESULTS AND DISCUSSIONS

The result of the study is a construction payment management system for clients with multiple building projects. The main advantages of this system are automation of payment certification, follow-up, control, and reporting on a real-time basis while being accessed from anywhere. The result of the thesis will be discussed below by explaining the major parts of the web-based application.

4.1 Development of Construction Payment Management System

The construction payment process should adhere to the standard conditions of contract and the system should ensure this. First, contract conditions related to the payment that is found in the general conditions of the contract were extracted. There are 18 conditions in the PPA standard condition of the contract that is related to payment (refer to Table 1). The PPA is used because it's the most commonly used condition of contract. The client will be responsible for using the latest version of PPA standard condition of contract when specifying the contact values.

Table 4 List of Contract Conditions

No.	Contract Conditions for Payment	PPA 2011
1	Modifications by Change Orders	Clause 15
2	Payment upon Termination	Clause 22
3	Liquidated Damages	Clause 27
4	Payment	Clause 32
5	Delayed Payments to the Contractor's Staff	Clause 33
6	Performance Security	Clause 58
Payments to the Contractor		
7	General Principles	Clause 59
8	Advance Payment	Clause 60
9	Retention Monies	Clause 61
10	Price Adjustments	Clause 62
11	Valuation of Works	Clause 63
12	Interim Payment	Clause 64
13	Final Statement of Account	Clause 65
14	Direct Payments to Sub-Contractors	Clause 66
15	Delayed Payments	Clause 67

16	Payments to Third Parties	Clause 68
17	Claims for Additional Payment	Clause 69
18	Acceleration	Clause 75

Some of these conditions such as acceleration cost are not applied since there is no systematic way of quantifying this value. Consequently, these conditions of contract are not integrated into the system. Next, the contract conditions are broken down and categorized into three to easily incorporate into the system. These three categories are prerequisite, notice/advice, and limits. Each category has its conditions and actions based on the contract. The conditions are either built-in or based on user input.

Prerequisite

The first category is Prerequisite, which is a list of conditions that should be met for an action to execute. They are taken from the general conditions of the contract. Hence, they can't be modified by the user. For instance, before any payment certificate is prepared the system checks three things. These preconditions are the contract must be signed, performance security is valid and the contract period has not expired.

Table 5 Contractual Prerequisites

Contractual Prerequisite	Condition
Contract period	Active
Performance guarantee	Active
Advance guarantee	Active
Advance guarantee	Covers advance payment
Minimum interim amount	As specified by SCC
Minimum gap between interim period	As specified by SCC
Contract period	Active

Notices

The system provides notices and advice to clients at various stages during construction based on the conditions of the contract. Notices are linked to various important dates, preconditions, or financial limits set out in the contract. For instance, once a new project is created and a contract

signing date is provided the system check if the performance guarantee is recorded or not then checks the expiration date of the performance security. If the guarantee doesn't cover the contract period it will give notice to the user.

As mentioned above, notices are linked to contractual prerequisite and limits that are built-in or supplied by the client. They provide notification and advice as a follow-up mechanism. Additionally, if the client input doesn't align with the contract limits they provide warnings as part of the input data validation process.

Limits

Limits are values that are taken from the contract conditions and serve as a control mechanism. There are two types of limits one is the financial limit and the second is the time limit. Limits are further categorized into two as system limits (GCC limits) and user limits (SCC limits). This categorization is based on the fact that user limits are based on user inputs for a predefined attribute. The user inputs are taken from the Special conditions of the contract (SCC) and might be different for each contract. These conditions of contract are integrated into the contract information and payment settings.

Table 6 Contractual Limits

Contractual Items	Contractual Limits
Performance guarantee within limit	As specified by SCC
Advance payment within limit	$\leq 30\%$ of Contract amount
Variation amount within limit	$\leq 30\%$ of Contract amount
Retention percentage within limit	$\leq 10\%$
Liquidated damage within limit	$\leq 10\%$ of Contract amount
Advance repayment starting point	As specified by SCC
Advance full-repayment point	As specified by SCC

Database

Then the database is developed to act as a container for the BOQ and payment. The database allows us to store large files and manipulate data based on relations. The system is developed to create an ID for each line of excel that the user submits as contract BOQ. Then use these values to perform arithmetic operations and prepare the payment.

The system used PHP for back-end development and JavaScript for front-end development. This allowed the system to have a user-friendly interface while maintaining a secure database. Database security is achieved through hash encryption, the use of multiple servers, and constantly updating the data. The report is developed to provide concisely and summarized information on the payment progress and critical contract values.

4.2 Composition of Construction Payment Management System

Based on the excel prototype as a foundation the web-based application is designed to overcome the limitation and fulfill the objectives. The construction payment management system is composed of Data input and validation, Data processing, Control and follow-up and Reporting. This system is piloted on three projects located in Ethiopia and being constructed by Commercial Bank of Ethiopia as branch office buildings'.

The following are the list of design documents that the client has furnished in pertinence to the three selected projects:

- Contract BOQ (Soft copy)
- Project Information (Specifically needed for the thesis work)
- Variation BOQ (Soft copy)
- Payment BOQ (Soft copy)
- Payment certificates (Soft copy)
- Guarantee letters (Scanned soft copy)

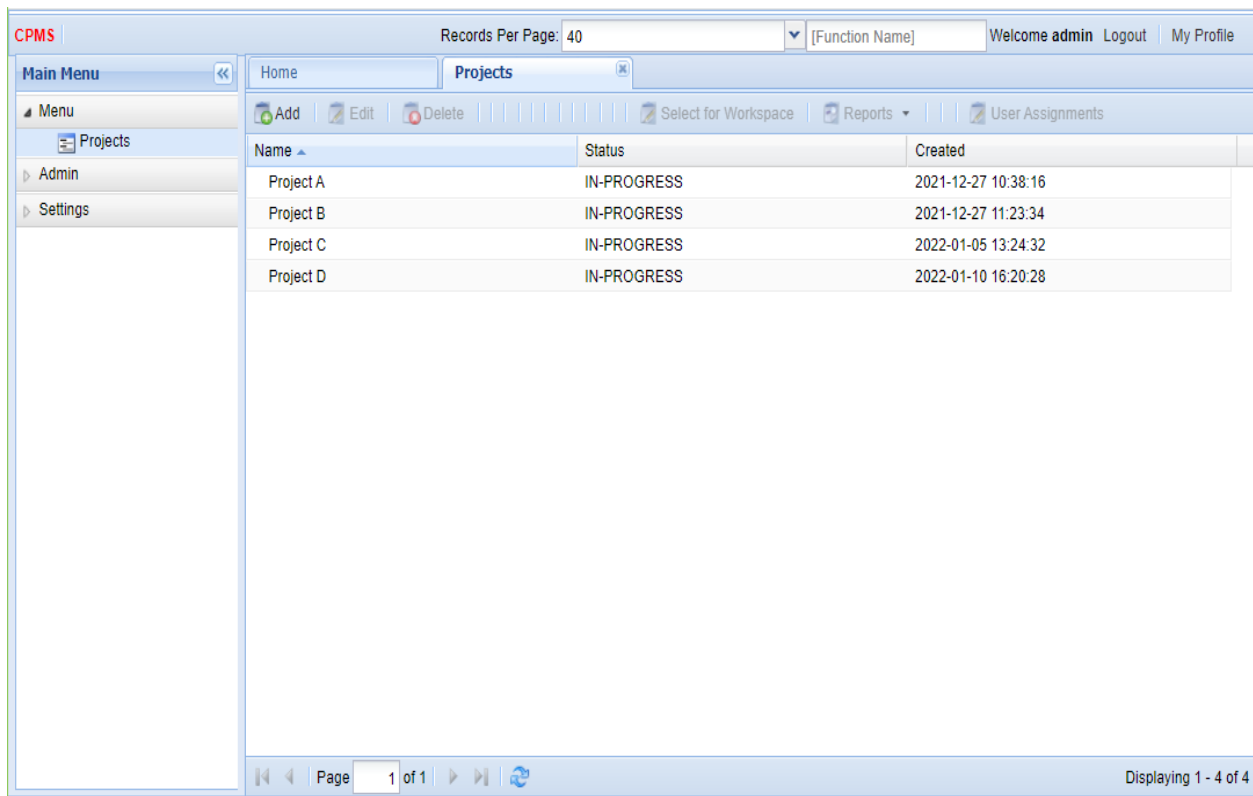
4.2.1 Project Interface

The project interface is the connection point for each subsystem of the project. It's part of the Frontend or User Interface (UI) of the system. It integrates multiple pages including Home page, Project page, BOQs page and Payments page. Each page has its own functions and can be left open or closed at any time. The first page is the Home page where the user is instructed to select a project. Once the user left click the project's tab then the project window will appear. The user can create, update, add, delete, or view the status of projects.

As mentioned before, the system is applied on three projects but a fourth project is created for practical reasons. The fourth project is a dummy project and it's used to test the different features

of the project and make necessary changes. The system can handle multiple projects and multiple contracts simultaneously and allow multiple users to work and share payment related information.

Furthermore, it provides a single source of truth based on a centralized database. All three parties will see similar information at the same time. This would enhance communication and collaboration while minimizing claims. It will provide a transparent platform that is suitable for auditing which creates accountability.



