Univerza *v Ljubljani*
Fakulteta *za gradbeništvo*
in geodezijo

NABIH MOUSHARBASH

BIM-BASED DEVELOPMENT OF BILL OF MATERIALS WITH CASE STUDY

RAZAVOJ SEZNAMA GRADIV NA OSNOVI BIM S ŠTUDIJAMI PRIMEROV

BIM A+ European Master in Building Information Modelling

Master thesis No.:

Supervisor:
Doc. Dr. Tomo Cerovšek

Ljubljana, 2020

Co-funded by the Erasmus+ Programme of the European Union

ERRATA

Page	Line	Error	Correction

»This page is intentionally blank«

BIBLIOGRAPHY – DOCUMENTATION PAGE AND ABSTRACT

UDK: 004.7:691(043.3)

Author: Nabih Mousharbash

Mentor: Ass. Prof.. dr. Tomo Cerovšek

Co-mentor: prof. dr. Vlatko Bosiljkov

Title: BIM-based development of bill of materials with case studies

Document Type: Master Thesis

Scope and Equipment: **182 pg, 82 img., 11 pgs**

Key Words: BIM, RICS, BOQ, Quantity Surveying, Architecture, Python, Programming.

Abstract:

This thesis emphasizes the research and methodology impacting BIM (Building Information Modelling), beginning with the problems arising after the project is modeled to its 3rd, 4th, and 5th dimensions. Most BIM projects stop after the model is done and not use it for Schedules and Bill of Quantities (4D and 5D).

The research started with a survey, taken by companies all around the world. The companies are selected based on their experience in the 4th and 5th dimension in BIM and Quantity Surveying. As well as hearing their comments regarding the advantages and disadvantages of the process, such as time, price, quality, and accuracy. There are a lot of concerns that are common between firms such as the level of security in the project and the accurate readings generated from the project.

First of all, The traditional style of BOQ generation (Manual) is used by many firms, The case study got implemented and the result is used in the next step of the research. Later on, a semi-traditional style was done (using CostX). PDF plans from the models were extracted and then imported to the software, the readings were recorded in the Quantity Takeoff (QTO) and then organized in the New Rules of Measurement Bill of Quantity Template. Last but not least, a prototype plug-in was used to generate the readings in which later generated organized in the Bill of Quantity template. The higher the Level of Detail (LOD) of the project, the more accurate the reading will be.

To conclude, the model will be tested in three BOQ methods (Traditional, Semi Intervention, Plug-in). The final reading (traditional, Semi-traditional, Plug-in) is given to experts and the outcome was graded based on several matters such as time, accuracy, and template, and the data will be analyzed to draw conclusions and formulate questions for future research. A feedback review of the QTO and BOQ is done with NRM II adaption. The research is tested on all continents. Therefore, finding a smart and practical solution that will revolutionize the thinking methodology of the quantity surveyor profession. A test trial of a real model is done and the outcome is reviewed by experts in that field, its a refurbishment project of a music academy located in Ljubljana, Slovenia.

»This page is intentionally blank«

BIBLIOGRAFSKO – DOKUMENTACIJSKA STRAN IN IZVLEČEK:

UDK: 004.7:691(043.3)

Avtor: Nabih Mousharbash

Mentor: doc. dr. Tomo Cerovšek

Somentor: prof. dr. Vlatko Bosiljkov

Naslov: Razvoj seznama gradiv na osnovi BIM s študijami primerov

Tip dokumenta: Master Thesis

Obseg in oprema: **182 str, 82 slik, 11 tab.**

Ključne besede: BIM, RICS, BOQ, Merjenje količine, Arhitektura, Python, Programiranje.

Izvleček:

V diplomski nalogi so poudarjene raziskave in metodologije, ki vplivajo na BIM (Building Information Modeling), začenši s problemi, ki nastanejo po modelu projekta v 3., 4. in 5. dimenzijo. Večina projektov BIM se ustavi po izdelavi modela in ga ne uporablja za urnike in predmete (4D in 5D).

Raziskava se je začela z raziskavo, ki so jo opravile družbe po vsem svetu. Podjetja so izbrana na podlagi njihovih izkušenj v 4. in 5. dimenziji v BIM in Quantity Surveying. Pa tudi njihove pripombe glede prednosti in slabosti postopka, kot so čas, cena, kakovost in natančnost. Podjetja imajo veliko pomislekov, kot so raven varnosti v projektu in natančni odčitki, ki jih ustvari projekt.

Najprej tradicionalni slog generacije BOQ (Manual) uporabljajo številna podjetja. Študija primera je bila uvedena, rezultat pa uporabljen v naslednjem koraku raziskave. Kasneje je bil narejen poltradicionalni slog (z uporabo CostX). Načrti PDF iz modelov so bili izvlečeni in nato uvoženi v programsko opremo, odčitki so bili zabeleženi v količinskem vzletu (QTO) in nato organizirani v novi predlogi merilne predloge za količino. Nenazadnje je bil za generiranje odčitkov, ki so bili pozneje generirani v predlogi za količino, uporabljen prototipni vtičnik. Višja kot je raven podrobnosti (LOD) projekta, natančnejše bo branje.

Za zaključek bomo model preizkusili v treh metodah BOQ (tradicionalni, polpreizkusni, vtični). Končno branje (tradicionalno, poltradicionalno, plug-in) dobijo strokovnjaki, rezultat pa je bil ocenjen na podlagi več zadev, kot so čas, natančnost in predloga, podatki pa bodo analizirani, da bodo oblikovani zaključki in oblikovana vprašanja za prihodnost raziskave. Pregled QTO in BOQ s povratnimi informacijami je narejen s prilagoditvijo NRM II. Raziskava je preizkušena na vseh celinah. Zato najdemo pametno in praktično rešitev, ki bo revolucionirala metodologijo razmišljanja poklica geometarja. Opravljen je poskusni preizkus pravega modela, rezultat pa pregledajo strokovnjaki s tega področja, ki je projekt prenove Akademije za glasbo v Ljubljani v Sloveniji.

»This page is intentionally blank«

ACKNOWLEDGMENT

This thesis is dedicated to the many people who made it possible. First, to my grandfather, Nabih Rahmeh, who was a great personal supporter, but passed away before my enrollment in this master's program - May his soul rest in peace.

Second, to Dr. Tomo Cerovsek, my thesis supervisor. Dr. Tomo has continuously supported me along with this endeavor and pushed me to the limit to deliver a worthy and fruitful project. With his professionalism and wide knowledge, I was able to execute all the work diligently without hesitation. Despite the challenges presented by the COVID pandemic, as well as the multitude of issues typically presented in writing such a thesis, I was well prepared with Professor Tomo's assistance.

Third, to all the friends whom I met on this program and formed a special bond with. My sincere thanks go out to Ana De Luna, Tousif Rahman, Orjola Braholli, João Vieira, and Giovanni Coviello; You made this journey special and memorable from beginning to end. My gratitude also goes to Roger Peicho, an important friend on this long journey; I am thankful for your motivation and support throughout everything, be it the thesis, the course work, or any of the number of things you have offered me help with. Furthermore, I give my regards to my friend Faika Darwish who was always there for me, supporting and guiding me all the way; I cannot express my gratitude to you. You were a buoy and a grounding source of advice and guidance. A special place in my heart for my soul mate and partner in crime Renad Samaan who was with me day and night and with my weakness and strength, I love you so much and I am blessed to have you in my life, more is yet to come and I am looking forward to it.

A big thank you and appreciation go to Styria Architects for supporting my research by providing me with a 3D model that sculpted my model and closing conclusion statement. Without this case study, the research would only be theory on paper with no real implementation. The model was super detailed to meet the standards of an excellent if not the best quality of work in Europe and the world.

The biggest debt of gratitude and love I owe, however, is to my mother, who has always supported my dreams, and continues to do so without fail; You always lift me up and push me back on the right track when I need it the most. No matter how I grow or how far I go, I hope I will always deserve to be the source of pride and joy you see me as today and always have. And to my brother, Micheal Mousharbash, my backbone, who always made the hard times easier, showing me the meaning of professionalism and sharing the most valuable of his life lessons. Last but not least, my father, who stayed up night after night to support me spiritually and vocationally, and tell me that everything will be okay, no matter how hard the times, or how weak my spirit at the time. I love you all, now and always.

Believe and achieve. The sky is your limit, nothing is impossible when you are consistent.

»This page is intentionally blank«

TABLE OF CONTENTS

INDEX OF ACRONYMS

BIM – Building Information Modeling

RIBA – Royal Institute of British Architects

RICS – Royal Institute of Chartered Surveyors

NRM – New Rules of Measurements

FIDIC - Fédération Internationale Des Ingénieurs Conseils

SMM – Standard Methode of Measurement

BQ – Bill of Quantity

OGC – Outline Plan of Work

IFC – International Federation Class

GC – Generative Components

ha – Hectare

hr – Hour

kg – Kilogram

kN – Kilonewton

kW – Kilowatt

m – Linear Meter

m^2 – Square Meter

m^3 – Cubic Meter

mm – Millimetre

mm^2 – Square Millimetre

mm^3 – Cubic Millimetre

nr – Number

t – Tonne

wk – Week

QTO's – Quantity Take Off's

PHP – Hypertext Preprocessor

MySQL – Michael Widenius's Structured Query Language

C# – C Sharp

VR – Virtual Reality

AGR – Augmented Reality

UK – United Kingdom

CPD – Continuing Professional Development

ARB – Architects Registration Board

FRICS – Fellow of Royal Institution of Chartered Surveyors

MRICS – Member of Royal Institution of Chartered Surveyors

ASSOCRICS – Associate of Royal Institution of Chartered Surveyors

LOD– Level Of Detail

BoM– Bill of Materials

NBS– National BIM Survey

CAWS – Common Agreement of Work Sections

CPIC – Construction Project Information Committee

GIS – Geographic Information System

IoT – Internet of Things

CDE – Common Data Environment

EIR – Employee's Information Requirments

IP– Intellectual Property

AECOM – Engineering Firm (Architecture, Engineering, Construction, Operations, Management)

GCE – Golf Coast Enterprises

POMI – Principal Of Measurement International

NRM 2 – New Rules of Measurement 2nd book

CESMM4 – Civil Engineering Standard Method of Measurement 4th Edition

JBCC – Judicial Branch Certification Commission

CAD – Computer-Aided Design

PDF– Portable Document Format

API– Application Programming Interface

SDK– Software Development Kit

APO– Advanced Planner and Optimizer

FEC– Filtered Element Collector

ASAQS– Association of South African Quantity Surveyors

JDBC– Java Database Connectivity

ODBC– Open Database Connectivity

CESMM – Civil Engineering Methode of Measurement

CAWS – Common Arrangement of Work Sections

INDEX OF FIGURES

INDEX OF TABLES

1 INTRODUCTION AND ELABORATION

The concept of BIM has existed since the 1950s but it only began receiving wider attention after being redefined in the 1970's [1]. To clarify: BIM, in short, is the process covering the generation and management of the physical and functional information of a building project [2]. The figure below shows the development of BIM definition with time.

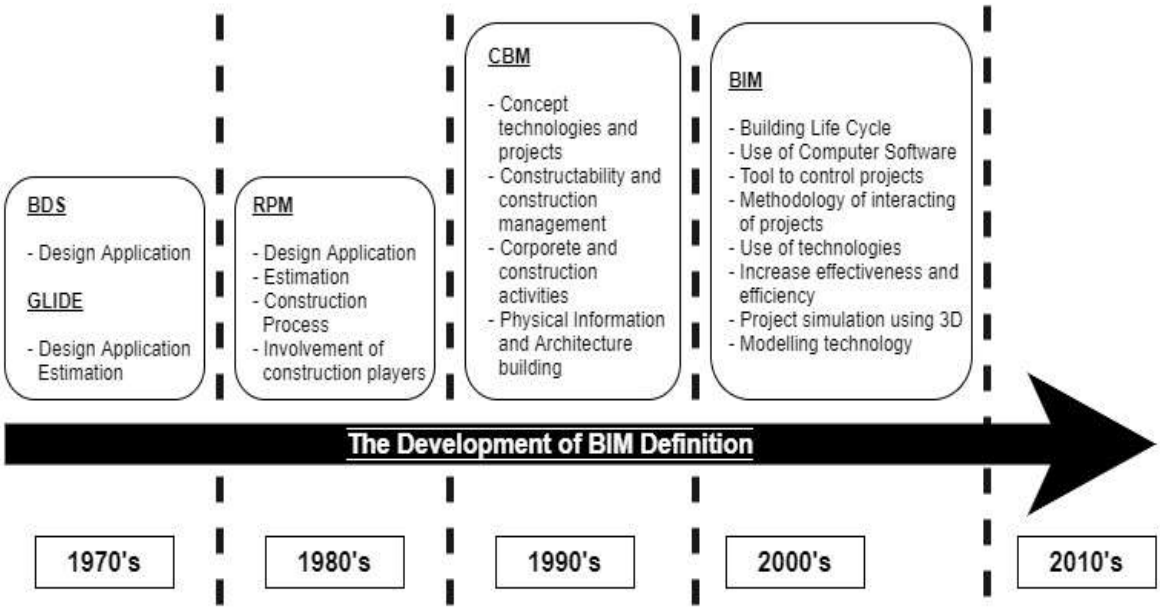


Figure 1. History of BIM Definition

The outputs of the process ultimately consist of the digital files that may describe every feature of the project and support decision-making regarding a built asset. A common misconception is that BIM is merely a process of 3D modeling (width, height, and depth), the process. However, also includes further scopes such as 4D (time), 5D (cost), and even 6D (as-built operation) [2].

1.1 History of BIM

Throughout history, BIM has seen multiple iterations and concepts, with its early beginnings in 1957, and it has since passed through a long evolution, with these many different programs leaving their marks in the footpath of BIM development and formation. The following table shows the detailed timeline of BIM throughout history[3]:

Table 1. BIM milestones [4]

Year	Progress
1957	Dr. Patrick J. Hanratty, viewed as the father of CAD / CAM, develops CAM (Computer Aided Machining) which is the first commercial computer-aided machining. It is an NC (Numerical Control) machining software.
1963	Sketchpad created, becoming the first CAD with a graphical user interface that allows the user to enter parameters and constraints.
1975	The BDS (Building Description System) published by Charles Eastman and is one of the first projects in BIM history to successfully create individual library elements which can be retrieved and added to a model
1977	Charles Eastman creates Graphical Language for Interactive Design (GLIDE), which already exhibited most of the characteristics of the modern BIM platform.
1982	Gábor Bojár starts developing ArchiCAD and AutoCAD version 1 is released (2D CAD).
1984	Gábor Bojár releases Graphisoft's Radar CH for the Apple Lisa OS, similar to the BDS technology.
1985	Vectorworks developed by Diehl Graphisoft. It is one of the first (first what?) to introduce BIM capabilities.
1986	Universal Computer-Aided Production System RUCAPS created; the first CAD program in the history of BIM to be used in prefab construction.
1987	ArchiCAD released, making it the first BIM software available on a personal computer.
1988	Parametric Technology Corporation (PTC) releases Pro/ENGINEER, considered the primary marketed parametric modeling design software in BIM history.
1992	Building Information Model acknowledged as an official term by G.A. Van Nederveen and F. Tolman.
1993	Building Design Advisor developed at Lawrence Berkeley National Lab. The software performs simulations and suggested solutions based on a model.

1994	Mapsoft in Australia designs Medicaid, which becomes the first survey CAD software to run on a handheld computer.
1995	International Foundation Class (IFC) file format is developed to allow data to flow across platforms making a file compatible with different BIM programs.
1997	ArchiCAD's Teamwork released. It revolutionizes team collaborations and allows more architects to work on a building model simultaneously.
1999	Onuma allows virtual teams to work on BIM through the Internet and creates a database-driven BIM planning system.
2000	Revit revolutionizes BIM by using a parametric change engine made possible through object-oriented programming.
2001	NavisWorks develops and markets JetStream, a 3D design review software that offers a set of tools to 3D CAD navigation, collaboration, and coordination.
2002	Autodesk buys Revit.
2003	GC (Generative Components) developed by Bentley Systems, a BIM platform that focuses on parametric flexibility and sculpting geometry that supports NURBS (non-uniform rational B-spline) surfaces.
2004	Revit 6 update makes collaborations on one integrated model easier for larger teams of architects and engineers.
2006	Digital Project released by Gehry Technologies which was similar to GC.
2007	Autodesk buys NavisWorks.
2008	Parametricist Manifesto invented by Patrick Schumacher.
2012	A format is developed by Autodesk which is an application that enables the conception of a BIM model on a mobile device.

1.2 Bill of Quantity Workflow

The concept of trade associations started to emerge in the United Kingdom at the beginning of the 19th century, it is worth noting, however, that the firm Henry Cooper and Sons of Reading was technically associated since 1785 [4]. Before the term "Quantity Surveyor " was introduced and first used in 1859, the terms "Measurer", "Custom Surveyor" or " Surveyor" were used.

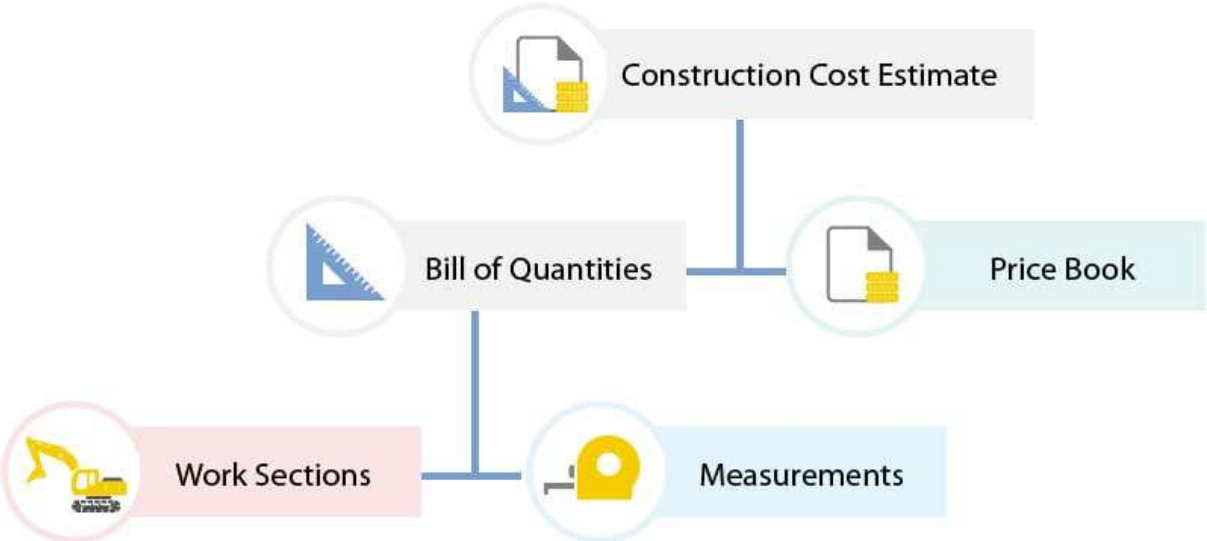


Figure 2. Quantity surveying workflow [68]

The modern-day quantity surveyor is considered a primary master tradesman, as they tend to the tasks of post-compilation, constant tracking of deliverables, and Final Accounts to the client and the building owners. As a result of these increasing duties, quantity surveyors became vital and essential, and it became common practice for building owners to have specifications [5]. A procedure was established where the clients would approach the architect to design a building or a project. Drawings and specifications were given to be chosen by master builders.