The screenshot displays the CPMS (Computer Aided Management of Construction Payment) interface. The top navigation bar includes the CPMS logo, a 'Records Per Page' dropdown set to 40, a search field for '[Function Name]', and user options for 'Welcome admin', 'Logout', and 'My Profile'. The main menu on the left lists 'Home', 'Projects', 'Admin', and 'Settings'. The 'Projects' section is active, showing a table with columns for 'Name', 'Status', and 'Created'. The table contains four entries: Project A, Project B, Project C, and Project D, all with a status of 'IN-PROGRESS'. The bottom of the interface shows a pagination control for 'Page 1 of 1' and a status indicator 'Displaying 1 - 4 of 4'.

Name	Status	Created
Project A	IN-PROGRESS	2021-12-27 10:38:16
Project B	IN-PROGRESS	2021-12-27 11:23:34
Project C	IN-PROGRESS	2022-01-05 13:24:32
Project D	IN-PROGRESS	2022-01-10 16:20:28

Figure 6 Project Interface

The client can create multiple projects by providing project name as shown in the figure above. The system will register the date a project is created and its status. The status of the projects could be in-progress, completed or terminated. The project can be used to check final payment for projects that are completed or terminated. Additionally, once the project is completed the system will stop routine checks.

Once the project is created the user clicks on "select for workspace" to go to the specific project. The home page will show notifications regarding the time left to renew performance and advance guarantees. The home page will also provide notifications regarding pending payment and guarantee expiry starting six months before expiry of each guarantee. This would help the client to avoid the risk of having an expired guarantee, making payments without having a valid guarantee and payment delays. From this page the user selects one of the five tabs on the left to submit project information that will be used to control payment creation and certification.

4.2.2 Contract Information

Construction payment management system uses user data and system values to manage payment certification process. There are four pages for data submission. These are contract information, payment settings, guarantee and BOQ uploads. The system will check the validation of these input values and when there is invalid input it shows error message.

Here the Client will submit project information, contract time information and contract limit. The project information includes basic information that will be needed in the payment certificate and for guarantee validation. The Contract time information submitted here will be used to control project completion time, contract validity, guarantee information validity. The Project and Contract Information window is presented in the figure below.

The contract limit includes conditions that are set out in the SCC by the Client to control payment certification and approval process. The system will check these values every time a payment is prepared and approval can only be done when the contract limits are satisfied. The contract limits contain both financial and time limits. Additionally, some of these limits are used to provide warning or notice to the client.

The value of work not completed reflects the maximum limit of liquidated damages calculated by the system. Typically, this value will be 10% of the contract value. The price adjustment dropdown will have yes or no option regarding unit rate change. If the contract allows price adjustment then the user will choose the yes option otherwise the no option. Deadline to certify payment is a limit set by the client to determine the number of days any payment certificate will remain pending. The system will check this value once a new payment is made and will notify the user to approve payment before the deadline.

Project Information	
Project Site Location:	Ethiopia
Client:	CBE
Consultant:	Consulting Plc.
Contractor:	Construction PLC.
Contract No.:	001/2018

Contract Time Information	
Signing Date:	06/26/2018
Mobilization Time (in days):	21
Contract Period (in days):	450

Contract Limit	
Variation Amount Limit (%):	30
Minimum Interim Amount:	0
Advance Renew Prior to (in days):	30
Performance Renew Prior to (in days):	30
Minimum Interval between Interim Payments (in days):	30
Value of work not completed (%):	10
* Price Adjustment:	No
Deadline to Certify Payment:	7

Save Cancel

Figure 7 Project and Contract Information window

4.2.3 Payment Settings

The Client will submit basic payment information like contract amount, rebate, retention and variations if any. The user can submit multiple variations amounts by separating with a comma. The contract amount submitted here may be different from the contract sum calculated by the system from the contract BOQ. Regardless, the system will use this value as the contract sum. The variations amount submitted will be checked by the variation amount limit set previously by the client.

Then information regarding advance payment will be submitted below in advance information section. Advance payment will be calculated based on percentage of contract amount. The client has the option to define the number of installments, the value of each installment and the

advance repayment percentage. Furthermore, the client can insert percentage values which dictate when the repayment should start and when the repayment should be completed. The system will use these values to automate and control advance payment certification. The payment setting for Project D is presented in the figure below.

The screenshot shows a software window titled "Payment Settings" with a standard Windows-style title bar (minimize, maximize, close buttons). The window is divided into three main sections:

- Basic Settings:** Contains input fields for "Rebate (%): 0", "Retention (%): 5", "Contract Amount: 500000000", "Supplementary Agreement (separate by /): 0", and "Variations (separate by /): 0".
- Advance Information:** Contains input fields for "Advance Payment (%): 30", "Advance Installments (Separate by /): 10/10/10", "Advance Repayment (%): 25", "Start Repay Advance when Work Reaches (%): 0", and "Full Repay Advance Before Work Reaches (%): 70".
- Invoice Details:** Contains input fields for "Contractor Bank Name: Awash Bank", "Account Number:", "VAT Registration No:", "Payment Signed By:", "Consultant Representative:", and "Currency: Birr".

At the bottom right of the window, there are "Save" and "Cancel" buttons.

Figure 8 Payment Settings Window

The invoice details are submitted once to be used for reporting purpose and to make sure it matches with the payment request letter submitted by the contractor. The client can check the account information, the person who signed the payment and Value Added Tax (VAT) registration no. Additionally, the client can change the currency used for payment calculation. Any change to this information should be sent by a formal letter notifying the change and required power of attorney and crosschecked against the invoice details presented above.

4.2.4 Guarantee

Guarantees come in various forms they could be performance guarantee, advance guarantee, payment guarantee, retention guarantee and Insurance cover. Performance guarantee is an assurance given to the client by the contractor for the successful performance of the contract. The user can add guarantee by specifying the guarantee type, amount, and expiry date. Additionally, the system shows a list of items the user needs to check to validate the guarantee letter sent by the contractor.

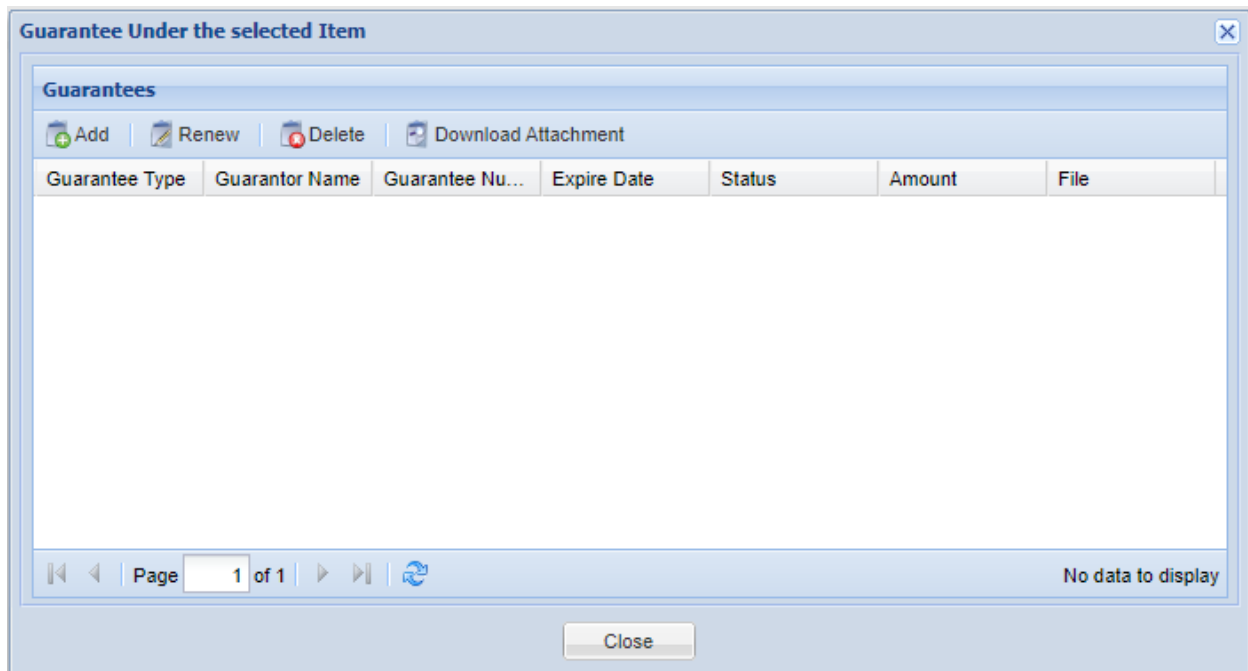


Figure 9 Guarantee Window

The client can add, delete, extend time or view guarantee from this panel. The delete function is there if the guarantee information was submitted incorrectly. However, only the client can add or delete guarantee information. The client should upload the guarantee letter to be used as a proof. The client, consultant and contractor can easily see all the guarantees with their amount, expiry date and other essential information. The status shows if the guarantee is active or expired so that the client renews it on time.

This information will be linked to the project information and it will show the number of days left before expiry of guarantee on the home page and on the follow-up report. Furthermore, it will provide notice and advice to renew the guarantee based on the number of days left.

4.2.5 BOQ Uploads

The client will submit the 'Plan/Contract BOQ', 'Variation BOQ', 'Supplementary BOQ' and 'Payment BOQ' in this window shown below. The system takes excel file arranged in the order presented in the image within the tab. Once the BOQ is uploaded the system will calculate the total amount and assign specific ID to each line in the excel file. This ID will be used to check the BOQ and perform payment certification. The total amount calculated from here may be different from what has been given in the payment settings.