The purpose of defining an accurate estimation of the price or tenders is the measurement of the quantities and materials and labor work which are essential to executing the work. For instance, when preparing a BOQ, as all engineers must have preparatory bills and documentation for each project, it is more beneficial, economically, to have all of said documentation processed as a batch by one surveyor, who measures the quantities for each project individually [5]. This is done to distribute costs and facilitate sharing the information of the quantity surveyors, obtaining closer estimates to the original bill of quantities and prices which will guarantee all parties to be working off of the same background and data.

The client or the owner of the project will conclusively realize that it would be in his benefit and leverage to allocate a quantity surveyor. As a result, the professional expert in this field can hold consultant status.

1.3 Programming and Scripting with QTO interventions

Programming and scripting in the field need of BIM require a lot of preparation and storage areas to implement commands for developing and programming, as a primary step the proper language to set the work must be chosen. For the purposes of this research, all languages were studied and analyzed however, the three languages selected to be investigated here are PHP, Python, and Java [6].

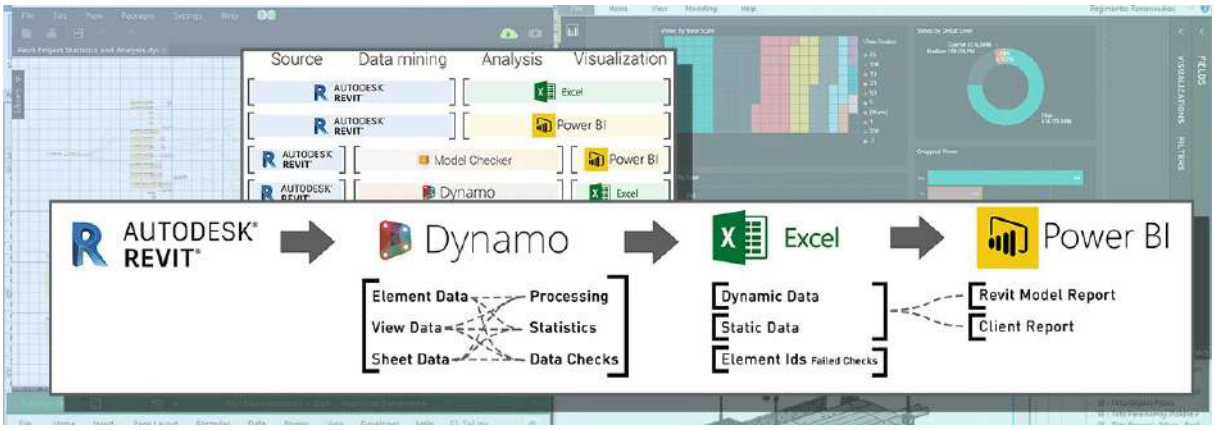


Figure 3. Programming process

Python is one of the most reliable programming languages to utilize within web development, it is also highly accessible as users do not need to concern themselves with syntax, which is integrated automatically [6]. It is a highly suited match for web-site development. This language was recently updated to match current modern technology in 2019 (python 3.8). It is also used in machine learning, slowly becoming a major tool in that field. Statistics and research show that python continues to grow and develop, steadily matching web and computer technology [7].

PHP, on the other hand, is considered better for server related functions than other languages. Moreso, even, when programming on MySQL. Most projects will require some personal tailoring of the database, however, as it will eventually rely on said database. It is worth noting that a new version, PHP 7.4 is scheduled to be released soon [7].

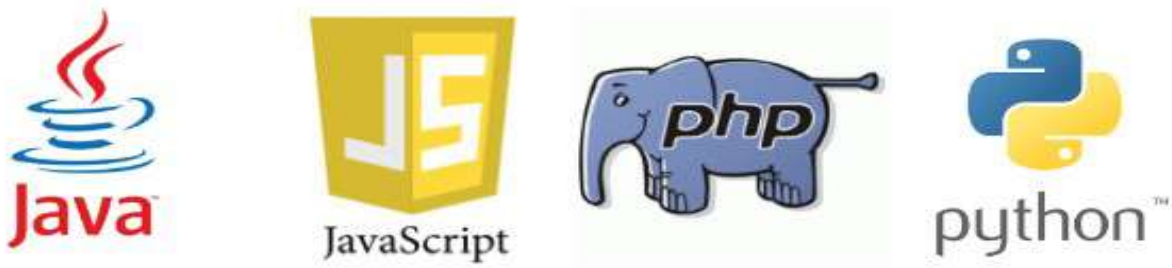


Figure 4. Common programming languages

Java script is a back-end development language and consequently is not as good as PHP and Python, since they are front to end. This is further compounded by a lack of steady improvement for the software.

It is however recommended for use with Autodesk Forgue Viewer. From a practical point of view, unless developing a messenger (such as a server bot for instance), the language will not need to know the JavaScript for BIM purposes, but it remains well known in programming in general [7].

Python was considered a reliable source to generate and develop a plugin on Revit since it will quickly acknowledge commands [7]. Moreover, its availability to have direct and indirect access through the whole process of the plugin with any forge interfering. Applicability is easier than any other language since recognition will be less encrypted to be processed into commands. C# for Revit and engineers with the focus of BIM management, Architecture, and MEP to customize plugins. It was highly recommended C# to be used for such a project due to its versatility and applicability in other fields of programming. On the other hand, Revit's APIs are based on .NET so all languages can be used in that platform. Therefore Python is preferred over C# [7] [8].

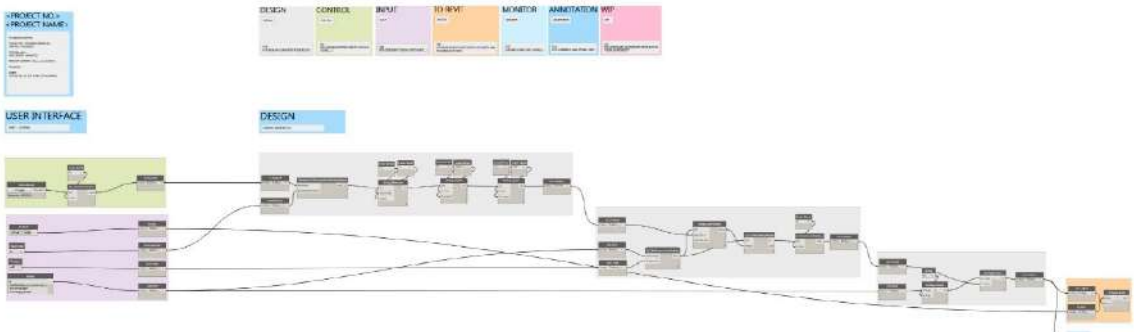


Figure 5. Dynamo interface

Dynamo is a convenient tool as an alternative to coding. It is a powerful tool and it is easily adapted and its commonly used. Regular nodes fir at the primary level of Dynamo. Several nodes are increasing vividly with new versions that meet the Revit Autodesk Revit margin. Intermediate level users can assemble work that is created by others and easily diagnose the error and fix the issue. Codes can be translated into nodes. Thus, the user can design all the scripts and commands at the highest advanced level. The codes can be written in python and get access to the API. In conclusion, it would be considered as easier access to reach the same level of programmers who hate scripting without any graphical interference [8].

Regarding the quantity takeoffs that are considered important in the industry, there is some confusion over the processes entails. For instance, most conclude QTOs are referred only to material estimation, or the process simply contains reviewing the project set and plans (model) and then quantify information about the physical materials that are specified by the engineers (architect, engineers, or draftsmen). This is only one partial part of the project that will lead to others such as estimation, analysis, and tendering [9]. This process is technologized and processed in BIM models in reliance on the additional dimensions of BIM.

1.3.1 BIM Renderings (Virtual Reality and Augmented Reality)

Augmented reality (AR) is the technology that makes you visualize and have to replace the attributes in Computer models that are created in CAD of BIM. It can be within the computer or with external hardware such as VR goggles and 360 cameras. The experience in working in such software gave a revolutionizing product which combines the team of innovators that has leveraged limitless possibilities on augmented reality, virtual reality, or combines reality [10].

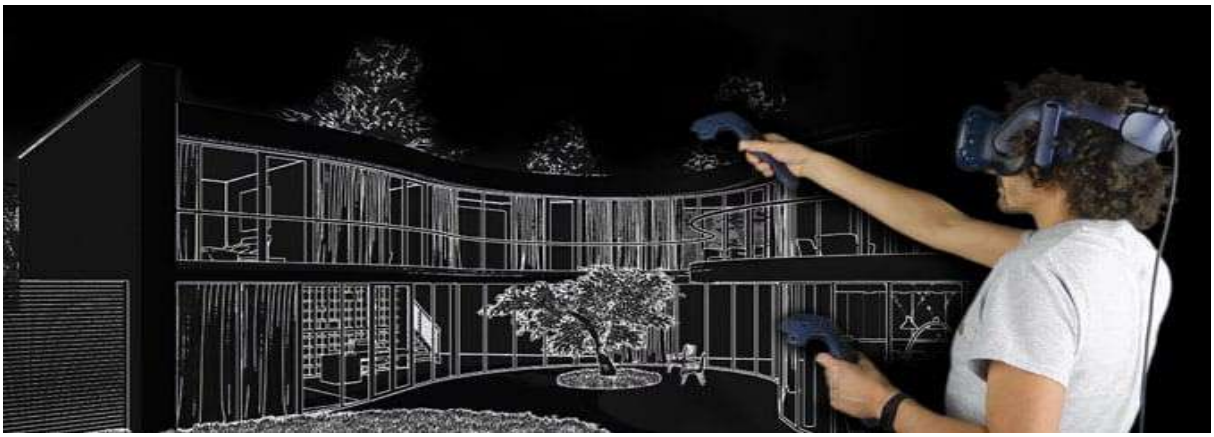


Figure 6. BIM VR rendered model output to user [69]

VR and AGR are considered the final phase of the project design for architects and engineers. Taking into matters BIM360, Revit, and Navisworks models into Virtual Reality is not an easy task. If the Unity Platform is used. Conclusions, it will be used with the AutoDesk forge (AR/VR) tool kit. Although C# is highly recommended programmers recommended python since its more useful to analyze and be easy to use out of the current platform for modifications and enhancements. As well as an easy interface [11].

1.4 RIBA (Royal Institute of British Architects)

The Royal Institution of the British Architects was established in 1834 for advancements of civil architecture in the united kingdom, as well as promoting and enhancing the knowledge of engineering and architecture. Therefore, the Royal Institute of British Architects became reality and in 1837 it was awarded the Royal Charter title [12].

RIBA established a board of architecture education to generate a system of authentication of architecture schools in the UK. The first office was based in London back in 1934, as well as 30 members [12]. 2020 RICS statistics and database shows more than 28 thousand membered pledge the association.

RIBA professional practice is divided into three courses. The final section is equivalent to seven years of academic study and professional experience [13]. The course is based on the knowledge and experience of the student that got gained over the period, it is intended to support and acquire the students the right and suitable skills, awareness, and abilities to show professional competence and integrity. The

course prescribed ay the architects' registration board and validated by RIBA; successful students can apply for registration as architects with ARB and membership for the association.

The practice is provided through a diversified board range of tasks and activities, frequently conflicting demands. All members should be able to detect through the spectrum of legislative regulatory, and commercial constraints [13]. And the ethical act with integrity and provide communicate appropriate and professional service to clients.

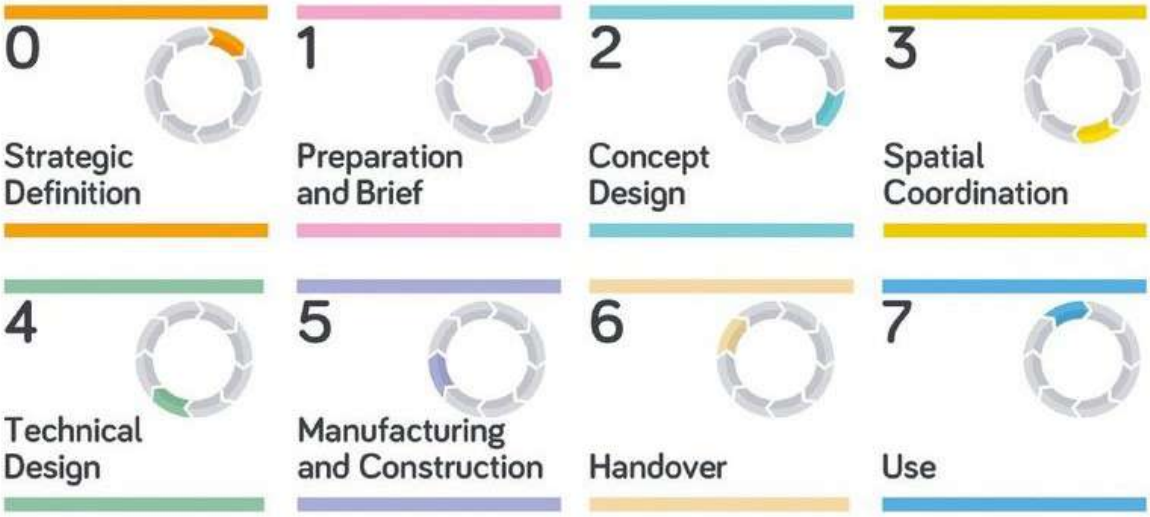


Figure 7. RIBA plan of work

RIBA panel consists of 60 members to direct and manage overall business and coordinate operations from projects, companies, and business point of view [12]. The profession protected the title ' Architect ' by law, for confidentiality and authentication purposes, however, it is not regulated by the RIBA association. All in all, the parliament established the responsibilities are set out for the person to hold the title architect back in 1997 include:

- Perscription the qualifications to become an architect
- Maintaining the UK register of architect
- Guaranteeing that architects meet standards to conduct and practice profession and continuing professional development (CPD)
- Investigation complaints about architects
- Ensuring complaints that are related to architects
- Making sure that only registered architect offer services as an architect

The association does not certify programs at UK schools of architects. the authentication criteria are jointly held by the RIBA and Architects Registration Board (ARB) [12]. And if selected for the validation criteria that statutory duties and responsibility should meet the above criteria for students earning the title 'Architect'. The standard procedure to qualify to practice and earn the title 'architect' in the united kingdom is a combination of an academic degree (minimum Bachelor degree or Diploma) with practical experience. In which earning training for five years at an authenticated school by the RIBA ARB board and the minimum without exceptions of two years experience, and as a last step

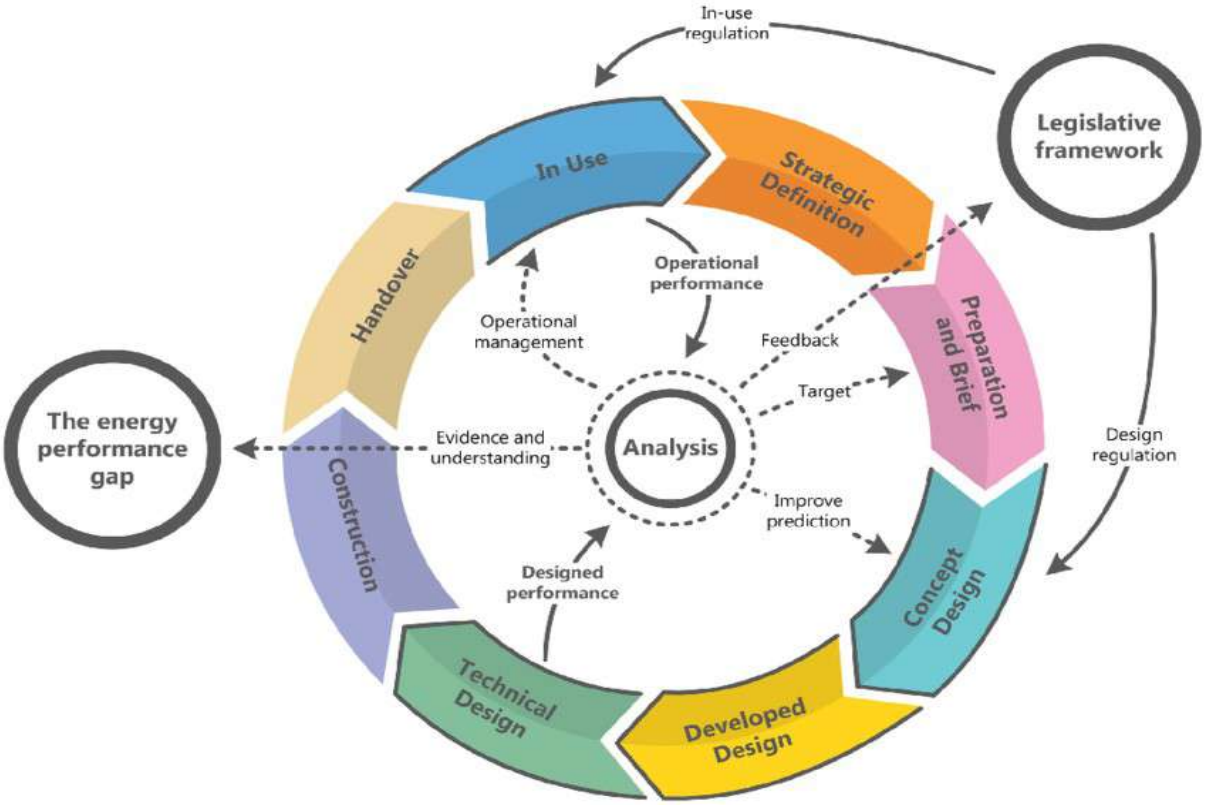


Figure 8. Legislative and energy performance gap framework of RIBA

qualification exam and professional interview.

Standards have a lot of declarations and duties for the status of 'architect' for instance maintaining the professional service and competence in areas related to professional work. As well as discharging requirements of any further engagement with commensurate knowledge and attention. If the architect is not maintaining the criteria required for the title 'architect' the title of 'architect' will no longer be applicable for his profession and association pledging which will be decided upon investigation [12].

To maintain the required criteria of the title. Every member should set at least 35 hours of CPD annually. Last but not least, 'architects are required to maintain adequate and suitable Professional Indemnity Insurance [12].

1.5 RICS (Royal Institute of Chartered Surveyors)

RICS originated back to 1792 where the club was formed [4]. Due to challenges occurred due to rapid industrialization and the higher demand stringent check and balances to control development [1]. The title 'surveyor' is generic that tackles allot of tasks and duties that are segmented with a different broad range of disciplines and activities include management, land, property, construction, and engineering.