The system will use the contract amount in the payment setting as the contract sum but the unit rates and quantity will be checked based on the contract BOQ. The system will not allow the contract BOQ to be uploaded more than once. However, users can add variation or payment BOQ's multiple times. The client can add multiple payment BOQs' for a single certificate. The system will store these BOQs', their total amount, errors found and date created. This information assist payment related claims by showing the payment certification history and providing reliable payment documentation.

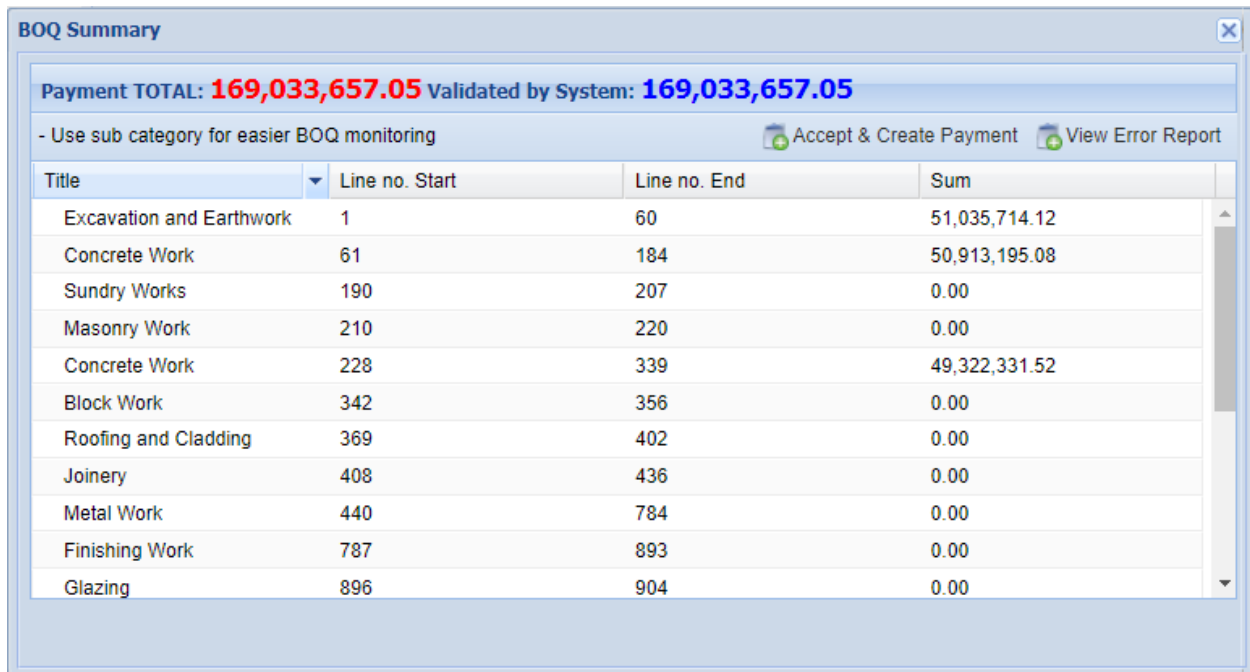
The screenshot shows the 'Boqs' window in the CPMS application. The interface includes a main menu on the left with options like Projects, Contract Information, Payment Settings, Guarantee, BOQ Uploads, and Payments. The main area displays a table of uploaded BOQs for 'Project B'. The table has columns for Project, File, Type, Total, and uploaded date. The total amounts are highlighted in red.

Project	File	Type	Total	uploaded date
Project B	Contract BOQ.xlsx	Plan BOQ	778,819,024.96	2021-12-27 13:31:09
Project B	Variation BOQ.xlsx	Contract Variation BOQ	19,477,363.31	2022-01-03 14:57:24
Project B	6th Payment BOQ.xlsx	Payment BOQ	155,223,241.97	2022-01-04 07:27:43
Project B	7th Payment BOQ.xlsx	Payment BOQ	169,033,657.05	2022-01-04 08:24:25

Figure 10 BOQ Window

The system will display the project name, BOQ type, BOQ amount in the main window and the user can right click to see the summary. Here the client can create subcategory based on the original excel file individual category (Excavation, block work, etc...) line number. This allows the user to see the subtotal amount in the BOQ and later on, on the payment. The user can add, edit or delete these subcategories at any time. The subcategories created here will be available for the payment BOQ and will help identify the mistakes quickly.

The system checks for any exceeding quantities, new rates, and new items and prepare an error report. Furthermore, the system will perform the BOQ summation and provides the total sum. The payment BOQ summary for Project B is presented in the figure below. This will avoid manual checking that is prone to errors and can take long time. It will also avoid errors that are caused because of value linking and use of formulas in Microsoft Excel. This is because the formulas used here are not accessible to the user so no tampering will happen.



The screenshot shows a window titled "BOQ Summary" with a blue header. Below the header, it displays "Payment TOTAL: 169,033,657.05 Validated by System: 169,033,657.05". There are two buttons: "Accept & Create Payment" and "View Error Report". Below this is a table with the following data:

Title	Line no. Start	Line no. End	Sum
Excavation and Earthwork	1	60	51,035,714.12
Concrete Work	61	184	50,913,195.08
Sundry Works	190	207	0.00
Masonry Work	210	220	0.00
Concrete Work	228	339	49,322,331.52
Block Work	342	356	0.00
Roofing and Cladding	369	402	0.00
Joinery	408	436	0.00
Metal Work	440	784	0.00
Finishing Work	787	893	0.00
Glazing	896	904	0.00

Figure 11 Payment BOQ Summary Window

4.2.6 Payments

There are two options to create a payment certificate. One way is for the client to go to the payment tab and then click on new payment. Here the client will submit the work executed

amount, supplementary work executed, variation work executed, and penalty. The system will use these values to calculate the payment certificate. The client has also the option of submitting the 'Payment BOQ' and the system will calculate the work executed and use the value to prepare the payment certificate. The system can automatically calculate liquidated damage and the client has the option of including this value in payment calculation.

The system can calculate advance, interim and final payments and prepare their respective payment certificates. The client can easily make the payment certificate by clicking payment certificate. The system checks all the limits and prerequisites that were set by the client in the previous windows. If there is an error it will show the error message and will not execute the payment certificate. However, this is not true for warning. The system will show warning messages to the client to make changes but the system will execute the payment regardless of these warning messages. The only warning in the system is if the contract period is expired.

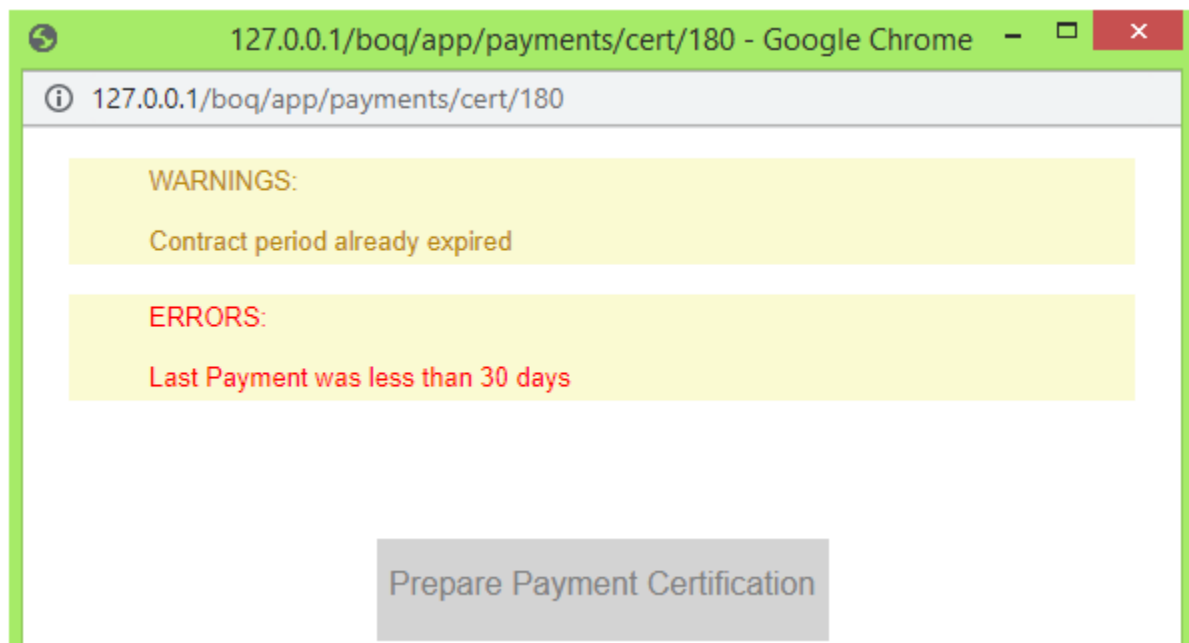
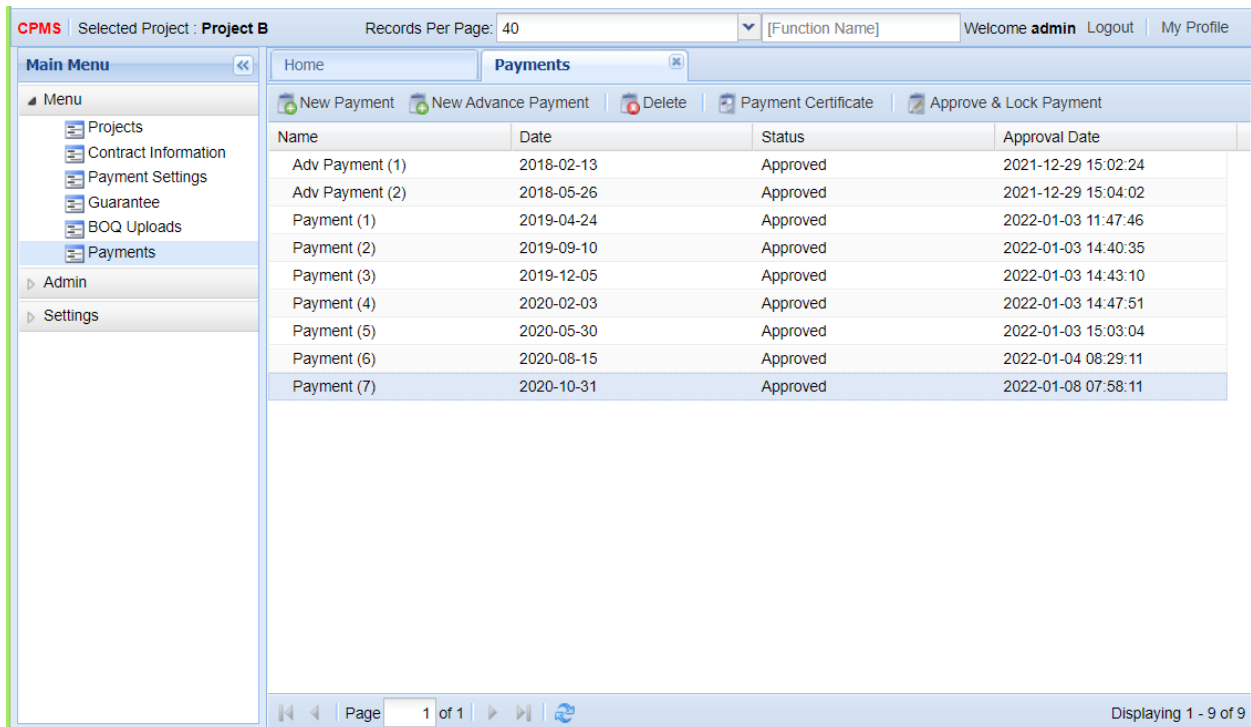


Figure 12 Warning and Error Messages

The system first calculates the total sum for each contract/variation BOQ then performs sums for subcategories. These values with the BOQ will be stored in the database for payment checking. Then the payments were calculated with either the executed work to date value or the payment BOQ. In the latter case, the system first checks for rate error, exceeding quantities and new items then calculates the total and subcategories sum. The sum is calculated by only including items

with correct rates and item descriptions. This value and the values entered in the payment setting will be used to prepare the payment certificate.

The system prepares payment certificates in automated manner to avoid human errors. This will minimize the possibility of certifying a negative final payment by deducting the advance repayment, retention, penalty, and other deductions per the limits given before. The possibility of overpayment is reduced while enhancing the efficiency and timing of payment certification.



The screenshot displays the 'Payments' window in the CPMS application. The interface includes a top navigation bar with 'CPMS', 'Selected Project : Project B', 'Records Per Page: 40', and user information 'Welcome admin Logout My Profile'. A left sidebar contains a 'Main Menu' with options like 'Projects', 'Contract Information', 'Payment Settings', 'Guarantee', 'BOQ Uploads', 'Payments', 'Admin', and 'Settings'. The main content area shows a table of payments with the following data:

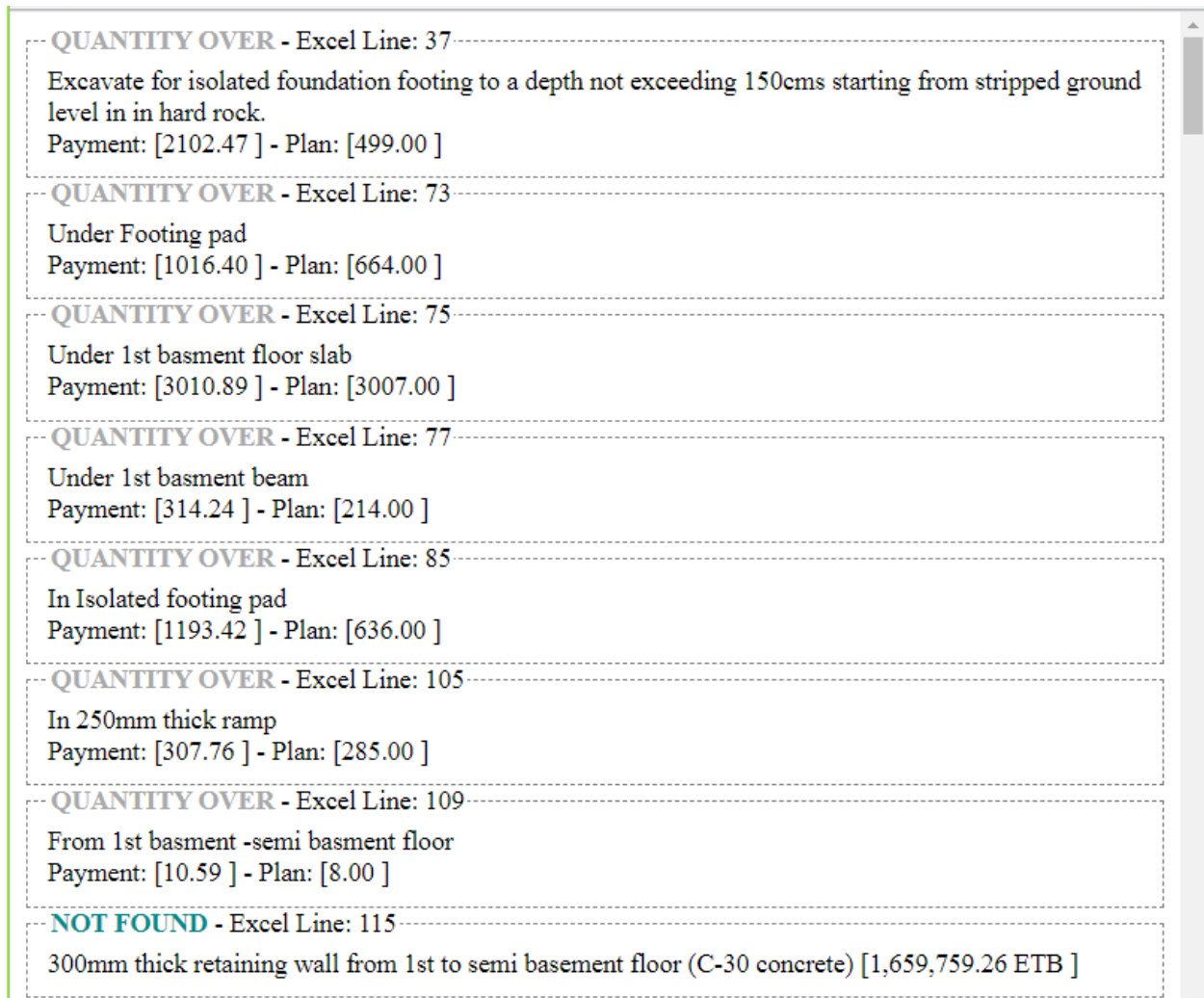
Name	Date	Status	Approval Date
Adv Payment (1)	2018-02-13	Approved	2021-12-29 15:02:24
Adv Payment (2)	2018-05-26	Approved	2021-12-29 15:04:02
Payment (1)	2019-04-24	Approved	2022-01-03 11:47:46
Payment (2)	2019-09-10	Approved	2022-01-03 14:40:35
Payment (3)	2019-12-05	Approved	2022-01-03 14:43:10
Payment (4)	2020-02-03	Approved	2022-01-03 14:47:51
Payment (5)	2020-05-30	Approved	2022-01-03 15:03:04
Payment (6)	2020-08-15	Approved	2022-01-04 08:29:11
Payment (7)	2020-10-31	Approved	2022-01-08 07:58:11

The bottom of the window shows a pagination control 'Page 1 of 1' and a status indicator 'Displaying 1 - 9 of 9'.

Figure 13 Payments Window

The system also performs Value Added Tax (VAT) calculations for the net payment and retention. The status indicates if the payment is pending or approved. Once the payment is approved it can't be modified. The system will register and show the date the payment was created and the date the system was approved. The figure above shows payments that are certified and approved with their status and date stamp. These dates are used to show the number of days it took to approve the payment. The client can easily make advance payment by clicking on new advance payment. The system will check the contract limits set out before when making advance payment certificate. Additionally, the system will check if the repayment is being deducted at the amount and in the manner set out in the contract limits.

The user can click on the view error report button to see a list of differences between the payment BOQ and contract BOQ. The report will show if the payment BOQ contains exceeding quantity, new item or new rate. Below the error report for the fourth payment of Project C is presented. The payment requested was 41,117,555.17 however; the system checked the payment and approved 39,457,795.91 after excluding items with incorrect rates or items not found on the Contract BOQ. The system displays the items with exceeding quantities as "QUANTITY OVER" and items not found in the contract BOQ as "NOT FOUND" with different colors to easily notice them. Additionally, it displays the items description; excel line number, and the contract and payment amount. Additionally, it provides a summary of the quantity and total amount differences between the payment BOQ and contract BOQ.