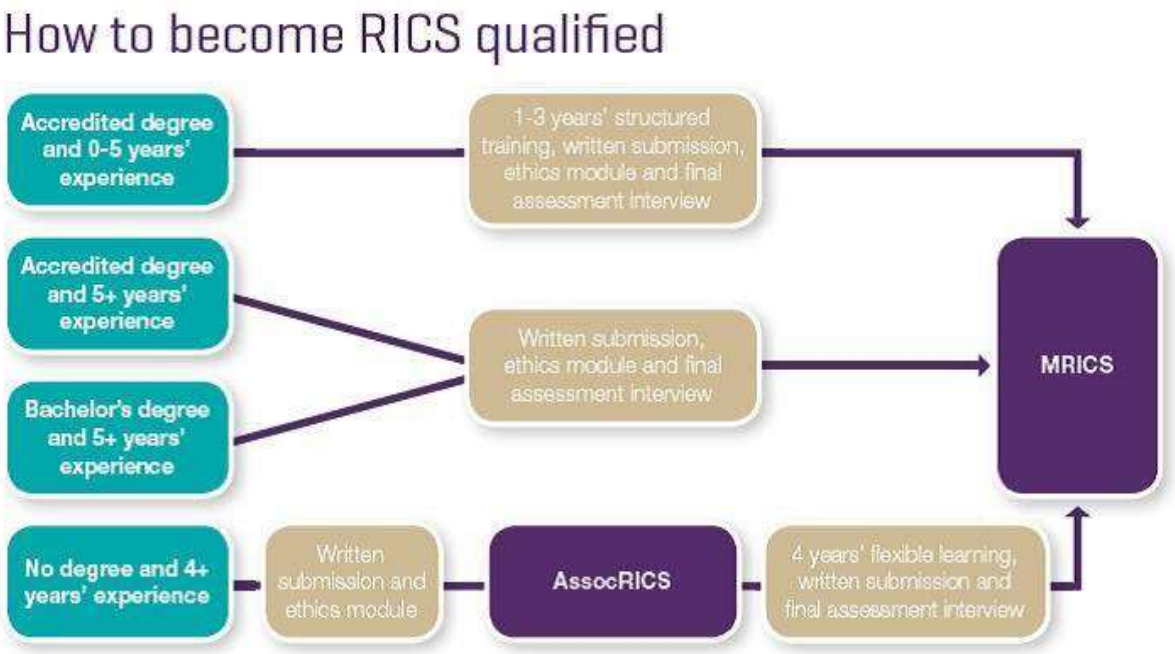


Figure 9. RICS qualifications

The Royal Institute of Chartered Surveyors was established in 1858 and got chartered by the royal charter in 1881. To promote the proper and right use of the profession that both parties be treated fairly and be used as a public advantage in other parts of the world. Statistics in 2020 show that RICS has more than 500 staff and 10000 on the global level. [10] The turnover annually varies above 50 million pounds. Members can use the designation under FRICS (Fellow of RICS) MRICS (Member of RICS) ASSOCRICS (Associate of RICS). [11] A chartered surveyor is a Quantity Surveyor who passed the evaluation of the board and became a member of the club [12].

Members must follow the code of professionalism and meet ethical standards. As well as keeping up with modern technology standards through a program of lifetime learning [13]. The professional is regulated but changes its constitution to ratify the government (UK government).

The chartered surveyor aims globally for this profession to regulate and give exposure to the professional by spreading the profession, Maintaining the highest educational and professional standards to protect the professional, protecting both parties from law manipulation and setting coding standards of ethics and professionalism, and provide impractical advice on analysis and guidance point of view [14].

They also offer services such as dispute resolution services, professional development, and setting fair standards for construction guidance. RICS is operating locally with six locations as well as globally in all important landmarks such as Paris, Munich, Dublin, Tokyo, Auckland, New Delhi, Dubai, New York, Toronto to name a few [15].

Allot of affiliations associated with RICS that increased the footmark of the associations globally such as BCIS, RICS Business Services, RICS Holdings, RICS International, RICS Research foundation, RICS Services, Quantity surveyor association [16].

1.5.1 NRM 1: Order of cost estimating and cost planning for capital building works

Figure 10. New Rules of Measurment 1

The first version of the New Rules of Measurement (NRM1) provides guidance and recommendations on quantifying the construction building work for generating cost estimates and cost plans. Focusing on how to quantify other items as well as other working items such as preliminaries, overheads and profit, project team and design team fees, risk allowances, inflation, and other development and project costs [16].

NRM 1 is the keystone of good and fair management of construction projects. Emphasizing more on enabling effective and accurate cost consulting that is given to the clients, cooperates, and other consultant colleagues that conclude a super-effective facilitated cost control feature.

All in all, can be used for dispute and tribunal purposes that meet the morals and ethics of the profession, and it is highly trusted and relied on in the current construction industry [21].

1.5.2 NRM 2: Detailed measurements for building works

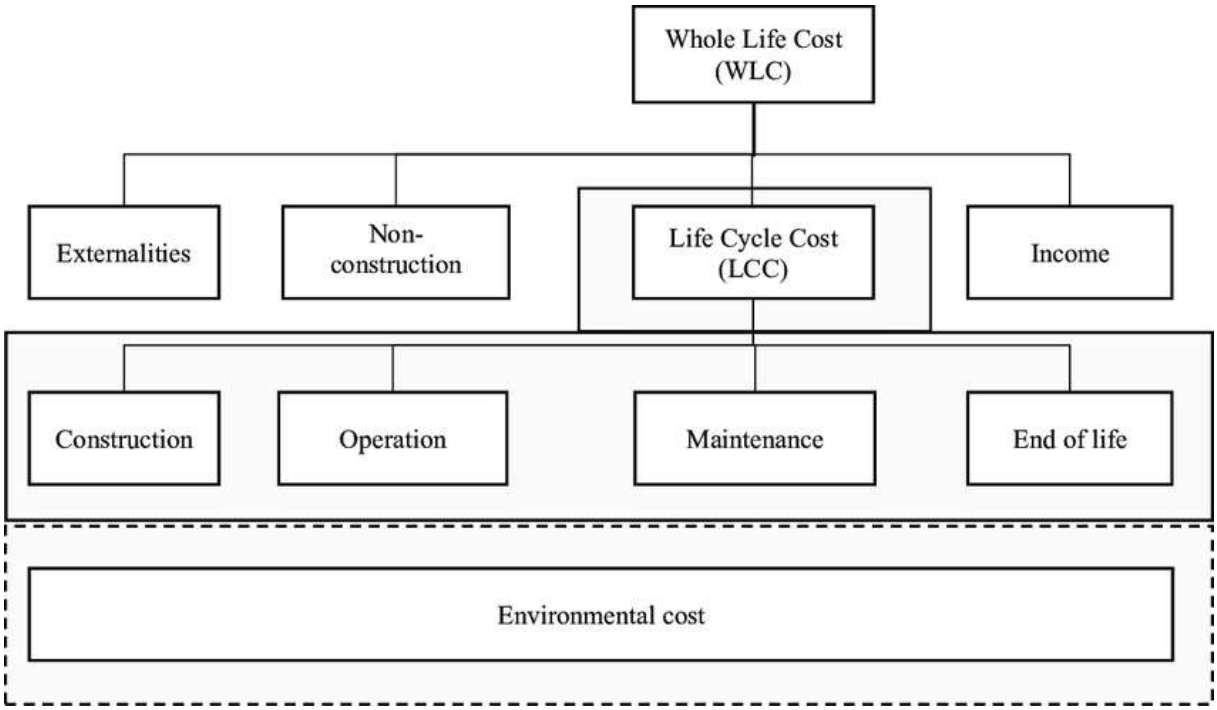


Figure 11. Building whole life cost breakdown [27]

The new rules of measurement authors state in the volume that is mainly focused on the detailed measurement and the proper methodology of building works to obtain a tender price [16]. The rules and regulations work on generating a clear and direct footpath for producing a BOQ that meet the required information for the employer and other construction consultants. As well as dealing with quantification of non-measurable work items, contractor designed work, and risk [17].

The rules and regulations work will be vital during designing and establishing standards or agreed upon schedules of rate. The framework organizes the process of managing and designing building project and administring building contracts, NRM2 Relies on The RIBA plan of work has 11 sequential steps known as RIBA Work Stages, the stages may need to be varied or overlapped to suit the proposed procurement method [18].

NRM 2 is prepared on the expectation that main contractors when they seek tenders from sub-contractors, will issue information about the rules of NRM 2. It shows that any extracts from BOQ should be companioned by suitable drawings [18]. Based on the preliminary specification bill items and description, it was given from the rules of NRM 2. It is also known that the format of the BOQ is a matter of discretion for the surveyors' preparations for the particular project.

Figure 12. New Rules of Measurment 2

It was advised that the items from the individual building should be separate. These will be documented. For instance. Giving different bills for each block, or giving a complex analysis on the page facing that item to be referenced for inquiries. The selection of project presentation is based mostly on a different degree in the form of construction in separate blocks.

On the other hand, if the document, 2D drawing, and BOQ of a specific project are coordinated with the Co-ordinator principles, it is preferred that parts of the Bill of quantities are needed to be generated as the common agreement of work sections (CAWS) Since they are cross coded, they are found in another specification of the project that is published by Construction Project Information Committee (CPIC). To define the accurate nature and extent of the proposed work. It will be vital to give, specification, and information to certain supplements of data, that include limits on tolerance and sequence imposed by the designer [18].

To define the precise nature and extent of the proposed work it will be necessary to give, in descriptions or elsewhere, certain supplementary information, including any limits on tolerances, method, sequence, etc. imposed by the designer. Additional information will be provided to make sure that full clarity of the description is in action. If any doubtful matter occurs, it will give information regarding the quality and location of work [18] [19]. For example, is all the brickwork was on the ground floor level but only some are at the roof level, the professional QS will measure the high and low level of brick and separate them in the bill of quantity to not mix all information regarding the number of bricks needed for the project.

1.5.3 NRM 3: Order of cost estimating and cost planning for building maintenance works

Figure 13. New Rules of Measurment 3

This volume focuses more on the description of maintenance work for the reasoning of the initial preparation of cost estimation and predictions in the preparation phase of the building project [22]. Generically NRM3 mostly focuses on the facility management part of the project in which provides roles and guidance as well to important factors that mainly are not pointed out in NRM1 and NRM2 such as procurement and cost control of maintenance and repair work.

NRM3 follows the same framework and premier as NRM1. It directs and answers questions in the construction phase such as how to quantify and measure other items in alliance with maintenance work. All in all, the volume emphasizes the time value of money, guidance on using the data measured to inform the life cycle of planned cost and maintenance forwarded, as well as VAT and taxation [22].

1.6 Research Methodology

For the following thesis, the work will be based on real-life case studies with the minor intervention of theory and reviews from prior research. A case study will be run under a test to show the final analysis and outcome result of the test in which will be evaluated by professionals. The research will develop during the process of plug-in establishing while comparing with semi interventions such as cost x. Furthermore, audiovisual data with reliable organization tags will be also counted on the research. For this methodology process [22]. The objective was to show all the options for such knowledge expansion on quantity surveying in the BIM world technology on different layers and interventions as well as its impact on important aspects such as time, money, and manpower needed to establish a BOQ whether it was traditional, semi-traditional or technologies style.

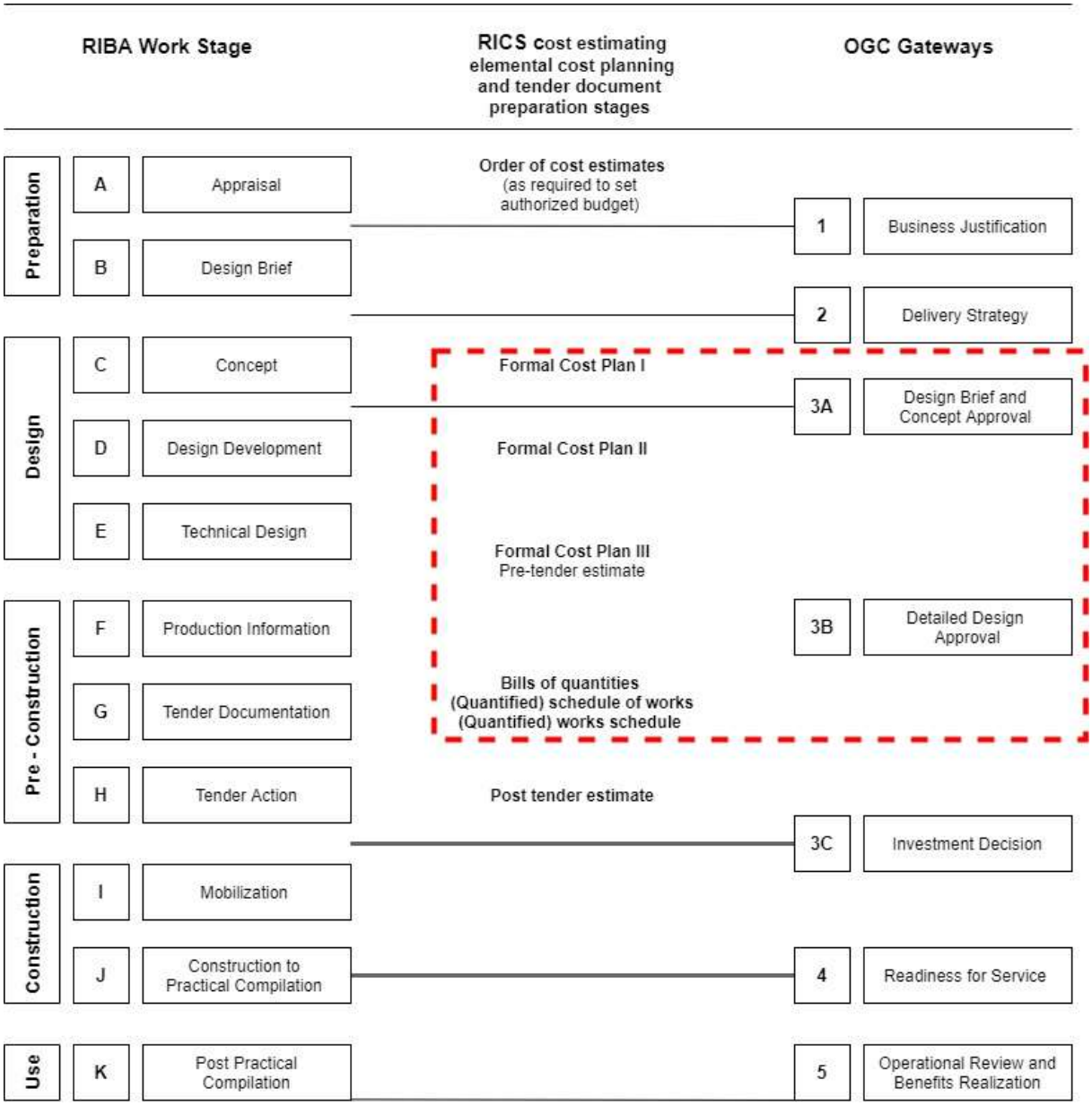


Figure 14. Traditional RIBA cost estimation process [27]

As a start point for data collection, a survey is generated to collect data in a quick, easy and reliable way globally from all continents (from Australia to brazil) the survey will be mostly filled by RICS members that got contacted through the official RICS search engine [22]. It will focus on a lot of aspects that will be a good addition to the BOQ generation such as speed and accuracy and confidentiality. To support the collecting data, the information will be adopted in the process and all matters and comments will be studied and evaluated as well in case the points are valid [22]. Moreover, companies will be asked about the current situation of BIM and RICS status to see if the plugin will be a challenge to integrate or just adapting a traditional style of implementation such as pilot, trial, or parallel comparison. YIN (2008) states, for the search methodology, multiple situations being the most consistent process to fully acknowledge the approach of the situation from reality and analyze the pros and cons of the matter. The use of multiple case studies is not the ideal approach from a general point of view, however, in this

thesis it is vital and essential to compare more than one case study to make sure that the information is replicated and accurate for all points of perspective. In case there is no replication and the information varies from one case to another, it will be important to further investigate the matter and edit the skeleton structure to meet such standards and matters [22].

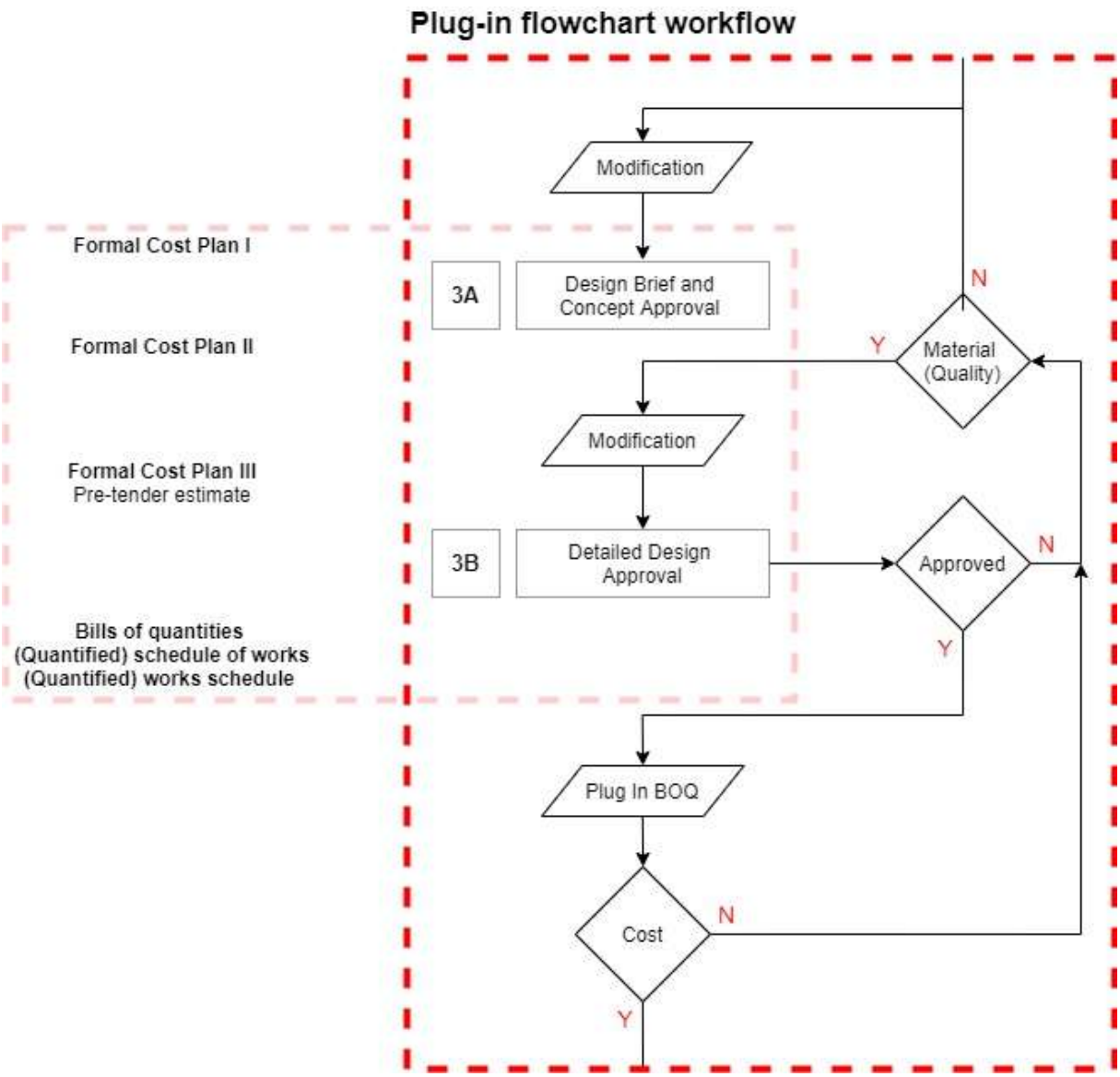


Figure 15. Proposed alternative solution from traditional with plugin

The survey is piloted on google forms, and the same engine was used to collect the data and provide graphs and statistics from different counties in various Quantity Surveying/Architecture/BIM offices around the world. The questionnaire is segmented and designed as macro and micro usage for case studies and thesis data in general [23]. It was also used during an interview with companies and firms to make sure all the information required is asked and recorded for future documentation. It was discussed during the interview the idea of a plug-in opinion is given for this matter and the concerns given and concluded in the discussion [23]. Taking into account systems used in different countries such as imperial and metric in which it was a big concern that research and conclusions were included in this

research. Researching if BIM implementation in the country will be affected or not for the plus in, depending on different conditions and scenarios shown in my search, surveys, and interviews.

Figure 16. Kazina Building Ljublijana, Slovenia. [23]

A full refurbishment project located in Ljubljana will be used as the primary case study and run all three tests. (traditional, semi-traditional and plug-in) the BIM model has a current and post-construction 3D to show the difference for the client. Other case studies will include current research is done and alternative proposals working with a professional evaluation that will be compared with the final product that this research is aiming for [23].