QUANTITY OVER - Excel Line: 37
Excavate for isolated foundation footing to a depth not exceeding 150cms starting from stripped ground level in in hard rock. Payment: [2102.47] - Plan: [499.00]
QUANTITY OVER - Excel Line: 73
Under Footing pad Payment: [1016.40] - Plan: [664.00]
QUANTITY OVER - Excel Line: 75
Under 1st basment floor slab Payment: [3010.89] - Plan: [3007.00]
QUANTITY OVER - Excel Line: 77
Under 1st basment beam Payment: [314.24] - Plan: [214.00]
QUANTITY OVER - Excel Line: 85
In Isolated footing pad Payment: [1193.42] - Plan: [636.00]
QUANTITY OVER - Excel Line: 105
In 250mm thick ramp Payment: [307.76] - Plan: [285.00]
QUANTITY OVER - Excel Line: 109
From 1st basment -semi basment floor Payment: [10.59] - Plan: [8.00]
NOT FOUND - Excel Line: 115
300mm thick retaining wall from 1st to semi basement floor (C-30 concrete) [1,659,759.26 ETB]

Figure 14 Error Report

4.2.7 Project Report

The system prepares various reports based on the information collected from the other subsystems. Based on the information from project data processing subsystem it will create project certificate and error reports. Additionally, it prepares a payment summary report containing all the necessary elements of the payment certificate. Furthermore, it prepares payment follow-up report based on the information from the control and follow-up subsystem. The follow-up report contains the progress of critical elements of the project like contract time, contract amount, variation, guarantees and liquidated damage. It also provides notice and advice to the client to assist in decision making process.

These reports aid the client by providing accurate and timely information regarding the project financial progress. Furthermore, these reports can be used to make decisions regarding variation, time extension and payment related claim management.

4.2.8 Security

The system can handle multiple users and runs on web pages therefore, security is a major concern. The use of PHP helps in building a secure web-based application. The database is secured using several techniques. These techniques include using different servers for the database and web pages, hash encryption, and regularly backing up the database.

Using password_hash function a secure and encrypted password is created every time a new user registers. This will make sure the username and password used are secure. To make the password more secure it should contain uppercase and lowercase letters. Also, it should contain numbers and special characters with a minimum total length of 8 characters.

The client will be the administrator with the capacity to create or delete users. Furthermore, the users will have different level of permission which limits their activities. The consultant and contractor could see the status of each payment, their sum or error reports but will not be able to edit the payments. The client will be the only party that can approve and lock payments.

4.3 Validation and Verification

The system was piloted on three sample building projects owned by the Commercial Bank of Ethiopia. For the first project (Project A) the system checks the contract/variation BOQ, and 12 payments including advance payments. For the second project (Project B) the system checks the contract/variation BOQ, and 9 payments including advance payments. For the third project (Project C) the system checks the contract BOQ, variation BOQ, and 6 payments including advance payments.

Project A is a building project with a contract amount of 69,043,500.79 birr including VAT. The building has four stories including the basement, ground floor, mezzanine, and two floors above ground. The total built-up area is around 2,878 m². The project is currently in progress and the Client has certified 2 advance payments and 10 interim payments. There is no pending payment and on average an interim payment takes two weeks to certify.

Project B is a building project with a contract amount of 895,641,880.36 birr including VAT. The building has 15 stories including two basements and a semi-basement, ground floor, and 11 floors above ground. The total built-up area is around 28,000 m². The project is currently in progress and the Client has certified 2 advance payments and 7 interim payments.

Project C is a building project with a contract amount of 888,410,773.19 birr including VAT. The building has 14 stories including a basement, ground floor, and 12 floors above ground. The total built-up area is around 29,000 m². The project is currently in progress and the Client has certified 2 advance payments and 14 interim payments.

There was no pending payment but based on the desk study the average time to process an interim payment is around a month from the time the Consultant receives the Contractor's payment request till the time the Employer makes the payment. This time may vary according to the payment amount, the number of times the payment certificate has to go back and forth, and other factors.

In addition to the above information, the Client has provided data on variation contracts, guarantee information (advance guarantee and performance guarantee), contract limits, and all other information required for the system inputs. These data are used to calculate the advance and interim payments and see if the system displays guarantee notices and reports.

Based on the validation plan presented in the methodology section the web-based application has been thoroughly checked. First, the web-based application is tested on commonly used web browsers like Edge, Chrome, Opera, and Firefox. It was found to be working smoothly on all browsers. Then two users are created to check the project interface integration.

The validation for the data processing subsystem consisted of three distinct steps. The validation process aims at making sure the system outputs are accurate and reliable. The total sum and sums for subcategories for the contract and variation BOQ are compared with the sum prepared by the traditional payment certification process. When there is a difference manual checking is used to identify the changes. Since the system can calculate the sum of each subcategory created by the user it was easy to find the errors. The client's project team verifies the accuracy of the system output using manual calculation.

The processing speed and accuracy of the system were recorded for each payment certificate. There was no error found in the calculation done by the system and the payment processing time was less than 5 minutes for each certificate. This was done in the presence of the client's project team members.

Then the system's ability to detect and display errors is tested. This includes errors in the payment BOQs' and errors in the input values. This was part of the automation and data validation process. The project team received the error report for each project. The client's project team cross-checked all the results and verified the system outputs. The errors are classified into two as minor arithmetic errors and major findings.

The minor arithmetic errors resulted from the use of inconsistent decimal places, items not summed, and items with blank quantity values. The major findings include items with incorrect rates, items not found in the contract, and items with exceeding quantities. Here, the ability of the users created to access the BOQs, payment certificates, and error reports was checked.

The contract conditions, contract information, and guarantees submitted that were fed into the system for each project were monitored if they trigger any warning and error message. Then a discussion was held regarding these warning and error messages with the client's project team to check their consistency.

Finally, the system prepares the payment summary report and follow-up report for each project. These reports were also checked and verified by the client. Finally, the critical items that need immediate decisions like guarantee renewal, liquidated damage, and exceeding quantities are reported to the client.

4.4 Sample Code

The following is a sample of the backend code that shows how the systems check and record errors. The code below checks for three errors. The first error checks if the gap between consecutive payments is less than the period defined by the client as per the contract. The second error checks if the performance guarantee amount is less than the required performance security for the contract amount.

The last error checks if the performance guarantee covers the whole contract period or not. If one of these errors yields true the software will show an error message and a payment certificate will not be issued. For instance, if the time gap between consecutive payments is less than the value specified by the user it will show the error message as shown in figure 12 above.

The code below shows the basic structure of PHP code which was used for backend development. The code also contains functions, variables, several data types, and comments. As shown below every line should end with a semicolon and variables have to start with a dollar sign. The information that the function uses to check the errors is called arguments. They are placed within the function.

```
function finderrors($payment){
$errors="";
$proj=$payment['Project'];
//print_r($payment);
//check guarantee errors
$time_gap=false;
$adv_pd=$payment['Payment']['work_executed'];$adv_gr=0;
foreach($proj['Payment'] as $pj){
    if(date('Y-m-d',strtotime($pj['date'].' + '.$payment['Project']['min_int'].' days')) > date('Y-m-d',strtotime($payment['Payment']['date'])))
        && $pj['status']=='Approved')
        $time_gap=true;
    if($pj['type']=='Advance Payment' && $pj['status']=='Approved')
        $adv_pd=$adv_pd+$pj['work_executed'];
}
if($time_gap==true)
    $errors.="<br>Last Payment was less than ".$payment['Project']['min_int']." days";
foreach($proj['Guarantee'] as $pj){
    if($pj['type']=='Performance Guarantee'){
        if($pj['amount']<($proj['total']*0.1)){
            $errors.="<br>Performance Guarantee is less than 10% of Contractual Agreement";
        }
        if($pj['expire_date']<date('Y-m-d',strtotime($proj['signing_date'].' + '.$proj['mobilization_time'].' + '.$proj['contract_period'].' days'))){
            $errors.="<br>Performance Guarantee Does not cover full project timeline";
        }
    }
}
}
```

Figure 15 Backend code sample

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

The main objective of the research was to develop a computer-aided construction payment management system for clients with multiple building projects. The specific objectives were to create an automated payment certification, follow-up system, secure database, integrated project interface, and a reporting system. The study was aimed at reducing time, error, and paperwork while achieving transparency. It was also aimed at assisting the payment-related claim management process by developing an integrated payment management system. The system has achieved its main and specific objectives as presented below.

5.1 Conclusions

The study developed a web-based application that integrates smart contract that is derived from the PPA 2011, standard conditions of contract, and are used to automate and control the payment management process in building construction projects. The conditions of contract are broken down and converted into executable codes and the web-based application was developed using PHP for the backend and JavaScript for the frontend.

As shown in the validation and verification process the web-based application was able to check the payment BOQ and identify all arithmetic errors, exceeding quantities, and items not found in the contract. Additionally, the web-based application was able to use the contract conditions to check the payment process and provide warning and error message which prevents the client from making payments without a valid guarantee or exceeding the contractual limits.

The system was also shown to prepare interim and advance payment certificates without the need for human involvement. This could reduce the error, time, and paperwork involved in the payment certificate process. Furthermore, the application allowed multiple users to be created allowing the client, contractor, and consultant to follow the payment certification process in real-time which made it transparent.

The database stores contract BOQs', payment BOQs', payment certificates and guarantee information which enhances payment documentation. Furthermore, the system shows which certificate is pending, for how many days it has been pended, and the errors found in that payment. This would aid the payment-related claim management process.