The thesis takes into account original trials and demonstrations and figures from prior references as evaluated and referenced case studies. By referencing all information of authors and researchers in the references respectively. The thesis will show allot of figures graphs and diagrams that will be generated to further explain and deliver the data to the user without any misunderstanding or information clash.

The appendix will be added in the end to reference or show any templated mentioned and used in the research and programming phase of this thesis. Moreover, the index of the acronym is added at the beginning to provide users of a small dictionary of all the acronyms that are used in the whole research thesis to make sure all information is clear and unexplained terminologies, acronyms, and definitions that are not known by the user [23].

2 IMPLEMENTATION OF THE THIRD DIMENSION OF BIM AND THE FOLLOW UP PROCESS OF FORTH AND FIFTH DIMENSION

The construction world is constantly undergoing changes that are revolutionizing the process of building construction and design. BIM, as mentioned earlier, used terminology that was defined in a very different way than the current day [24]. BIM started to shape up starting in the early 2000s where it focused on the third dimension as a focal point to set ground in offices and set an important mark that changed all the processes of design.

The next phase of modifying BIM is to focus on the further steps of the building lifecycle such as construction timetables, quantity, and price [24]. The methodology is replacing all traditional styles of problem-solving into technology solutions where it can benefit the client and engineers in all aspects such as time, cost, accuracy, and confidentiality.

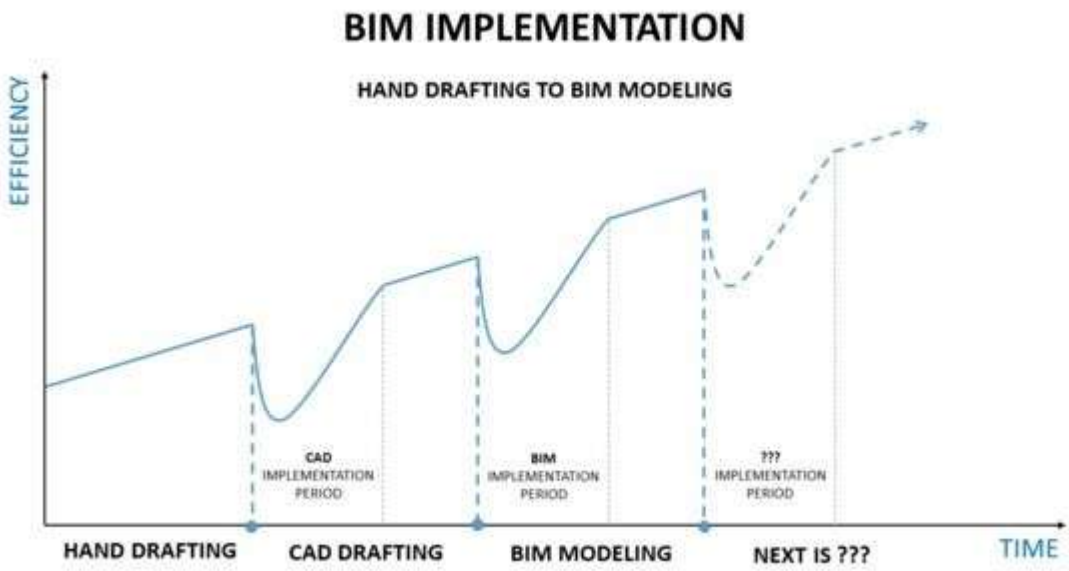


Figure 17. Time and efficiency comparison with all implementation [70]

Time is important in the process of construction and design. Taking into account all matters (scope, cost, and time). It will cost the client more if there are more engineers included in the project.

For instance, based on a survey held at the University of Brown, USA, researchers found that the average hours worked per project during the design phase were circa 600 hours back in 1980 – 1990, meanwhile, the average hours worked per project during the design phase have been closer to 300 hours in 2010-2020 [24]. This shows a 50% reduction in work labor that would be beneficial for the firm and the client, since the firm can calculate and allocate other engineers to other projects, in that way increasing the profit margin of the firm.

Cost-wise, BIM is considered a costly yet beneficial investment in the long run, as purchasing a network of new generation computers that can handle the large file storage and complex network of BIM cloud collaboration of the office is required [25]. This is in addition to training employees on BIM software such as Revit, BEXEL, and Bentley, depending on the country, firm, and clients selected.

The accuracy margin is very thin when using BIM software since all the numbers are run through the computer [26]. The numbers will be highly accurate, allowing the quantity surveyor to reduce the order material error percentage from 5% to 1-2% [25]. Adding to the positive aspects, it helps achieve a sustainable goal considering the importance of minimizing waste in construction sites.

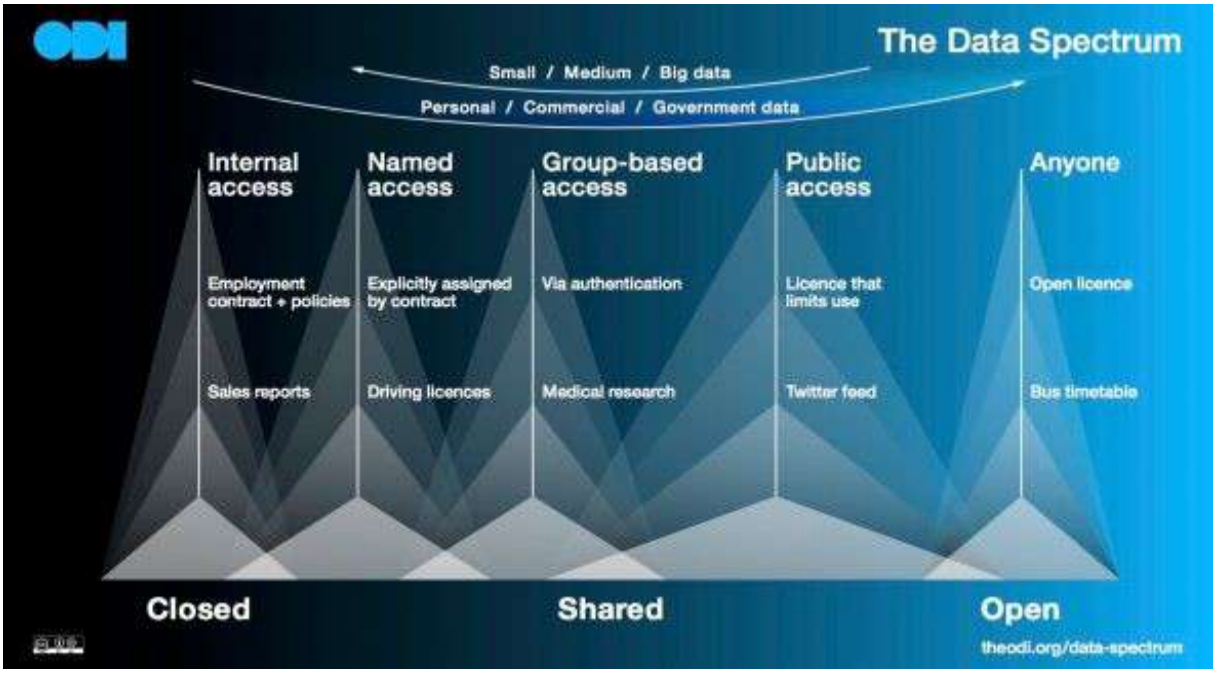


Figure 18. Confidentiality spectrum applied by most BIM projects [71]

Confidentiality is an important issue currently in BIM technology, where many firms are afraid of pricing issues to be published or extracted from the model, making the BOQ competition between contractors increase, and making it harder for the board panel to take their decisions. This is directly related to the company and client matter where the data is hidden and saved for the approval or denial of the selected contractor for the process of starting the project [25]. It was definitively confirmed that the accuracy margin will increase when the confidentiality matter is made 100 translucent and there is no leakage of pricing and data generated by the master quantity surveyor of the project allocated by the client and the engineer [25].

2.1 The traditional style of Quantity Takeoff

The traditional style of quantity takeoff is considered the most suitable in our modern days, considering the fear of intervention technology where information can be leaked and the work appears not reliable to win the project [24]. The traditional style does not have any technology intervention, the highest extent to which technology is used and emphasized on the project is to extract accurate measurement from the AutoCAD 2D plan. Furthermore, most companies use Excel sheet templates where they only add measurements and the master price of the item with a minor specification.

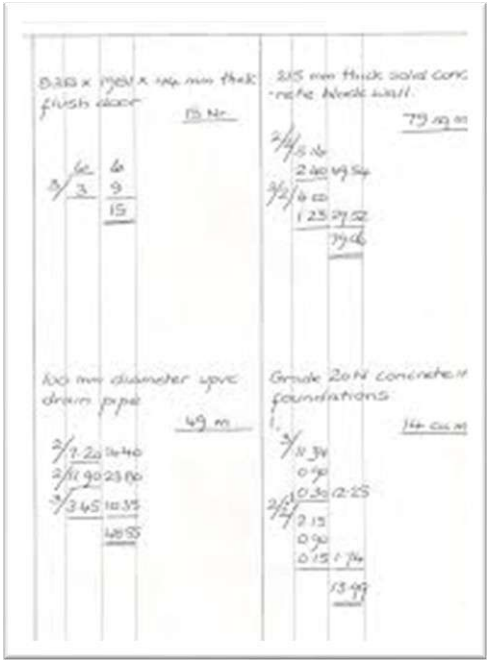


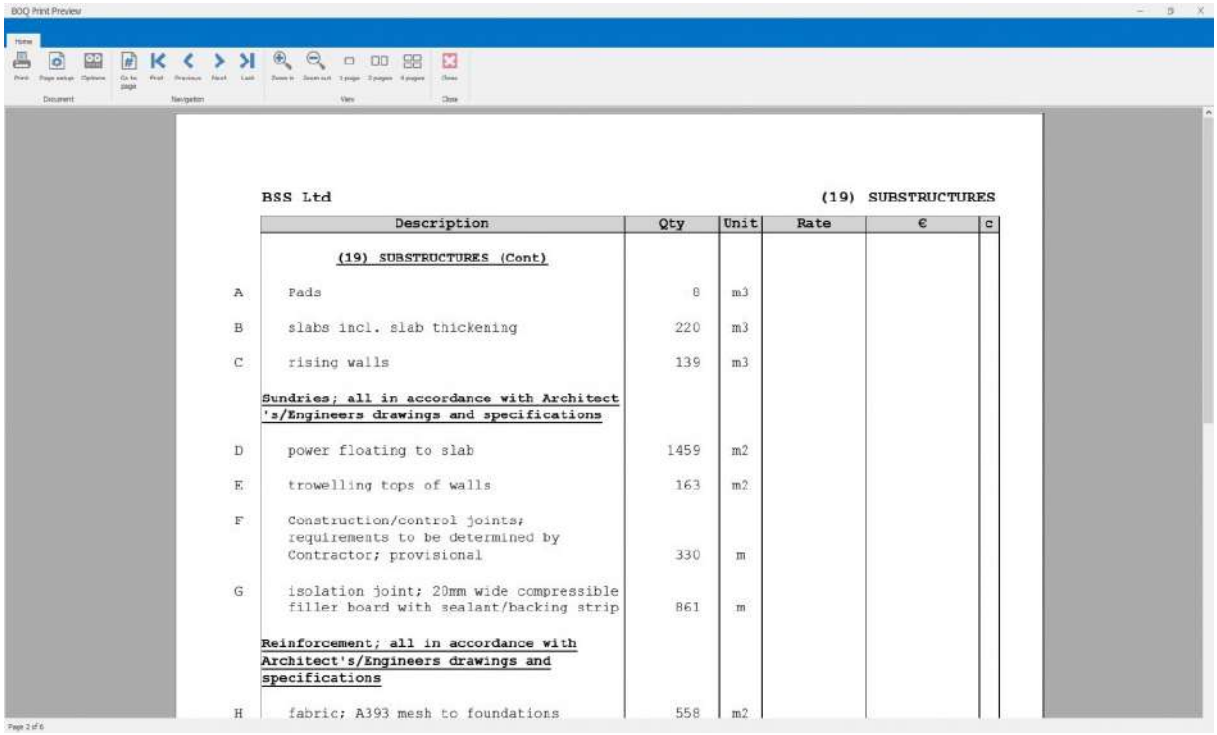
Figure 19. Traditional manual Quantity Takeoff [27]

In short, 'taking off' usually involves data determined and identified from project models, drawing, and specifications. Primer-wise for the reason of elaborating and understanding construction cost [24]. As a noun, 'takeoff' also references the actual quantity lists that are established and generated by the process of the take-off. It shows the progress and the development of detailed and accurate cost estimations from early phase projects. Taking into account providing a degree of design and information being made available.

Quantity 'takeoff' is an essential part of the cost estimate. The cost estimate must be accurate since all elements of the design data provided by the available engineers, architects, and designers rely on it [24]. Using the appropriate automation methodologies is advised and recommended. Completeness is crucial and vital in all estimates. An accurate and complete estimate is established by the accountability and creativity of the cost engineer (commonly known as a Quantity Surveyor). Thus establishing stronger estimation reports and analyses. The contingencies reflect the estimated confidence [24].

The material specification in the project is simply defined and elaborated upon in the drawings of the project. The cost estimate must check and evaluate each sheet provided by the engineers to calculate the number of materials and record the quantity and the number of units measured in the project, whether it is customizable or not. Each quantity surveyor must generate a system of QTO to ensure a lack of omitted values that are calculated twice [25]. The data is processed over a checklist of work that helps reduce the probability of replicated and forgotten data that the estimator may have overlooked. Another important aspect is calculating the percentage of waste for these items, where waste is mostly going to occur after construction. The material take-off is important in the project and this phase to be more specific to allocate and calculate the right experts and labors for the tasks and duties for the project and

in the right time, duration, and the right equipment needed to be added to the quantity take off for the contractor's section, and potentially to the subcontractors depending, on the situation and the case presented by the office and the client. [25]



BSS Ltd (19) SUBSTRUCTURES

	Description	Qty	Unit	Rate	€	c
	(19) SUBSTRUCTURES (Cont)					
A	Pads	8	m3			
B	slabs incl. slab thickening	220	m3			
C	rising walls	139	m3			
	Sundries; all in accordance with Architect 's/Engineers drawings and specifications					
D	power floating to slab	1459	m2			
E	trowelling tops of walls	163	m2			
F	Construction/control joints; requirements to be determined by Contractor; provisional	330	m			
G	isolation joint; 20mm wide compressible filler board with sealant/backing strip	861	m			
	Reinforcement; all in accordance with Architect's/Engineers drawings and specifications					
H	fabric; A393 mesh to foundations	558	m2			

Figure 20. Final BOQ before printing hard copy [27]

After the scope is processed, the analytical analysis is formed, broken into tasks, and finally dutied by milestones, each task is quantified before the price is inserted [27]. Both accuracy and pricing quantity are highly emphasized [25]. Quantities should be justified in standardized units of measures and be consistent with design units. 'Takeoffs' can be provided by others in the assistance of getting prepared in support of cost engineering (QS); the QS is responsible for the accuracy and preciseness of the quantities. A clear distinction should be made between 'net' quantities in negligence of waste versus quantities that should include waste or loss percentage of the item on the construction site. This is vital and essential to make sure duplication does not occur within the final estimate that will be given to the decision-makers. The detailing of the quantities which are prepared for each milestone or task is dependant on the level of detail. These calculations, beyond design details, are usually important to decide a reasonable and logical price to complete the scope of work with a proper budget and cost estimate. For instance, fabrication waste material would be a waste cost on the project after its use, thus having a high percentage of excess material that cannot be returned or used in other projects professionally [25]. Project notes will be added at the suitable range level in the estimate to elaborate and explain the basis of the quantity calculator, to clearly show the assumed quantity allowances and contingency quantities, ss well as to archive records of quantities decided by QS. The judgment can then be reconciled on refinement. Usage of the recommended guidelines in quantity development –

coordinating the QTO process and plan with the QS estimator of the main project and responsible for this scope. Last but not least, guaranteeing full project scope is reflected and matches the appropriate estimate. This includes the list of materials in the specification takeoff sheet that will be later generated to a BOQ and a reference to the project and site engineers.

2.2 BIM and Quantity Surveying

As seen in the modern construction era, the industry has and will be observing the changes and adapt to different approaches if they have benefits that outweigh its negative features such as time, money, and accuracy [5]. As mentioned prior, traditional methods of quantity take-offs from construction plans are done by extracting the data from drawings from architects, structural engineers, civil engineers, landscape architects, electrical engineers, mechanical engineers, and plumbing engineers. Under such an approach, estimators pass through all sheets and drawings and determine the number of materials while making sure not to get any duplications - which as indicated and shown in the reports, is the most time-consuming task in the process and cannot be set under any specific timeframe, since it varies from one project to another, as well as from one engineer to another [24]. In current times, many companies have been hesitant to invest in BIM since they are afraid of such a huge change from the traditional method that has worked for so long; 75% of the firms indicate that it is risky to invest time and money into new methodologies since it will take time to train and teach employees new software and purchase new computers to meet standards of the practice [24].

BIM is, despite this, beginning to trend and becoming very popular among construction contractors [24]. Based on the Autodesk report survey, between 2006 and 2007 AutoDesk license requests and certifications are doubled. And the popularity is growing on a big rapid scale. BIM is still not fully implemented and executed. Based on studies and publications by Sandeep Langar and Annie Pearce in 2014, the majority of architecture firms and construction companies surveyed were still not using BIM, although they know the pros and cons of BIM methodology and how it would benefit the firm and be less time-consuming. 70-90 percent of BIM licenses are adopted by architecture firms [25], and most architecture firms are considered small firms (1-10 employees). The research has also revealed that construction companies that have implemented BIM are generically international firms; and the biggest draws are currently for visualization and constructability purposes [24]. It also shows that firms mentioned the motive and interest of using software if generated that focus on estimation and cost control shortly in reliance on BIM.

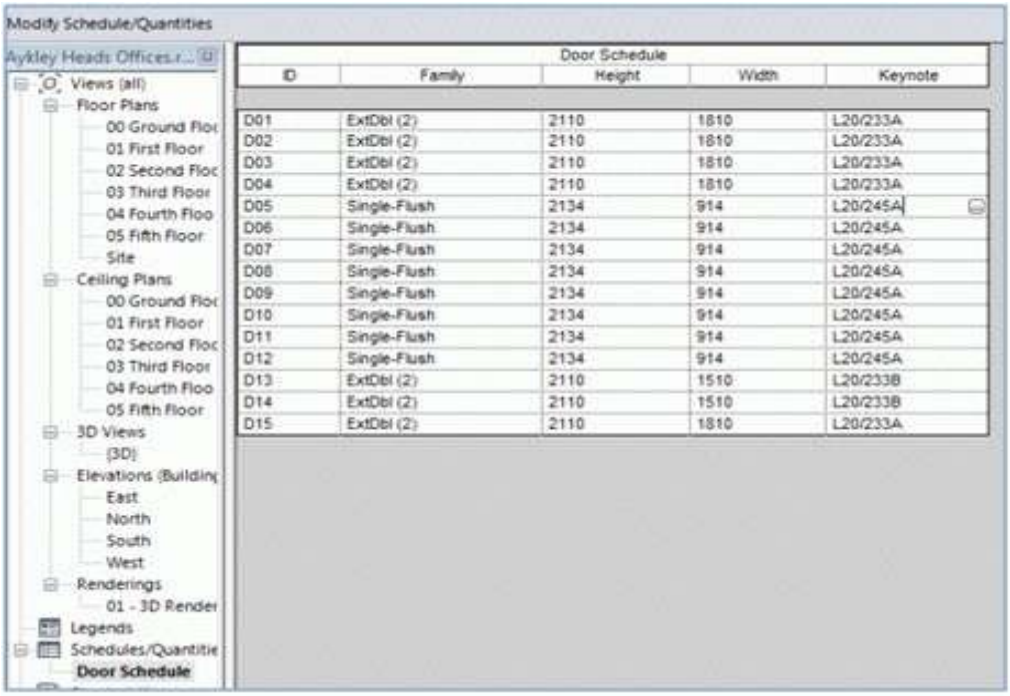


Figure 21. Door schedule extracted from a BIM model [72]

Alternative reasons suggested for BIM not being fully piloted and tested in the industry include the training needed to let employees recognize the approach in the proper professional manner [28], as well as upgrading the utilities and software, and the fundamental change in the data process should a firm adopt BIM in projects [25]. Another obstacle is also faced in the construction industry from a legal point of view, where the uses are addressed on how it is defined, on the scope of contact. The issue lies informally incorporating BIM into the contact, where its use is restricted to less essential activities such as marketing and coordination. In a survey conducted online by the University of Cambridge, questioning designers and construction professionals, a majority of those surveyed agreed that the generification of BIM models should be the duty of the architects. These participants also stated that models do not constitute a contract document but are rather used in project coordination. Moreover, if projects are processed in 2D plans and 3D models, the 2D plans are always governed in disputes over the 3D model plans [25].