5.2 Recommendations

The implementation of the web-based application could provide a platform for integrated payment management for clients managing multiple building projects. The author recommends the use of documentation and reports collected through the implementation of this system on multiple building projects as a foundation to enhance future studies to pinpoint and quantify the causes of cost overruns, and payment delays and provide pragmatic solutions.

Since the web-based application developed doesn't address price adjustment; future studies that incorporate this should be performed. Additionally, the use of industry-standard frameworks instead of open-source frameworks could yield a more reliable solution for the large-scale implementation of payment management systems.

Future research that incorporates on-site measurement and valuation of work is recommended to enhance the automation of the payment management process.

The author encourages similar studies that aim to automate the different aspects of project management by integrating smart contracts with web-based applications should be conducted to provide practical solutions to the construction industry.

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APPENDIXES

APPENDIX A: DATA COLLECTION FORM

Introduction

The research titled Computer Aided Management of Construction Payment: For Clients with Multiple Building projects will be conducted for the partial fulfillment of the requirements of the Masters of Science Degree in Construction Technology and Management. This data collected form is prepared and filled by the author. The information gathered from the document analysis using this form will be kept strictly confidential and will be used for academic purposes only. All the data you provide will be used for the generalized analysis of the research and no organization or individual will be identified and mentioned in the process.

I am grateful for your cooperation and assistance!

Type of Document	Data Category	Data Filled by Author	Remark
Contract Document	Project Information	Project Name	
		Project Location	
		Client Name	
		Contractor Name	
		Consultant Name	
		Contract No.	
	Time Information	Signing Date	
		Mobilization Period	
		Contract Period	
	Contract Limit	Variation Limit	
		Minimum Interim Amount	
		Minimum Interim Period	
		Advance Payment Limit	
		Retention Amount Limit	
		Liquidated Amount Limit	
	Basic Payment Information	Contract Amount	
		Rebate %	
		Retention Percentage	
	BOQ Information	Contract BOQ	
	Advance Information	Advance Payment %	
		Advance Installments	
		Advance Repayment	
		Start Repay Advance %	
		Fully Repay Advance %	
Invoice Detail	Contractor's Bank Name		
	Account Number		
	VAT Registration No.		
	Payment Signed by		
	Consultant Representative		
	Currency		
Variation Document	BOQ Information	Variation BOQ	
	Basic Payment Information	Variation Amount	
		Rebate %	
		Retention %	
Supplementary	BOQ Information	Supplementary BOQ	

Document	Basic Payment Information	Supplementary Amount		
		Rebate %		
		Retention %		
Guarantee Letters	Guarantee Information	Guarantee Type		
		Guarantee Expiry Date		
		Guarantee Amount		
		Guarantee Renewal Date		
Payment Certificate	Advance Payment	Advance Amount		
		Payment Date		
		VAT Paid		
	Interim Payment	Payment BOQ		
		Executed Work to Date		
		Material on Site		
		Rebate Amount		
		Retention Amount		
		Previously Paid Amount		
		Net Payment		
		Retention VAT		
		Net Payment VAT		
		Total Payment including VAT		

APPENDIX B: USER MANUAL

Introduction

This manual is prepared as part of the thesis research titled Computer-Aided Management of Construction Payment: For Clients with Multiple Building Projects. This web-based application provides an automated and controlled payment certification capability. It provides notices and advice based on the limits provided by the user or built-in to the system according to the PPA standard. This is a web-based application that works on Google Chrome, Mozilla, or other common browsers. It has been tested and found functional on the Windows operating system.

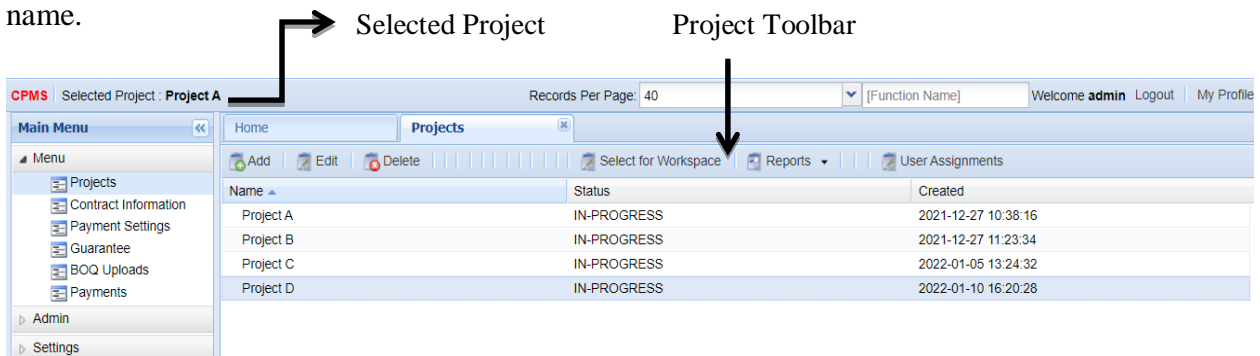
Login to Construction Payment Management System

The user creates a username and password that will be saved by the system. The user will then use this username and password to log in. The user will input the user and password and press the login button. Some web pages save the username and password if required. To make it more secure the password should contain uppercase and lowercase letters. Additionally, it should contain numbers and special characters with a minimum total length of 8 characters.



Main Window

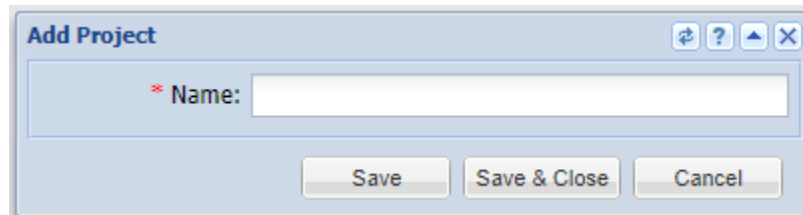
Once you're logged into the system, it will display a welcome message. The left side of the window shows the main menu while the right side shows the home page. The home page provides a message for the user to select a project for the workspace. Click on 'Projects' which opens the projects window on the right side. There the client can see the projects that are added previously. On the top, the client can 'Add' button to add a new project by providing the project name.



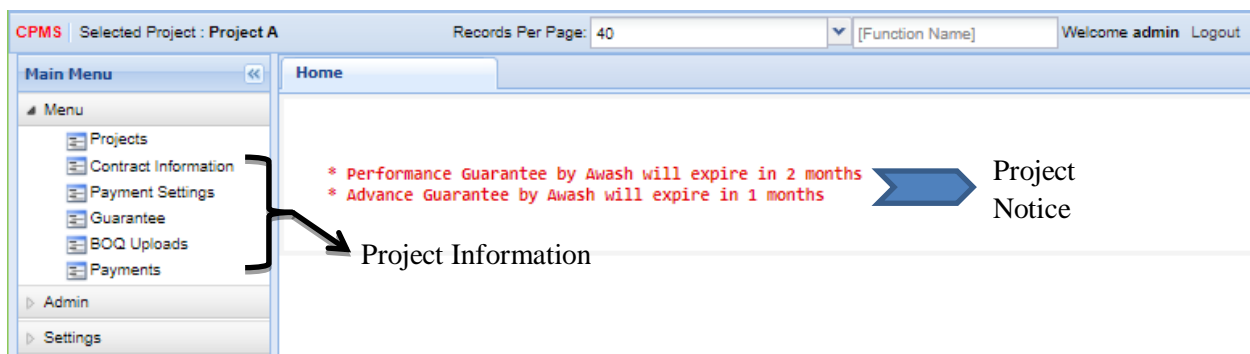
Name	Status	Created
Project A	IN-PROGRESS	2021-12-27 10:38:16
Project B	IN-PROGRESS	2021-12-27 11:23:34
Project C	IN-PROGRESS	2022-01-05 13:24:32
Project D	IN-PROGRESS	2022-01-10 16:20:28

Add, Edit, Delete Projects

To add a project click the 'Add' button and a small window will appear as shown below. The user will enter a project name in the name box then click 'Save and Close'. This will automatically create a new project file. The user can create multiple projects by providing the project name then clicking 'Save' and repeating this process.



Additionally, we can edit or delete any project from the list by choosing the project and pressing one of the two buttons. We can only edit the project name by using the edit button on this window. The default status of the project will be IN-PROGRESS however the user can change it to terminated or completed.



We can go to a specific project space by clicking on the 'Select for Workspace' button. Once we selected a project the left drop menu will display multiple 'Buttons' used to feed data into the system. On the top left corner, we can see the selected project name. Additionally, the project window will close and the 'Home' window will show notifications regarding guarantees.

Contract Information

The main window contains project information toolbars for the user to submit data regarding the project. The first toolbar is contract information which includes basic information that will be needed in the payment certificate and for guarantee validation. Left-click on the toolbar and a

new window will open as shown below. The user clicks on the empty spaces and fills out the form to provide contact information. This is a one-time submission and should be saved after completing the form.

The Contract time information submitted will be used to control project completion time, contract validity, guarantee information validity. The mobilization time will be the time between the contract signing date and the commencement date. The system will consider all days submitted by the user to be calendar days.

- Contract Completion Date = Signing date + Mobilization date + Contract period
- Deadline to certify payment = Date Payment certificate Approved - Date payment made

The screenshot shows a software window titled "Project and Contract Information" with three main sections:

- Project Information:** Includes input fields for Project Site Location, Client, Consultant, Contractor, and Contract No.
- Contract Time Information:** Includes input fields for Signing Date (with a calendar icon), Mobilization Time (in days), and Contract Period (in days).
- Contract Limit:** A table-like structure with two columns of input fields:
 - Left column: Variation Amount Limit (%), Minimum Interim Amount, Advance Renew Prior to (in days), Performance Renew Prior to (in days).
 - Right column: Minimum Interval between Interim Payments (in days), Value of work not completed (%), * Price Adjustment (with a dropdown menu showing "Select One"), and Deadline to Certify Payment.

At the bottom right of the window are "Save" and "Cancel" buttons.

Payment Settings

The second toolbar is payment settings left click on the toolbar and a new window will open as shown below. The Client will submit basic payment information like contract amount, rebate, retention, and work orders if any. Then information regarding advance payment will be submitted below in the advance information section. The user can submit multiple variation orders by separating them with a comma. The user should not use any comma to separate thousands; this will cause problems for the system.

Payment Settings

* : Select One

Basic Settings

Rebate (%):

Retention (%):

Contract Amount:

Supplementary Agreement (separate by /):

Variations (separate by /):

Advance Information

Advance Payment (%):

Advance Installments (Separate by /):

Advance Repayment (%):

Start Repay Advance when Work Reaches (%):

Full Repay Advance Before Work Reaches (%):

Invoice Details

Contractor Bank Name:

Account Number:

VAT Registration No:

Payment Signed By:

Consultant Representative:

Currency:

Save Cancel

The user has the option of manually submitting the advance amount or submits the advance payment percentage which the system will use to calculate the advance payment. The user has

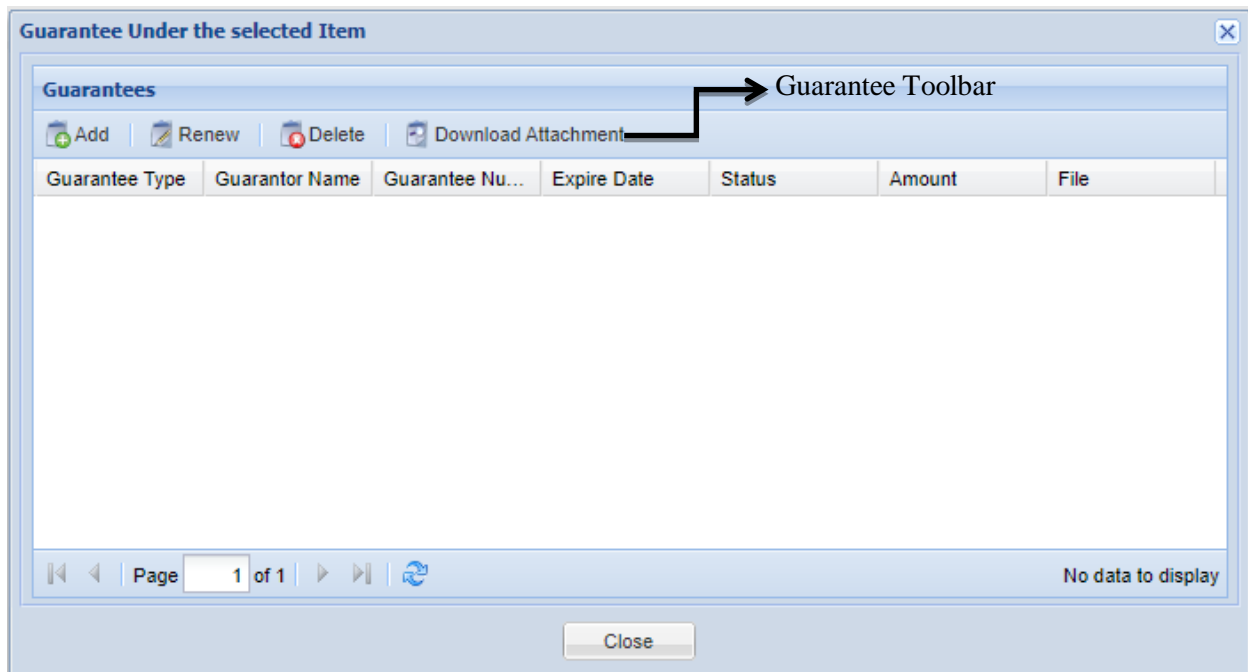
the option to define the number of installments, the value of each installment and the advance repayment percentage.

Furthermore, the user can insert percentage values which dictate when the repayment should start and when the repayment should be completed. This is taken as a percentage of the contract amount. The system will compare this value with the work executed at each payment certificate and controls the advance repayment.

The invoice details are submitted once to be used for reporting purpose and to make sure it matches with the payment request letter submitted by the contractor. The client can check the account information, the person who signed the payment and VAT registration no.

Guarantee

Guarantees come in various forms they could be performance guarantee, advance guarantee, or payment guarantee. A performance guarantee is an assurance given to the client by the contractor for the successful performance of the contract.



The user can add, delete, extend time, or view the guarantee from this panel. First, the user adds a guarantee by clicking the 'Add' button. Then choose from the guarantee in the drop-down

menu. Then tick on the checkboxes to make sure the guarantee information matches the project information. Then submit additional information regarding the advance amount and expiry date.

Add Guarantee

* Guarantee Type: Select One

* Guarantor:

* Guarantee Number:

Check on the Guarantee letter the following checkpoints

* Is Client name Aldon?

* Is Contractor name CID?

* Is Guarantor a Bank Or Insurance?

* Is Project name Project 1?

* Is it on Demand?

Expire Date:

* Amount:

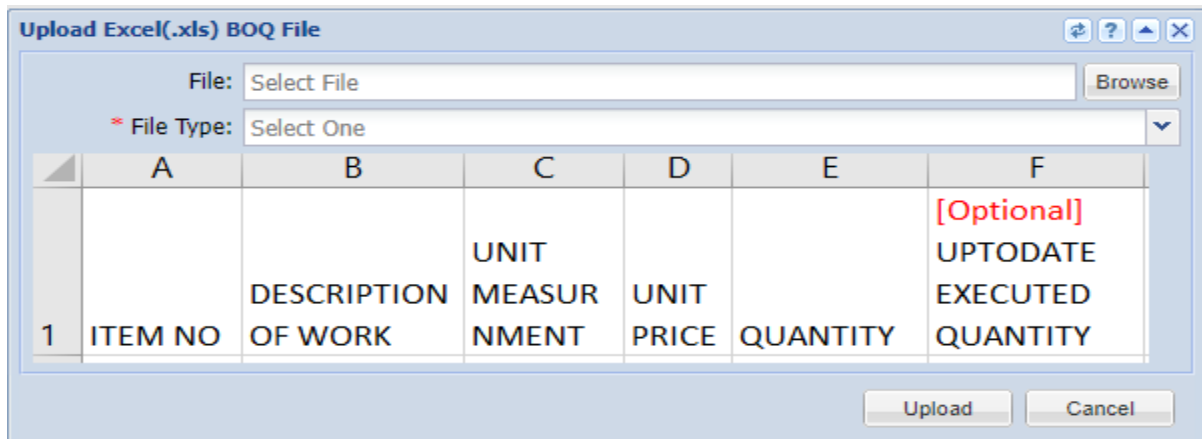
Upload Guarantee Letter:

Once all the information is filled and the boxes ticked you can save and close or save. The difference is that if you click the save button the software will save the data and will allow the user to enter multiple guarantees. However, when you click the save & close button it will save the data and exit the window. The guarantee to be uploaded should be in .pdf format only.

BOQ Uploads

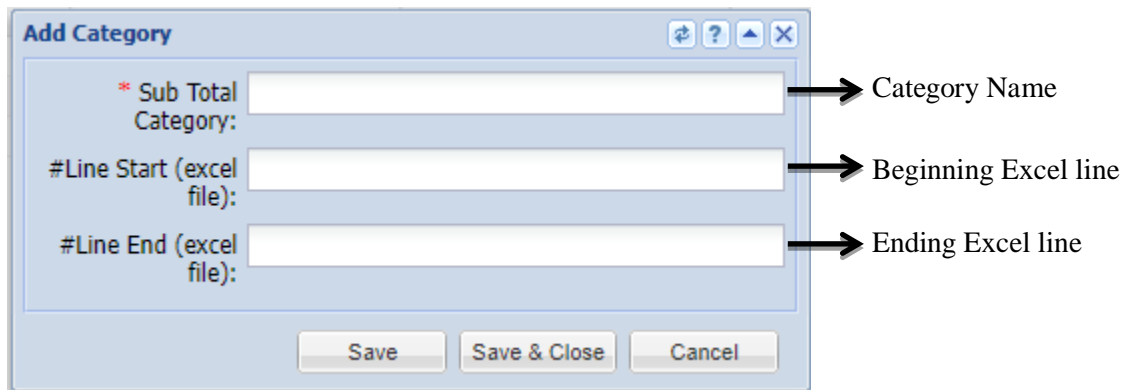
The fourth toolbar is BOQ uploads; left click on the toolbar and a new window will open as shown below. The user will submit the 'Main/Contract BOQ', 'Variation BOQ', 'Supplementary BOQ', and 'Payment BOQ' in this tab. To add a new BOQ the user left click on the drop-down and select the file then choose they select the BOQ type from the drop-down. The system takes

an excel file arranged in the order presented in the image within the tab. The user can add additional BOQ files or delete the existing BOQ's.