In common construction contracts, both parties should agree on the level of detail of the model that one of the parties should deliver to the other. This is commonly known as LOD (Level of Detail). The elements in the model are graded and ranked on a scale of LOD 100 to LOD 500 in multiples of 100. LOD 100 has a graphical representation of elements represented in an abstracted generic figure, while LOD 500 contains an element with size orientation, shape, and the quantities of every single item needed in the project. LOD 500 is the most suitable model to be used for a highly accurate price estimate while LOD 100 is used for preliminary generic price estimates [25]. LOD 100 estimates are usually plotted in accuracy between 10 to 15 percent. Unit price or final estimates are highly detailed and prepared near

the end of the design process in most cases and can be accepted with an accuracy rate of 3%. In traditional methods, material quantification can be 50-80% consumable of the QS time [26].

BIM models have proven, on numerous accounts, that they can reduce time requirements since the estimators can easily extract accurate measurements and material specifications with guaranteed quantities directly from the main model [26]. Many types of BIM software have been integrating the Bill of Materials (BOM) feature in the software that assists with the procurement of materials. The reduction in time spent on such matters was 80% while providing Quantity take-offs and estimates that are highly accurate and meet the RICS standards (3%).

Statistics suggest that more than 75% of engineers and architects, whether working in firms or freelancing, will change and switch from AutoCAD to BIM in less than 5 years. [26] It can be deduced that this trend will continue, as shown in the National BIM survey (NBS), where surveyors noted an increase of respondents who stated they have worked on at least one project with BIM adaption. In comparison, back in 2013, only 39% were reported to have used it on a project, while in 2014 some 54% of those surveyed did [26].

2.3 The future of QTO with BIM

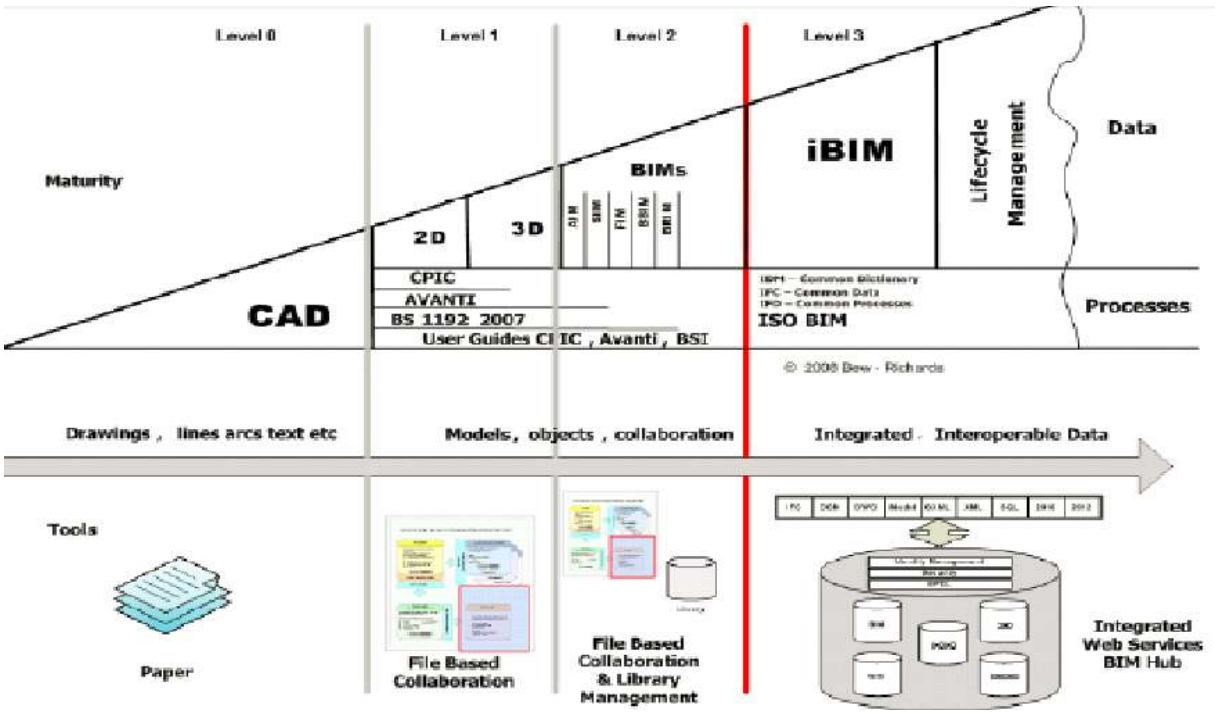


Figure 22. Evolution of Quantity survaying in construction technology and BIM [73]

The engineering and construction industry is growing fast, with little in the way of evaluation and reflection on new technologies that are introduced and worked upon by experts [27]. Some of the new methodologies and approaches seem to present a remarkable addition to the process while some are making it more complex and time-consuming.

Baxel Construction Ltd hosted a conference and discussed some of the new technologies, focusing on resolving the issues related to the effectiveness of the QS coming into the 21st century whilst integrating BIM and Quantity Surveying, and the present pros and cons of IT innovation with BIM compared to QS on its own [27].

Danny Frost, an expert in the field, states that he has been part of the industry of engineering surveying for more than 30 years, and during this timeline, there have been significant changes in the roles of Quantity Surveyors, with BIM technology threatening to replace the professional with programmed algorithms that will render the career as a whole obsolete. For instance, QS used to perform the calculations manually and then transitioned to the use of calculators, excel sheets, specific software, and again is expected to fully transition to BIM powered processes expected at the end of the century, with benefits such as instant folder transformation and the expectancy of high accuracy of measurements taking into account the replacement of labor calculation with supercomputers [28]. Having already made significant progress, BIM still appears to possess the potential to continue to change all of that in the future.

As expected. and endorsed by Microsoft, Bimcreator will soon be releasing their next 3D Design product, “once a giant moves into this space, things will change [29]. Those of us who still remember superclass will remember how Microsoft windows and Excel radically changed spreadsheeting and many other things, but we are presently at the Commodore 64 stage of 3D model developing, but radical change is on its way” Bill Gates said in Medicon London 2017.

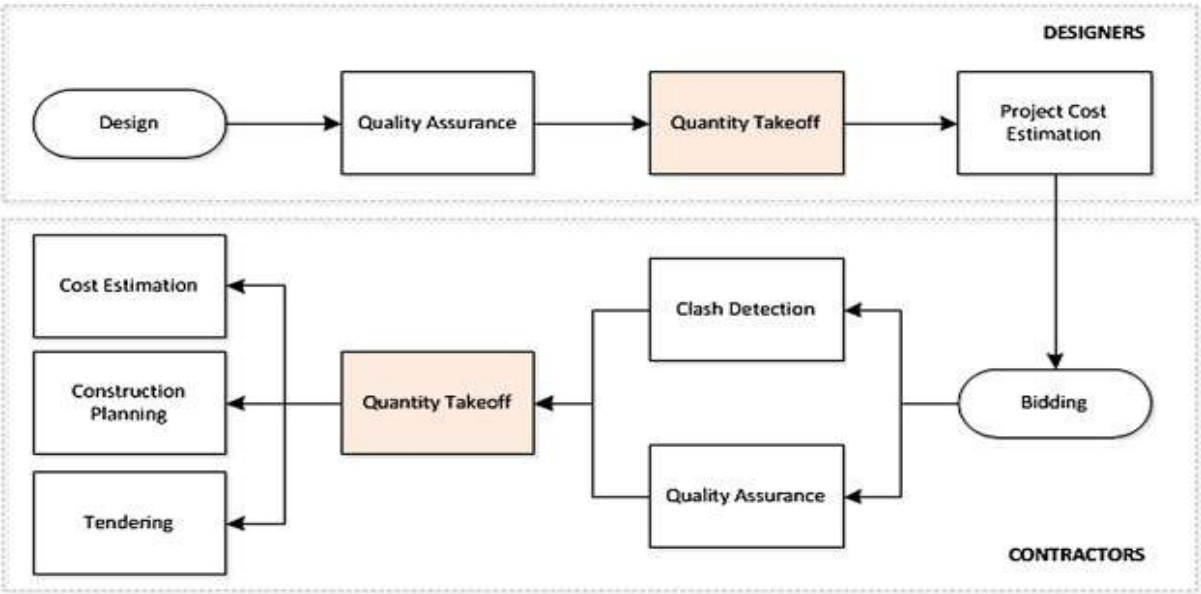


Figure 23. BIM BOQ workflow designers/contractors [30]

In the 20th century, a debate arose as to how construction sites and offices would become processed without papers. It sounded impossible at that time, but today we can see the possibility of those predictions to become reality [30]. This comes with the advent of technology that can consistently

guarantee that accuracy is closer to 100 percent, and it is highly improbable to have errors if all the items in the BIM model are properly defined. However, some companies are not catching the new generation of QS thus it takes time to translate work for companies that already adapted to the ones that still have not.

The role of QS professionals is heading towards management consultancy, where it could become more rewarding for firms and consultancies [31]. This highlights the need for a push to gain the support of this move, for instance making sure big associations such as RICS become part of the revolution and redefinition of the profession, while it seems that it is the end of the path for the profession but it opens other options for growth and progress. These opportunities open the market for Quantity surveyors, especially Autodesk users, for expansion - in which Revit Surveying will be labeled to focusing on the information and tasks allocated to QS.

2.4 Generic Problems that will be faced in the preliminary stages

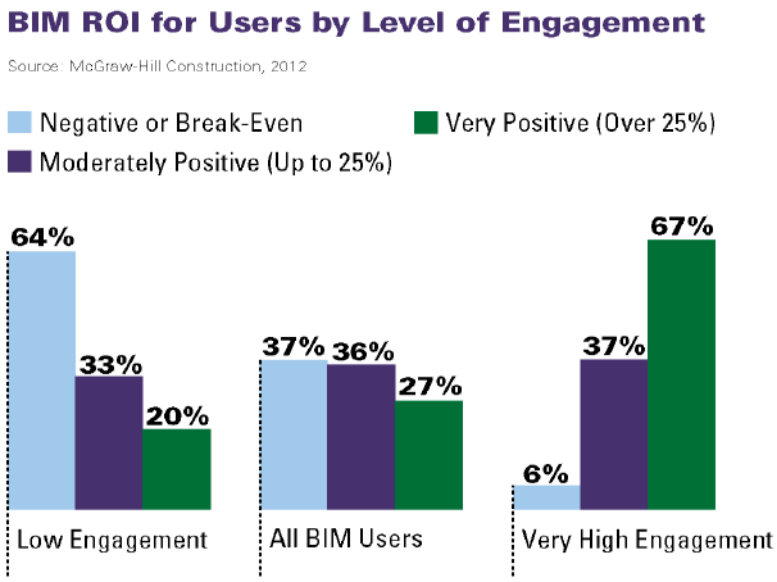


Figure 24. BIM Level of engagement statistics conducted by ROI [31]

The research started with determining the requirements necessary to pursue the research to develop a plugin that will assist in generating a Bill of Quantities that are specified to meet the goals and targets of the project [24]. The main focus is to achieve and optimize the three primary features on a bill of quantity, being time, quality, and cost, in a more modernized approach. These benefits do not come without disadvantages, however; there is much preparation to be done to make this methodology possible and applicable in all firms whether local or global [24]. Several problems, both detailed and generic, will be faced in the process of generating a prototype plugin on Revit but mostly the concerns are as follows:

Firstly, most of the experts in this profession state that BIM is not part of their process to generate documents. Currently, RICS is trying to make the process less time consuming by investing in research on new technology that will support the profession and make the work easier and more accurate with less cost of labor [26]. BIM models can be used to extract Quantity schedules and specifications based on the models' information inserted, not the whole schedule. They would generate a scattered data log that the QS must then compile and reorganize to meet layout standards.

Secondly, measurements are usually where the errors of the model occur. For instance, the outline of the building might differ in calculations if the modeler set the outline of the slab on the interior wall or extended to the exterior wall [32]. This difference will affect the volume of concrete and the rebaring of the structural slab, which in turn will affect the calculations and the quantities of materials for the project.

2.4.1 LOD (Level of Detail) Restriction

The BIM debate is currently centered on the conversion of the working project area that lacks clarity due to ambiguous terminology. To this day illustrations on design software lack clear-cut guidance, not to mention how widely varying implementations appear to be.

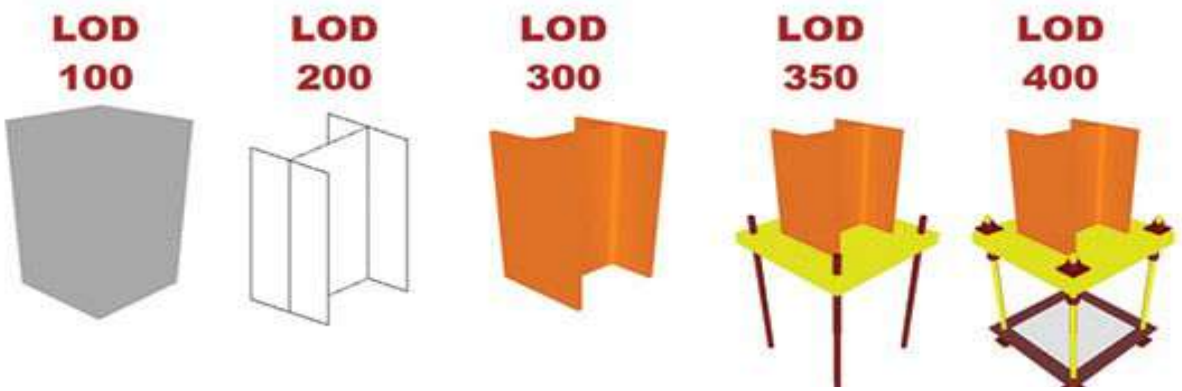


Figure 25. LOD levels [32]

Level of detail is another topic of contention in the construction world, where the majority of projects face disputes in that matter [32]. LOD plays a major role in the accuracy of the Quantity takeoff data that will be generated in the software since the data that is inserted and represented in the model (the item to be more specific) is directly proportional to the outcome. In summary, the more information inserted the more accurate the outcome is.

BIMs main standards and concerns are LOD, users cannot work without defining the level of detail wanted. One can also define LOD as the level of development. Both definitions are important and relevant to 3D design. LOD measures the amount of information provided for a component [32]. A chair, for example, can be just identified as a chair only (LOD 100), a chair with measurements (LOD 200), a chair with measurements and 3D specs (LOD 300), a chair with measurements, 3D specs, and material finishing (LOD 400) or a specific chair from a company that has a BIM model (LOD 500).

Most companies settle for LOD 100, 200, and 300, but by the time the model progresses to the last phase, which is LOD 300, some clients ask for LOD 400 based on the aim and target afterward [32]. LOD 500 is rarely used since the higher the LOD, the higher the cost will be as it will require more labor time.

Another source of confusion when using BIM is managing and meeting clients' expectations. Without the perception of LOD 300, the main question is how the visualized information will look like. A designer can under-deliver or over-deliver tasks and requirements that may not meet or even exceed clients' expectations [32]. This would be a drawback for the process and the profession since it is expected as a minimum to obtain LOD 300 to generate with the data a proper BOQ for the project. Based on research conducted by the University of Coventry in the UK. BIM models with LOD 200 would have a 15% error rate on BOQ while LOD 300 would only present an error rate of 5.3%, and LOD 400 would have 1.3%. The accepted error rate based on RICS standards is a maximum of 5%.

The main concern is to make sure that the model can extract all the proper information with accurate measurements and specifications. Otherwise, it will not deliver promising outcomes and would not meet RICS standards in which case the traditional style of BOQ generating documents is required.

2.4.2 BIM Cyber Security and Confidentiality

BIM technology implementation is becoming more important in modern times. Thus, Hugh Boyes concluded that making sure the proper cybersecurity is employed to guarantee a smooth and secure information flow [32]. From a security point of view, all tasks are focused on countering the attacks of hackers directed at the main model for personal benefit, as well as those directed at prepared and implemented tools that could be used at different phases of the project and cycle.

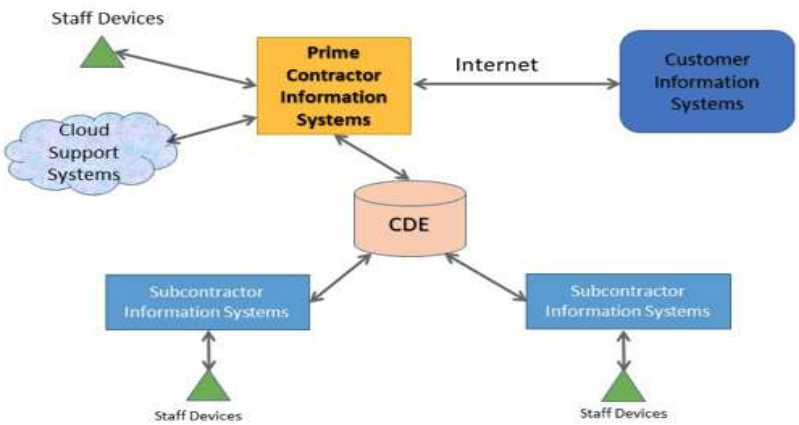


Figure 26. BIM cybersecurity lifecycle [74]

It is therefore recommended to recruit and provide courses to experts in the firm to stay updated with modern technology and be on the line with new information introduced to the cybersecurity of BIM

[32]. It is also crucial to submit emergency reports to the IT department or external security partner as soon as such arise, and take immediate action before any damage or losses can occur.

Most projects related to BIM cybersecurity are not focused on BOQ security, as BOQ generation is not a popular usage of BIM technology. There are several leading motives for hackers attempting to access the BIM model, whether they are for the benefit and usage of competitors or simply to affect the schedule of delivery. Sagiton mentioned that cyber-attacks can lead to total paralysis of a project [32]. Attacks by CDE may include

- Hindering of access to key data by the main team, which affects the time of delivery
- Stealing confidential data, whether to access company/firm secrets or harm the owners if published
- Identity theft of firms and/or their employees, which can affect their reputation and renown

Currently, projects, whether they are on a building or city scale, are created in BIM with many different programs, such as Revit, GIS, and Rhino, empowering the concept of IoT (Internet of Things). In this fashion, hackers can identify gaps and use them for their benefit to carry out attacks on the weak points of the project to access the main hub, with the aims of causing material and non-material losses and even sensitive data theft.

Considerable trials and testing are invested in this issue. An expert from the AEC industry suggested several solutions and proposal regulations targeted at counteracting the threats to BIM technology in this matter, developing a cloud computing system to store projects and documents for a specific project due to construction sectors adopting BIM level II [32].

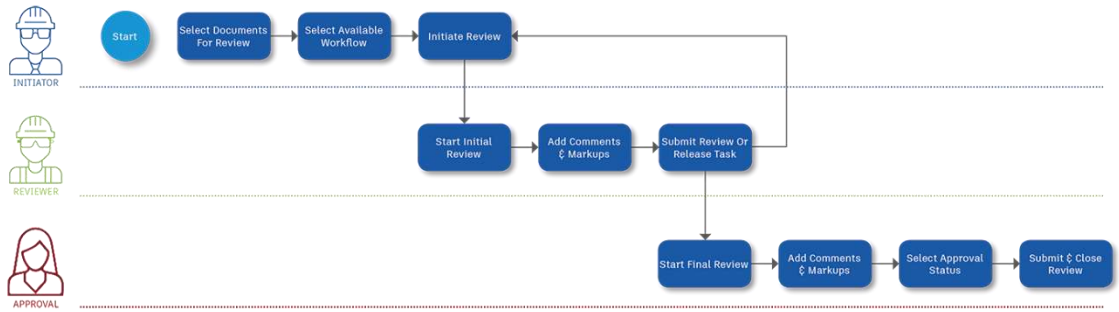


Figure 27. Construction document managment workflow [75]

According to several experts, when planning a CDE, it is suggested that a firm find the suitable matching mechanisms and safety guards to prevent unauthorized access to the project and the system, this is to maintain order and avoid time and data loss.

Finally, it is considered beneficial to use multi-level authentication to create an Identity and Access management system that authorizes monitoring of the project movement of the members in the CDE, to

define their roles and authorities [32]. The BOQ Plugin will make use of such counter-measures to mitigate the risk of data theft, which would prevent damage to the company's reputation regarding reliability. Lose the construction company's liability. The majority of projects are proposed to public contracting companies to submit a cost proposal and priced BOQ, the team appointed by the client and the head of the project will then select the suitable candidate based on the cost accuracy and timeframe.

2.4.3 Clash detection and updated field

Clash detection is a process wherein a built-up asset is examined for the presence of conflicts, these clashes can be spotted easily as early as the designing phase of the project, before starting on site. Experts from a variety of disciplines collaborate to work on several aspects of the project [5]. Using models proposed by an architectural office as a starting point, where structural, environmental, mechanical, and electrical schematics, along with any other schematics if requested, depending on the project situation. Every model has its procedure to arrive at the prefinal phase and will have its range of model items and files. All these models join together to form one main final cloud model to present what has been built and installed, arriving at a Level 2 BIM model (federated) [32]. The model will be situated in a Common Data Environment (CDE), most of the time there will be clashes that need to be resolved

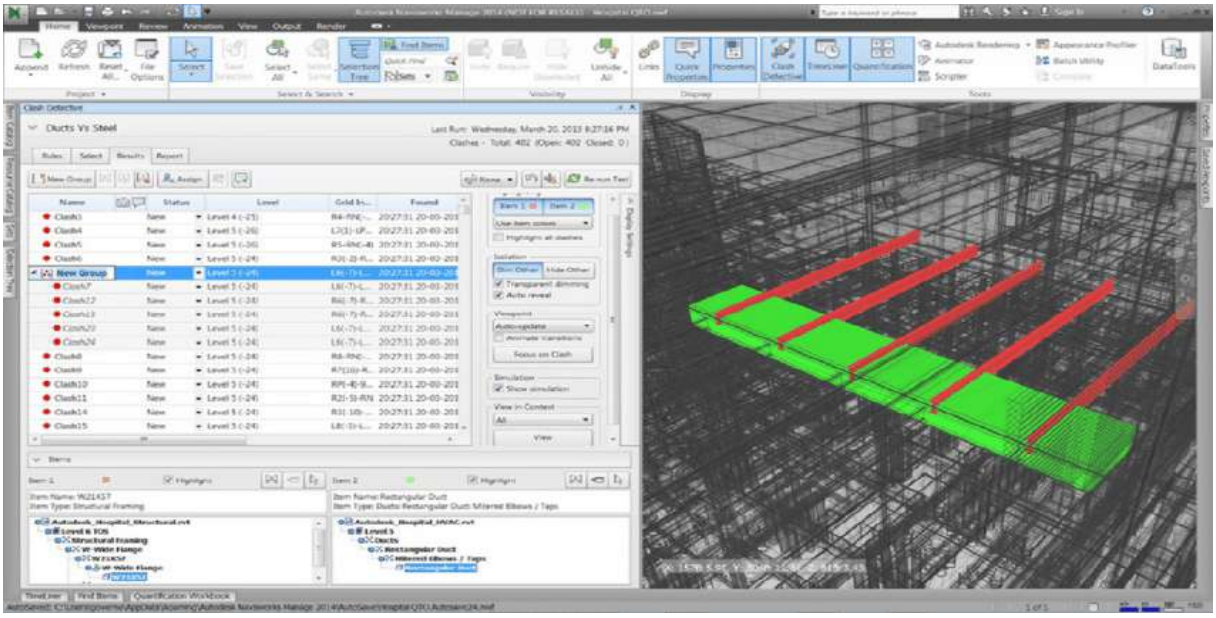


Figure 28. Navis work clash detection

when all models are combined. There are a lot of clashes that are commonly known where two components occupy the same space [26]. This is commonly known as a Hard Clash, for instance, a structural column that runs through an architecture ceiling or HVAC system of the building. If BIM is not used, it will be time-consuming and expensive to find solutions instantly on-site. Soft clashes appear when elements are not indicating spacial or geometric tolerances that are required/breaching the project's buffer zone, for instance, air-conditioning requires certain clearances to allow for maintenance, access, and security. When provided sufficient object data; plugins and software can be used to check

regulations and standards [26]. Finally, clashes that arise from schedules of contractors, the equipment, the materials, and general timeline conflicts are referred to as Workflow or 4D clashes.

Resolving clashes takes place in the main federated model before the construction process, and is the key to avoiding risks and unwanted additional costs [27]. It is crucial to document standards in BEP and set outlines for co-ordination in Employee's Information Requirments (EIR) as part of the agreement for the project contract. Clash detection should always be piloted and tested seeing as a lot of the sub-models or schematics will be amended and changed as the project progresses.

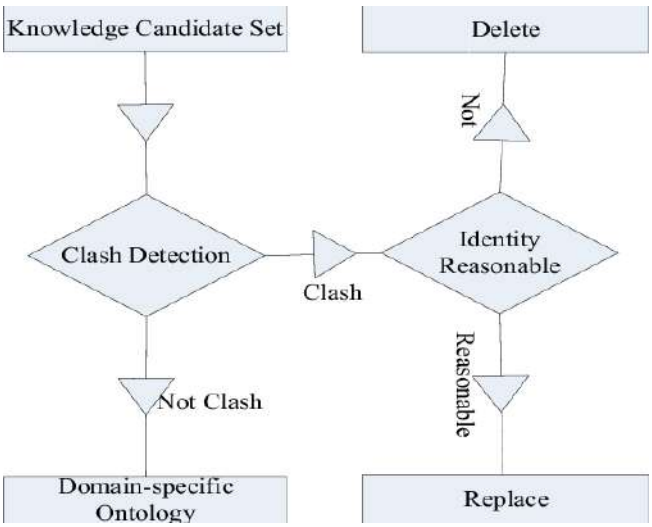


Figure 29. Clash detection investigation workflow [76]

The proposed plug-in will not be as responsive as hoped if clash detection is not up-to-date, since it will affect the readings and calculations concluded in the BOQ, however, this can be solved by regenerating another BOQ after every clash detection and resolution, resulting in higher accuracy [27].

2.4.4 BOQ format and folder forgery

Figure 30. Autodesk Forgue authentication (including Revit) [33]

BIM is still not properly defined and implemented in the construction industry. If it was requested to secure or market the company as a leader in this field of innovative, effective design, it is advised to include the acronym in the companies' marketing strategy or bid submissions of the construction phase. Clients' requests upon BIM increased with the turn of the century. Experts predict that it will eventually become mandatory on publicly procured projects [28]. The steps are taken in tackling legal issues justify how the project's process integrates with the aspects of BIM usage. Consequently, any appointment documents that BIM will take into account have occurred as a necessity from the outset. As an example, insurance is difficult to be addressed unless it is brought up and coordinated from the beginning of the project.

One aspect of legal issues associated with BIM is Intellectual Property (IP) issues. It is wrongly presumed that BIM is one 3D model to which all engineers, consultants, contractors, and subcontractors contribute [28]. That, however, is not the correct terminology, as it mostly encompasses several models, where each is generated by different consultants. These models are referenced and coordinated to generate a whole picture. From a traditional point of view, when constructing with two-dimensional drawings on paper, in the generic position the designer retains the IP rights of the design if an agreement is not reacher, and the employer has a license to use the construction design of the project. This does not differ from BIM; unless agreed upon, each model manufacturer owns the IP rights of their 3D model. Confidentiality is considered a sensitive matter for some consultants or suppliers, as trade secrets and confidential details are of great value to these parties [29].

Confidentiality clauses are incorporated with appointments and building contracts, where the agreements can be signed by all parties. On several levels, both parties must consider how and to what extent the BIM model will be used. Most of the manufacturing and material information must be known in the model provided and explained by the architect depending on the project scenario, and each case on its own. The team and client must discuss to what extent BIM is used - it could be used only in design, 4th and the 5th dimension, or even in managing the facility when it's done, and based on that it will be decided to what extent information should be inserted in the model [30]. In light of the technologies and software available, BIM is considered a seamless process of design by manufacturers. BIM is rarely fully considered from the beginning to the ending of the project. The aim of BIM is not to get entangled with legal matters, but to facilitate the collaboration of all teams together to avoid issues regarding matters affecting the process of generating BOQ's, starting with the quantity take-offs where the data is extracted from the model. The selection of the right contracting company can not be based on forged folders, stolen priorly to understand the company's target, and aim to manipulate the offer and win the bid [30].

3 READING AND INVESTIGATION

Surveys are used to collect data for a specific subject that is described by the surveyor. They describe, compare, or elaborate on matters defined by the data collectors (usually researchers, to gather evidence). This information will be based on knowledge, feelings, values, and behaviors. In the survey done for this research, ways and approaches were considered for the survey to be more easily distributed and filled out by the firms responding to the questionnaire, resulting in a successful collection of data with a high accuracy margin. 160 firms were selected globally for the survey based on their success in the field of Quantity Surveying and Building Information modeling. Some of these firms are investing in research and development of finding alternatives and solutions to combine both methodologies (QS and BIM) to produce beneficial outcomes. It is also believed that respondents, i.e, firms, are clear on what is the aim and target in the industry but not enough researchers are actively studying this issue for this platform to be implemented as mentioned in Gilham. Moreover, as part of the survey's introduction contained a request for support for this research topic, many participants were willing to fill out the survey and emphasized the importance of the issue.

Figure 31. Participating countries in the survey

The survey was distributed equally between continents and countries to provide accurate readings and international evaluations that would be beneficial to the research. The companies were selected from the official RICS firm finder and then refiltered based on whether the firms contain BIM departments and invested in related research [37]. In conclusion, based on the selection process, the search turned up 160 companies from Australia to America. Emails were sent to all firms, fifty-five firms replied, and filled the survey with additional comments. One of the firms agreed to an interview to give a deeper understanding of the current situation of the construction world.

The interview conducted revealed the advantages and disadvantages of the situation, in addition to the risks faced when bringing quantity surveying traditional/semi technology intervention to the BIM world, and generally when implementing the technology in this profession on the whole.

Further research was conducted regarding the current proposed solution for that matter, a variety of programs were found which had the trial of automatically generating the BOQ and the QTO, but these are not directly linked to the BIM model. They require a lot of complex programming and development to do so. The top four programs were chosen based on recommendations and use by a majority of offices globally, whether they are a requirement or the company grew accustomed to them over time.

Based on all this investigation, conclusions were drawn as to where the direction the program should be developed, and the recommended strength features requested to be in the plugin prototype that will be generated.

3.1 Survey Evaluation

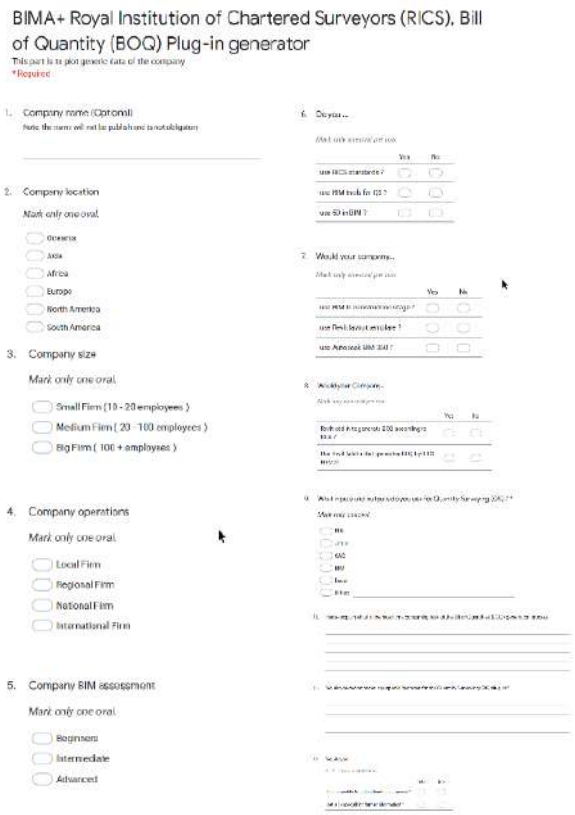


Figure 32. Survay questionnaire

It was concluded and reasoned to establish a survey to get a clear and direct response from companies regarding the 4th and 5th dimension matters obstacles and problems that companies face in connection with BIM models and RICS standards. The companies are selected from the RICS finder search engine and researched their background to make sure they meet all the criteria needed. 150 companies are selected and contacted 80 replied and 55 filled the survey online. The survey is sent via email with a link where they will open it and start filling the form answering the questions one at a time.

The survey focuses on three main features that are vital for the prototype plugin. First off, the company information - to understand their answers and point of view based on their level of experience and geographical location. Second, the focus on RICS and quantity surveying within the company - understanding their procedures and how they process the data, and showing the pros and cons of their procedure, as well as specific information

that may appear redundant but would be a beneficial addition to the prototype (eg. the final folder type). Last, BIM usage in the office - how it is linked to that dimension, how it benefits the office, and what it affects negatively. The survey can be found attached in the annex for further investigation [38].

3.1.1 Continent and location

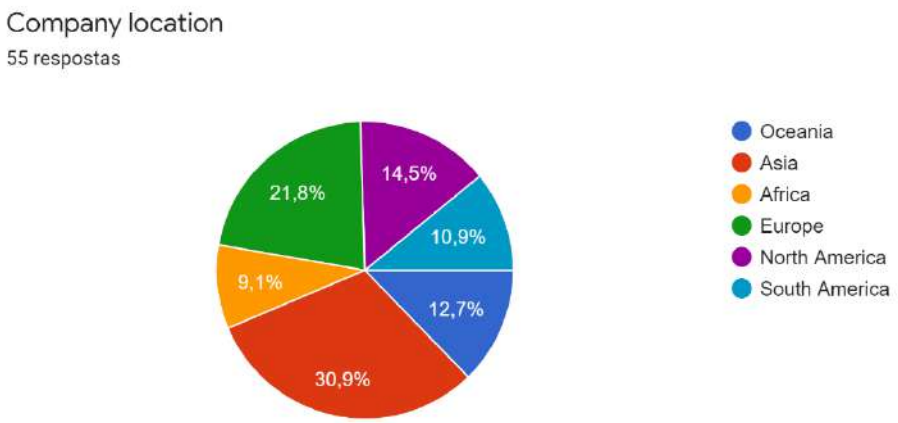


Figure 33. Company location per continent

As shown in the figure above, the companies which responded are distributed proportionately, although it shows Asia having a bigger percentage, this is due to the size of the continent compared to the other. The Americas were split into South and North since the USA have a different system compared to its southern counterparts. Myanmar and Liberia were not included in the survey since they follow the imperial system, and based on the research, had no companies adapting RICS standards.

3.1.2 Capacity

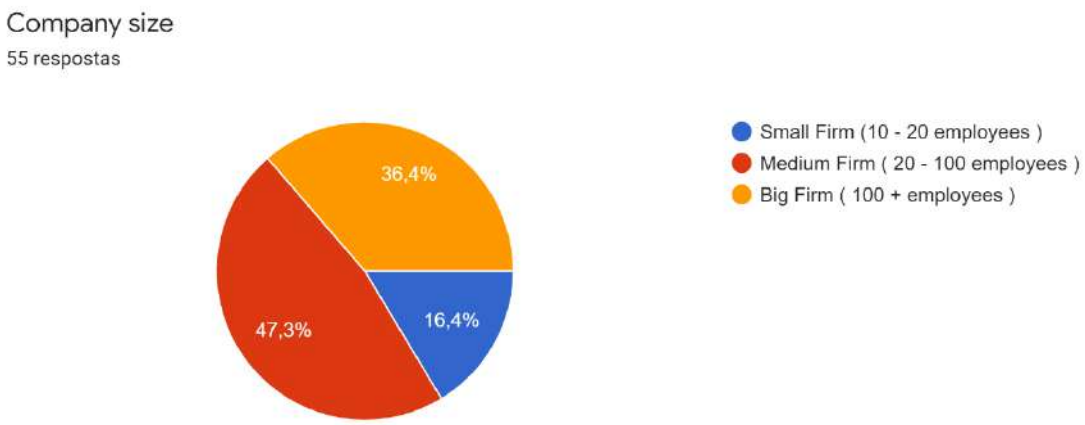


Figure 34. Company size

Capacity was divided into three categories: Small (10-20 employees), Medium (20-100 employees), and Large (100+ employees). This indicates the difficulty level of implementing new methodologies within these companies, whilst estimating their strength in the field, and the labor force the company is capable of training, and effort needed to transfer from their old process to the new modified process.

It shows that the majority of firms filled surveyed stated that they are medium-sized (20 to 100 employees). This indicates that if the company needs to change its process they would need significant steps to be taken from training to implementation. At the same time, they need to keep the work processed. Thus, implementation would have to occur by paralleling and fading the old process and emerging the new process gradually rather than abruptly to avoid fatal errors.

3.1.3 Operation and regions focus

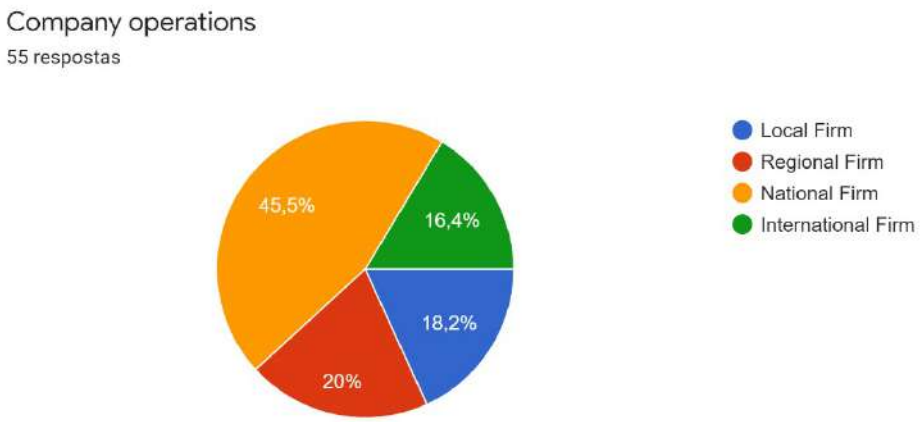


Figure 35. Company operation

Operations show the extent of communication between the company and the country, i.e, how much the company extended their work, whether locally, regionally, nationally, or even internationally. This will show what type of software is used and which models, ranging from Cloud Models, to Drive Models, or Individual Models. Last but not least, it presents the company's strength of workflow and its processing capabilities.