The plan BOQ can only be added once however, we can have multiple BOQ's for variation, supplementary, or payment. The system will show the project name, BOQ type, total amount, and uploaded date. The user can double-click on the plan BOQ and create a subcategory. The user can create a subcategory based on the original excel file individual category (excavation, block work, etc...) line number. This allows the user to see the subtotal amount in the BOQ and later on, on the payment. The user can add, edit or delete these subcategories at any time.

Project	File	Type	Total	uploaded date
Project A	Contract BOQ.xlsx	Plan BOQ	61,864,666.78	2022-01-05 06:30:15
Project A	Variation BOQ.xlsx	Contract Variation BOQ	462,889.10	2022-01-05 06:34:52
Project A	BOQ Payment.xlsx	Payment BOQ	43,894,265.75	2022-01-05 06:37:07

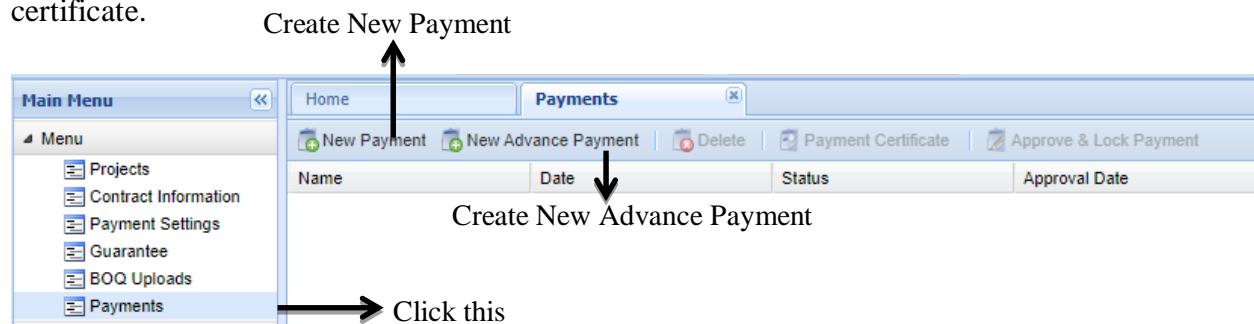


The total amount calculated from here may be different from what has been given in the payment settings. The system will use the contract amount in the payment setting for payment calculation but the unit rates and quantity are checked based on the contract BOQ. Once the user inputs payment BOQ, he can double click on the payment BOQ and see the summation for each category in the payment.

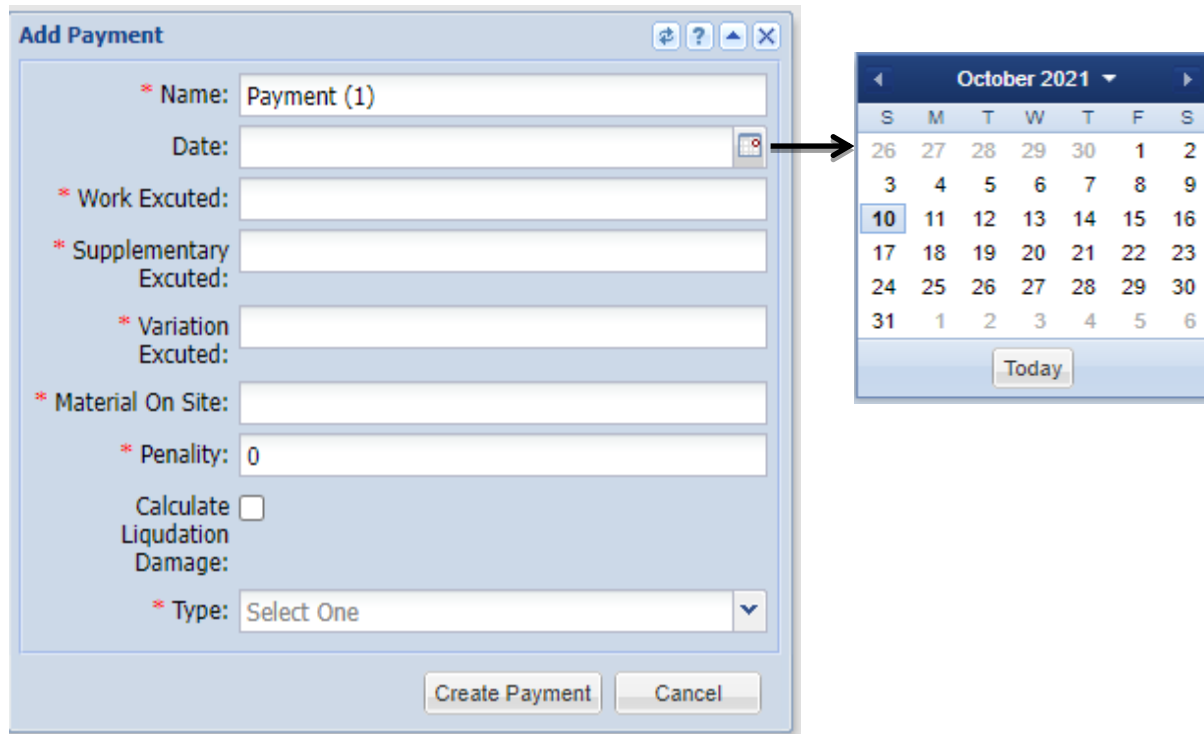
The user can click on the view error report button to see a list of differences between the payment BOQ and contract BOQ. The report will show if the payment BOQ contains exceeding quantity, new item or new rate. Additionally, it provides a summary of the quantity and total amount differences between the payment BOQ and contract BOQ.

Payments

Click on the payments toolbar under Main Menu then the system will open up a new window and toolbar. There are two options to create a payment certificate. One way is for the user to submit specific payment information as presented in the figure below. Then the system can generate the payment certification. The second option is for the user to submit the 'Payment BOQ' and the system will calculate the work executed and use the value to prepare the payment certificate.



The system first checks all the prerequisites and other limits before preparing the payment certificate. If any of these conditions are not met the payment will not be prepared and the system will show an error message.



Click on new payment and the above window will open then the user fills the form. The software will give the payment name by default. The user can submit the data by clicking the button on the right side and a new window will appear as shown above. Then the user can use the dropdown on the calendar to choose the date. The user will submit the other values as amounts without a comma.

The user can click on the calculate liquidation damage tick box to include liquidated damage. Finally, use the dropdown menu on the bottom to choose from interim payment or final payment.

To create advance payment the user clicks on "new advance payment" which opens a new window. The window is shown below.

The 'Add Payment' dialog box is a standard Windows-style window with a title bar containing 'Add Payment' and standard window controls (minimize, maximize, close). The main area contains four labeled input fields, each with a red asterisk indicating it is required: 'Name' with the value 'Adv Payment (1)', 'Date' with an empty field and a calendar icon, 'Amount' with an empty field, and 'Type' with a dropdown menu showing 'Select One'. At the bottom of the dialog are two buttons: 'Create Payment' and 'Cancel'.

Once the user has created a payment, the user can click on the payment, and other options on the toolbar will be active. The user can add a new payment, new advance payment, delete the payment, or approve and lock payment. The payment window will show the payment name, date created, and status. The user can approve and lock payment by clicking on the "approve & lock payment" button on the top. The web-based application will register the date the payment was approved.

The 'Payments' window has a title bar with 'Home' and 'Payments'. Below the title bar is a toolbar with five buttons: 'New Payment', 'New Advance Payment', 'Delete', 'Payment Certificate', and 'Approve & Lock Payment'. Below the toolbar is a table with the following data:

Name	Date	Status	Approval Date
Adv Payment (1)	2018-02-13	Approved	2021-12-29 15:02:24
Adv Payment (2)	2018-05-26	Approved	2021-12-29 15:04:02
Payment (1)	2019-04-24	Approved	2022-01-03 11:47:46
Payment (2)	2019-09-10	Approved	2022-01-03 14:40:35

Error Report

The system will show an error report when we click on the payment certificate button. This window will show all warnings and errors that the system found. The user can then correct the inputs and redo the operation. Prepare payment certificate button will not be active while there are errors on the payment. However, the button will be active even if there are warnings.

ERRORS:

Performance Guarantee is not equal to 10% of Contractual Agreement
 Contract period already expired

Prepare Payment Certification

The button is inactive
 (payment certificate
 will not be made)

Once the errors are corrected the software will prepare the payment certificate. The certificate will have similar format as the standard payment certificate used by majority of our construction industry. Every detail of the payment certificate will be automated and the client can see each value and approve the payment.

Report

The software produces various reports including payment certificates, BOQ error reports, and payment error reports. Additionally, the software produces a summarized project-specific report. The user can access these reports by clicking on the report tab on the projects window. Then the user selects the type of report from the drop-down menu. The payment summary report is a tabular report showing the approved payment certificates for the given project as shown below. The follow-up report contains the progress of critical elements of the project like contract time, contract amount, variation, guarantees and liquidated damage.

Payment Summary Report

Payment	Date	Work Executed	Material on Site	Variation Work	Supplementary Work	Total Work Done	Rebate	Retention	Advance Repaid	Net Payment	VAT paid
Payment (1)	2022-02-10	70,000,000.00	0.00	0.00	0.00	70,000,000.00	0.00	525,000.00	17,500,000.00	49,000,000.00	7,875,000.00
Total Sum		70,000,000.00	0.00	0.00	0.00	70,000,000.00	0.00	525,000.00	17,500,000.00	49,000,000.00	7,875,000.00