Based on the outcome it can be deduced that the majority of companies are national firms where they operate and serve within their home country. This shows that the main model can be either a cloud model (if there are several branches in a big country) or a Drive model (if located nearby, in a city-to-city range). However, it also shows a direct effect on the model when more than one user is making modifications on the final model, because they have to make sure that all engineers and HOD's confirm the finalization of the model to generate a primary draft of the project’s BOQ if the office has a BIM model.

3.1.4 BIM implementation in office

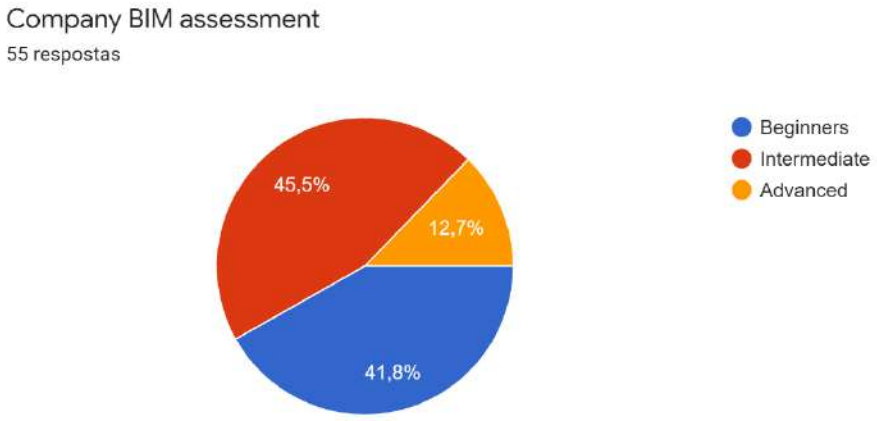


Figure 36. Level of BIM experience

The level of BIM experience within the companies shows how BIM technologies are being implemented. It gives a better understanding of how easy or hard it will be to integrate the plug-in into their processes, and helps predict whether they will be capable of adding a 4th and 5th dimension of the model without any difficulties.

The survey results show a noticeable split between intermediate and beginner levels. It is presumed that a level of preparedness can help adapt the plug-ins feature in their projects, where others need further training and development to reach the same level without any errors or issues.

3.1.5 BIM and QS collaboration

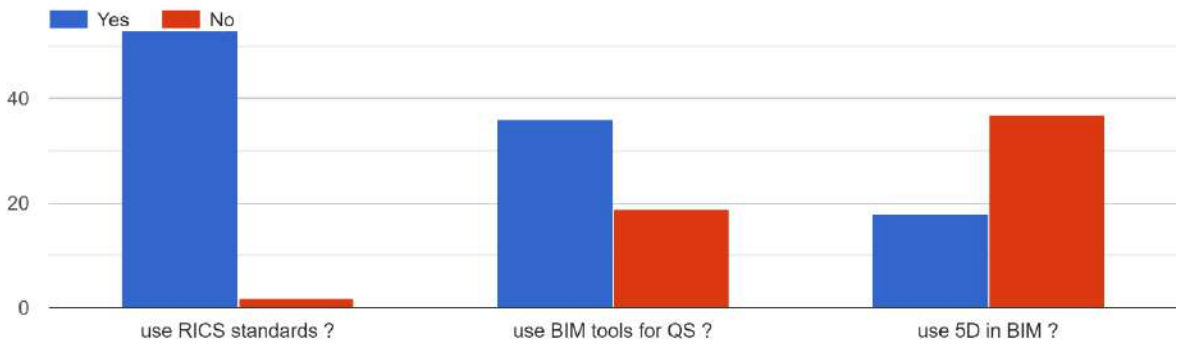


Figure 37. BIM and RICS integration in the company

Focusing on the QS and maturity level in those companies, the usage of any other BIM tools that would be beneficial to the project, and the utilization of the 5th dimension in BIM projects, this figure displays the level of integration between BIM and QS in the firm generically.

It shows that all companies surveyed are implementing RICS standards, where they use all three New Rules of Measurements to deliver the final BOQ to clients and to manage the building upon the standards therein. However, based on comments received, some companies tailor the standards based on each project and its location. For example, BOQ standards in Dubai differ from the USA since the currency and the measuring system are different, as well as having clients who request different distribution that matches their layouts.

The usage of BIM tools in QS is highly common as shown in the survey, but after further investigation, a conclusion was drawn that BIM usage is not as direct as it is supposed to be. It is a transformational method, where the BIM model is transferred to Industry Foundation Classes (IFC) and then this model is imported to specialized software such as Cost X, Prism, Win QS, and Dimension X. Measurements are taken and then recorded back to a traditional style of Quantity take off. However, a very small number of companies use a powered plugin by Revit that directly estimates the calculations of the model, but it is not practical since they need to check again to make sure all the input is correct and is recorded properly.

Usage of 5D in Revit was not common, as only international companies confirmed such usage, indicating that they only recently started due to the current COVID-19 crisis and airport lockdowns, stating that it was a positive experience and they will be surely investigating and trying the 5th dimension in the future projects. Although the pros outweigh the cons, project managers are concerned about the data loss occurring in the model in the 5th dimension affecting or possibly fully changing all the concluded outcomes and readings, thus greatly increasing time expenditure.

3.1.6 BIM and Revit Implementation

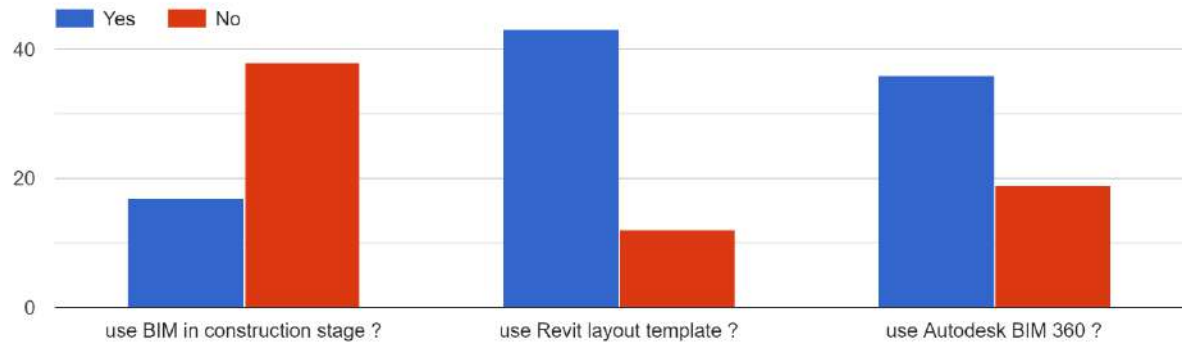


Figure 38. Company usage of Revit and 5th dimension

The post design and tendering phase is important to be investigated since one of the BIM benefits is reducing time and cost with an increase in the project's quality - doing so by generating accurate 4th and 5th dimensions in a short amount of time, allowing for the project to start construction and making the error margin less than 5% as stated in the NRM II and achieving an accuracy level of 0% of errors in BIM models.

Based on the results it is reasonable to infer that the majority of companies do not use the BIM model after the design phase and tendering. It is revealed after further investigation that the main three reasons for that issue are: lack of experience in the 4th and 5th dimension, high running cost on the office, and most importantly not trusting the technology yet, assuming that there might be a huge risk of complete data loss if not stored and backed up properly.

Revit templates are common between BIM models for exchanging information internally between colleagues and BIM modelers and managers. When delivering the project, it is common to have a customized template for each company and firm with their logos, contact details, and revision sheets. However, it has been deduced through the survey that some companies do not use their company templates, but rather transfer the model into two-dimensional software, such as AutoCAD, where drafters will plot the work on the original template set on that software.

Autodesk BIM 360 is found to be a challenging program for some companies, it relies on the size of the company and their various departments; AECOM, for instance, have their architecture departments located in Kaiserslautern, Madrid, and Johannesburg while their Quantity Surveying Departments are in London, Paris, and Rome, and their MEP in Geneva, Doha, and Lisbon. After the project team is chosen, an Autodesk BIM 360 cloud is made for the project, through a coordinated agreement on the BIM process with the client and the team leaders of each related department. However, feedback stated

that BIM 360 in small companies with one branch or small projects would not be used due to its cost, time, and complications in the server.

3.1.7 Plugin and add-ins intervention

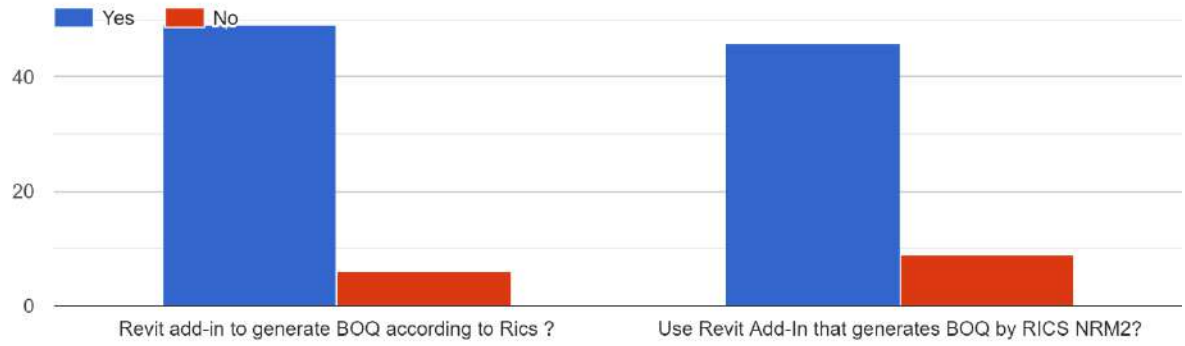


Figure 39. NRM 2 and BOQ plugin to BIM

Plugins and intervention on the BIM model showed numerous benefits, whether they serve design duties, optimization features, documents generation, or even rendering appearance. Four in five of the companies surveyed indicated that they will be surely looking into adding plugins and support if there is a proper BOQ generator that follows RICS standards and the reasons are manifold: It is nearly certain that the cost will be less on the company and client, which will grow the construction market. Additionally, a budgeting feature will be offered as a service in the post-design phase if the plugin gets developed, allowing the company to use the BIM model to reduce cost by changing material and adding and removing features in the project.

The majority of the firms also clarified that the RICS NRM II plugin is one they would be willing to invest in and use in their projects. They also stated their willingness to train employees to use it in their work, predicting that it would lift standards and deliverables to a very high level, making it no longer acceptable to receive minor errors, yet with big errors in the template, calculations, or even structure layout.

3.1.8 Output formats

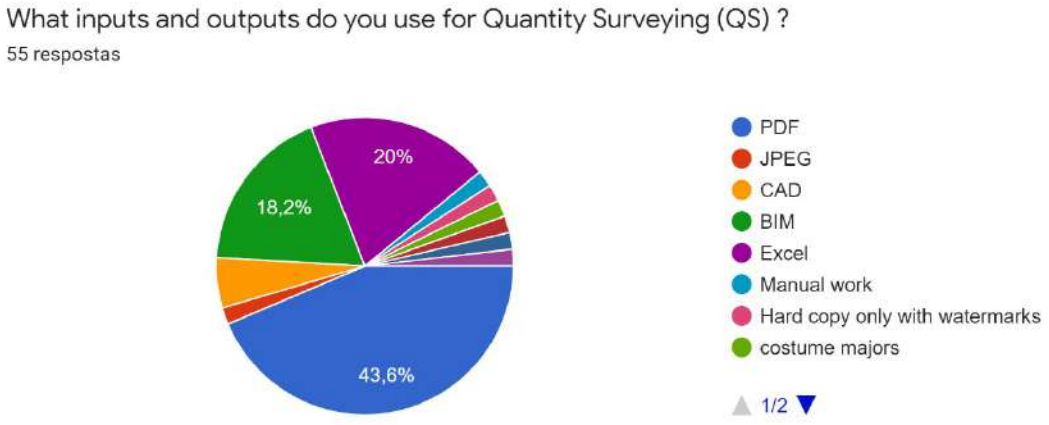


Figure 40. Output format per company

The final result of the BOQ varies from one company to another, factoring in the different continents, project scenario, and reasoning per company. Projects in Gulf countries are digitalized and then sent (mostly in PDF format), this is also the case in Europe and far east Asia. Only African companies finalize work as a hard copy with watermarks to keep the rights reserved to the company without any legal forgery issues. In some projects such as the renovation of historical buildings, BOQ documents are submitted manually as hard copy written without a computer, and that is because the documents are not as accurate as modern-day projects. The traditional style would be implemented in such situations.

3.1.9 Negative aspects of quantity take-offs

The disadvantages of doing a regular QTO without any technology intervention vary from one company to another, but there are a lot of similar answers. In manual calculation or minor technology interventions such as Excel formulas, the calculations are checked three times by different employees to make sure readings are accurate with an error margin of around 5%. If the numbers still do not match then the whole bill will be crossed out and recalculated all over again and tests are rerun.

A major disadvantage in this process is not understanding the project as a whole without any visuals. Before BIM companies assign a team and process the project in a highly detailed matter, making sure that all team members understand the project fully, elements such as concept, specification, circulation, and massing would create many obstacles. Such elements will take a lot of time to understand, allocate, define, and record in the final BOQ proposal.

Last but not least, the layout would be an issue since the header and footer might shift and page numbering will mix up the bill, costing time to reorganize and to reset all the calculations in the right

row and column. Code reference will be an issue as well if there is no column in the sheets identified in the template and fitted to the page layout.

3.1.10 Recommendations to modify quantity take-offs

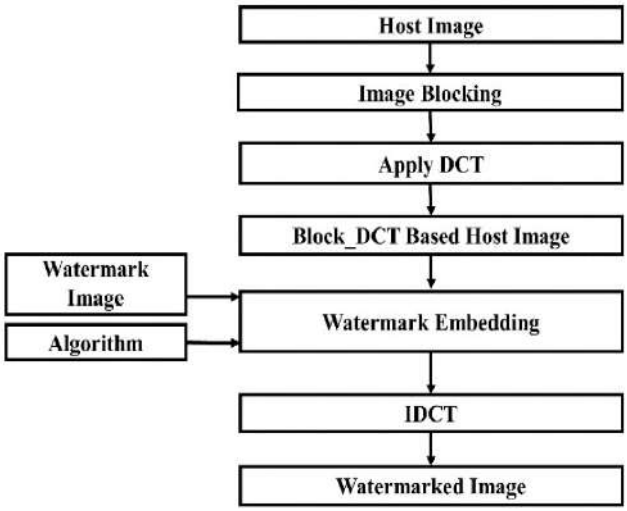


Figure 41. Proposed watermarks and BOQ generation [77]

Most of the records suggested that additional features could save time to increase accuracy and make it easier and more understandable for users with NRM standards. These are divided into six sections, which are: references - where a copy of the NRM will be inserted with the appendix samples, library - where all the BIM terminologies can be stored for clarification, calculator with formulas - to calculate for instant inquiries and assumptions per item and specification, connection to an online active platform - this activates taxes and rates for all items, most importantly steel rate globally and locally per country, the BOQ generator - this will provide a checklist and export a prefinal draft, and security - this focuses on watermarking and hiding project data of BOQ in case it is needed for bidding competition between contractors.

3.1.11 Conclusion

All in all, it is evident that all companies surveyed are looking forward to such a feature but are afraid of how it could affect the timeframe, and the risk it carries for their projects, such as data loss and lack of experience for implementation.

Data loss is a critical matter that has been in constant consideration for the past century, and a huge obstacle, as a result of which many companies are afraid of implementing fully technological solutions in their projects. But based on recent studies conducted by the School of Computer Science in the Massachusetts Institute of Technology, it is estimated that 70 percent of projects related to technological visual engineering and smart system methodologies like BIM are reused again in future refurbishment and adaptively reused in projects, since they are secure and will not have any data loss anytime shortly if the drive meets the regular secured standards.

Lack of experience of current employees will be a challenge to the companies as well since they will be investing money and time to train and guide the whole team into the new modern era of BIM technology with additional dimensions for the project. As experts agree, despite being costly and time-consuming in the short term, it will be a highly beneficial investment for the long term.

3.2 Interview with DG Jones and Partners

DG Jones and Partners have a vast experience in various engineering and managerial fields such as Project Management, Quantity Surveying, Arbitrators, BIM technology implementation, and programming. All their employees are required to receive special training that meets the company standards from programming, engineering, and standards knowledge to make sure all deliverables meet the quality of the consultancy.

3.2.1 General information

Figure 42. DG Jones and Partners

DG Jones was founded in 1962 by Donald G Jones, his target being to provide services to the Middle East, where they provide for clients cost-effective solutions for their construction needs. It is built upon professional staff working from local offices with experienced knowledge that will be integrated with collectives across the region to be a leading force in the market in an unequaled region.

DG Jones mostly operates in Gulf countries such as the KSA and UAE, but have minor offices located in Lebanon and Jordan. Every branch and region specializes in a specific field, in KSA, for example, they focus on Quantity Surveying and Project management with the hope of integrating these features in BIM models. DG Jones is renowned for always looking for alternatives in such fields to be integrated and optimized and to give added value to the industry. Although the first office opened in Beirut, it showed a huge impact on the growth of projects located in Gulf countries, therefore shifting offices and focus to the GCE region, eventually coming to own ten branches across the middle east.

DG Jones Riyad is located in the city center and serves a lot of projects in the city, country, and region. Services include Quantity Surveying and BIM modeling. The office includes 100 employees that vary from engineers and project managers to construction site representatives. The office operation for construction sites is mostly centered in the Riyad branch where digital services such as QS and PM are regional, not to mention exchanged support between offices in Riyad, Beirut, and Amman.

3.2.2 BIM assessment and standards used in QS

DG Jones had several trials in optimizing time and money expenditure in the field of QS. Every project has a unique situation where it will be customizable based on the size scope and the approval of the client and the representative from the company. Based on the experience and the archive in the main

branch server, several treatments that took place over time. Most of the projects are converted to 2D and imported to CATO where all the accurate calculations are done and then translated into authenticated standards.

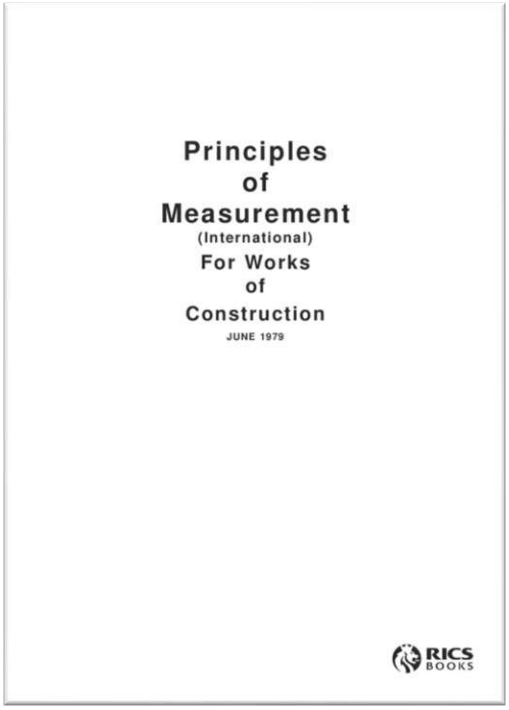


Figure 43. Principals of Measurment International

Different sets of standards are taken into consideration since these differ from one region and project to another. Three main measurements are taken into account with the firm, which is POMI, NRM2, and CESSM4. POMI stands for Principal of measurement and provides a uniform base of measurement for quantities and construction material count and machinery for the Bill of Quantity for project construction installment. NRM II is a standard published by RICS and generated by experts in the field - providing standards, measurements, and rules for estimation cost planning, procurement, and life span pricing for the construction project, along with a dedicated part specialized in dispute rules and regulations. CESSM4, meanwhile, is prepared under the ICE's review community and retains many on the prior characteristics and other references such as NEC, FIDIC, and ICC, while changes are introduced and influenced by industry practices that reflect the emergence of new technologies, as well as removing local British standards to remove obstacles for global implementation.

LOD is an important factor in the process and standard selection as mentioned prior. If the project has a low level of detail it will be a waste of time to increase the level of detail and then translate the BOQ with semi intervention or a full technology intervention. Some projects work better with the manual traditional style. All of these are determined on the situation of the project time, location, budget, and data.

3.2.3 Fifth dimension and construction project layouts

Figure 44. 5D golden triangle

The fifth dimension is still not implemented as much as prior dimensions globally, this is because the experience is modernized construction technology Furthermore, technology as a primary step in firms so. It is clearly emphasized that these features are used on large with the biggest budget cost and scope that will be suitable to test and pilot new trails and technologies which can be backed up in traditional style if failed. Participation in the construction phase is not common in the firm's services, but this may also vary from one region to another. The Riyadh branch clearly states that its services do not cover construction site supervision but that such services are offered by neighboring offices and branches such as Jeddah and Alkhoubar, which cover different types of services that might be branched to any other office location if necessary. For instance, having a construction site in Riyad for a project supervised by the Alkhobar office, it would be more feasible to recruit one of the employees in Riyadh to supervise the project than moving engineers back and forth between the cities.

Numerous templates are used in projects done by the company, as well as templates for different types of drawings such as MEP, Architecture, and even structural templates. All the information is changed and expanded upon based on the branch that takes over the project and the regulation of the region and the area where the project is executed. These matters are closely considered and must be updated and modified yearly for the company, and changed immediately if needed for the project.

3.2.4 Software and Documentation

Documentation is a matter of contention for different corporations since some projects could require privacy (eg. government-related projects) and the detailing should be kept a private matter. These projects would have a special drive in the server, requiring strict authorization and permission to access once the data is stored for documentation purposes. Projects employ on a cloud drive that is used for the project and made accessible only to the team's departments and the people who are working on them. These eventually produce final documents and are then stored for reference, education, and portfolio archiving.

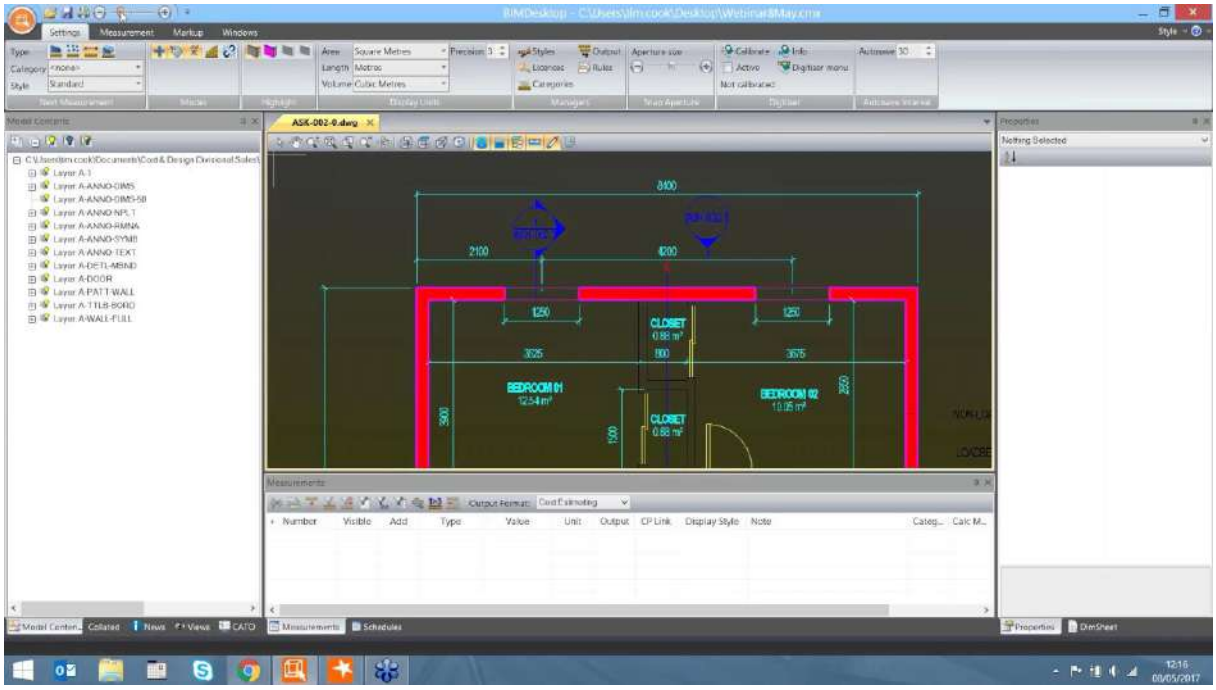


Figure 45. CATO software interface

CATO is a common software that has been using another billing solution yet decided to introduce higher functionality. Compared with other software such as Prism, Cost X, and Dimension X, it follows a competitive exercise, as it provides take-off and bill solutions that are selected as a replacement. The software is heavily used by the office and referenced for training new employees to get in touch with the company's vision and implementation. CATO runs 60 percent in all projects held in the branch as a minimum. It is highly recommended for semi-traditional implementations in cases where the budget is limited and the work needs to be delivered on a faster track than the traditional manual style.

Before the project starts, the client asks for a professional recommendation on which approach can be used. The company aims to have its customizable plugin or software sometime in the future, to seamlessly provide all the companies' services such as producing schedules and cost plan proposals efficiently and instantly. Thus, considerable research was done and the company recommends a BIOM model that has the minimum LOD of 300/350, meeting the acceptable error percentage rate and being able to generate NRM II standard BOQ.

3.2.5 Refurbishment Projects

A lot of projects are adopted and implemented in the Riyadh office, with some of the projects taken needing some form of refurbishment. Refurbishment is defined differently from one region to another. For the term adopted by the firm, refurbishment is used to describe projects that have several features to be done such as improvement of cleaning, decorating, and re-equipping. It also includes elements such as retrofitting the target building with extra energy-efficient solutions and increasing sustainability. Refurbishment is often used interchangeably with renovation and restoration (in which work is

performed towards restoring the building to its former condition). Generally, refurbishment can be competing in works that can be considered 'cosmetic ' renovation such as painting and decoration, upgrading, repairing, alterations, conversions, extensions, and modernization.

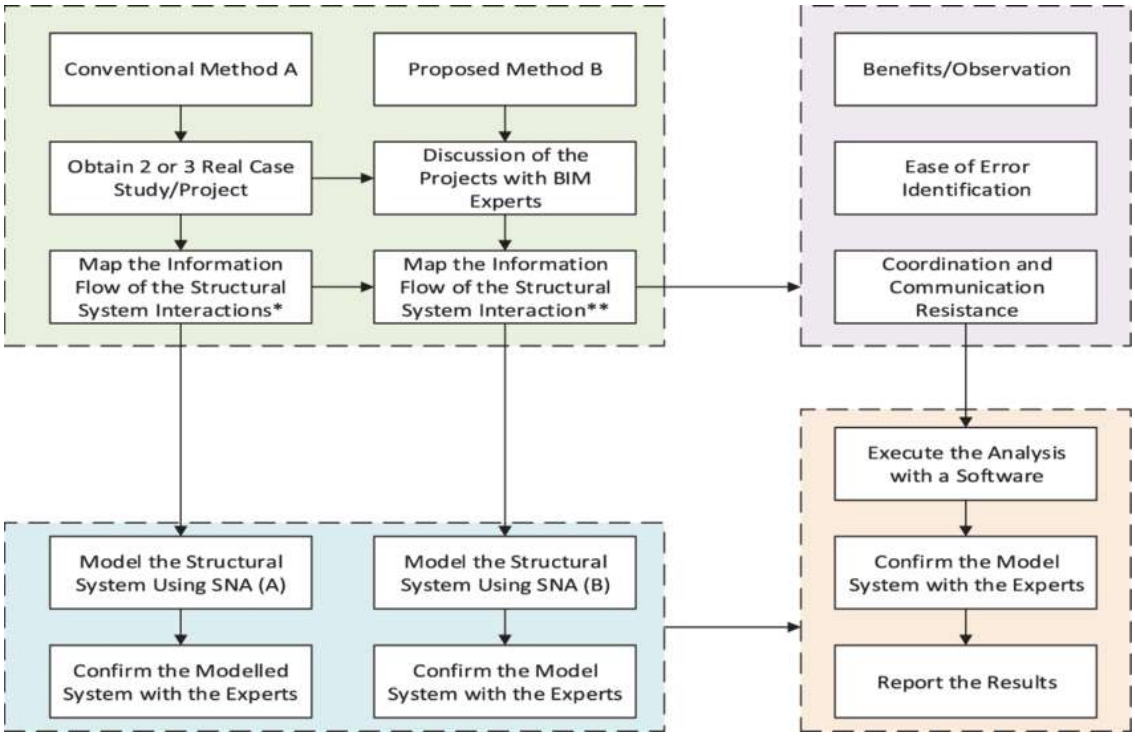


Figure 46. Optimizing schedule of refurbishment project [78]

The footpath and the lifecycle of the building can be significantly expanded, making it effective for refurbishment as the firm stated that every building is taken and adopted uniquely and differently from others. These buildings are studied individually and emphasizing the financial budget plan for the proposal. From a technical point of view and a local context, the proper approach to refurbishment should be guided based on the particular regulations and the current status. Architects should look at and understand the uses of the buildings and connect with diversified holders from the primary point of the project to the end of the refurbishment project.

The company faces a big challenge with refurbishment. The factors that attract the firm in Riyad to take such a project are the building potential and client profiling, where they can negotiate future projects, as well as the level of technology integration injected into the project. For example, a refurbishment project was proposed and accepted by the firm where they had to clean and renovate rooms in an old hotel that got purchased by a new owner, the project was unique since it had a high LOD BIM model (LOD 400), the projects high standards revolutionized the market by being one of the first and only hotel towers that adapted the 4th and the 5th dimension of the BIM model. In the aftermath of that project, competitors started investing in new technologies to offer an outstanding portfolio for investors and clients in KSA and the Arab peninsula.

3.2.6 Problems and Issues in BIM/QS

There are various problems associated with the new technology implemented in the process. However, many matters have been pointed out in the preliminary steps of generating documents required to start the construction phase of the project. Whether using the new approach of producing BOQ and schedules or the traditional style by an experienced project manager manually, it is indicated by the company that there are a lot of matters that take time in generating QS documents whether they are tenders, BOQ, or timeline of construction. One example lies in the calculations that play a huge role in the owners' approval. The readings should be as accurate as possible and should be checked multiple times to pass the quantity surveyors site. If readings do not match the prior reading it means that there is an error, therefore, a motion to take a third, fourth, and even fifth measurement should be crucial.

Due to such hindrances, a prerequisite was imposed - that measurements be done by a third party software capable of giving 100% accurate readings and calculations with a near 0% error margin. Therefore, a variety of creative alternatives are suggested as mentioned prior, which will have pros and cons during the timeline of the generation of the project.

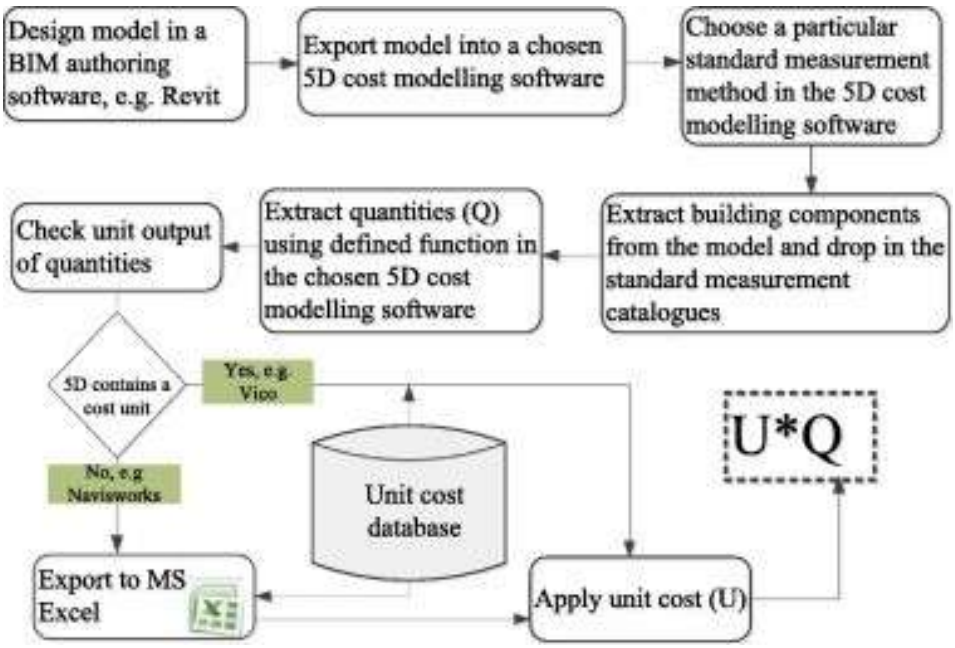


Figure 47. BIM quantity take off ontology [79]

BIM models and technology are surely pushing the envelope and would be beneficial to integrate into the process to optimize the golden triangle, that will change the thinking and methodology of how the project is processed from concept design to delivery, and even manage the facility upon request and given the right budget. However, this cannot be up for modification since a minimum specified level is needed to obtain the correct readings. The company always urges the client to maximize the LOD to offer these services in a fast and convenient manner.

3.2.7 Cybersecurity and safety of the project

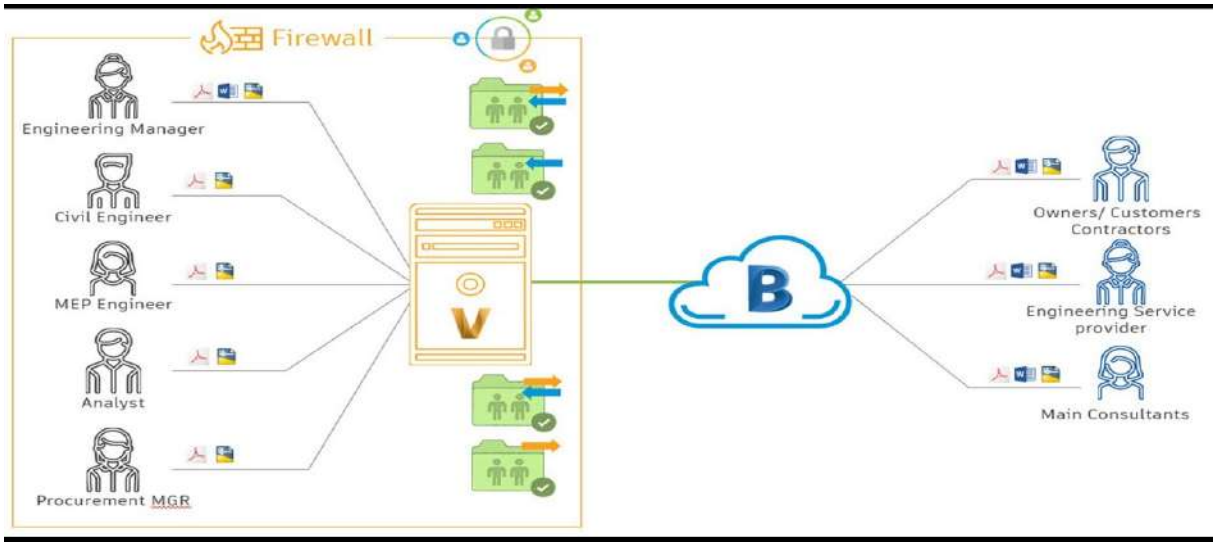


Figure 48. Common firewall security on BIM models [9]

Security is again a concern as it has been an issue since moving away from the traditional-style project. The hacking phenomenon is common among competitors. Nonetheless, it shows a huge decline since computer engineers and developers are continuously developing and upgrading firewalls and security for a safe environment of data exchange between engineers and managers. The matter is not addressed and was not an issue for DG Jones because the standard server and cloud drive between branches and offices globally is well protected with a comprehensive IT department backing up and protecting projects.

The confidentiality kept between company and client is one of the key elements of its morals and ethics. Projects are not allowed to be shared for research purposes as a third party, the projects are always moderated securely to avoid any publicity or wrong advertising over which the client could sue or penalize the company should such occur. If the model is shared, certain consequences could arise, such as the emergence of security matters of the project. Data and pricing details will be compromised if they fall in the wrong hands, and mistrust may grow between third party contractors and the main contracting company, who may tailor the project to their means.

It was proposed by the company to produce QTOs and BOS with companies' watermarks and information in the header, however, a feature that will be beneficial for the company is remove any information related to the participants in said tenders to increase transparency and fairness in the selection process of the subcontractor.

3.3 Quantity Surveying software evaluation

Readings show that companies which mainly focus on the quantity surveying profession and tendering, state that all projects are recommended to be generated in the traditional old style since the field has not yet technologized the procedure. However, it is stated that the industry is moving to the second phase of the construction industry through technology, with multiple software suggested and used globally. The most common software are Prism, WIN QS, Dimension X, and Cost X. And upon a deeper investigation, the conclusions were as follow:

3.3.1 Prism

Figure 49. Prism interface logo

Prism is a well-recognized project control software that covers the entire project management life cycle. It focuses mainly on dependable forecasts, cost control, and performance measurements. A lot of firms take advantage of this software by using it to manage projects, programs, and portfolios of growing size broaden the variety in the industry [39]. It helps project and construction managers to gain control of their project while increasing predictability, risk reduction, accuracy, efficiency, and visibility.

Taking into account its scalability, robustness, and intuitive system. The industry harnesses their profession and practices and integrates all such aspects of the project; that includes cost and schedule, changing management, estimating, earned values, contracts, procurements, and field progressing [39]. It also helps project managers to reach goals and milestones with a high increase in visuals and control, taking into account the maintenance and enhancement of accuracy, efficiency, and performance.

One of the main advantages of the software is the improvement of financial performance with proven solutions that are out-of-the-box. This prevents overrunning the budget and helps avoid delays, with the use of comprehensive features in the software [40]. Furthermore, improving the workflow, visibility, and control, project standardization and measurement across the project will allow better execution and performance, by using simplified dashboards instead of having to rely on big and long spreadsheets.

Scalability means having the ability to easily increase project data load for a given project to meet all the user's needs with higher standards. PRISM will maintain its high-performance level and have the capacity to take full advantage of large operating systems in terms of user response time and the amount of data that is handled [40]. The processing time will remain short regardless of the amount of project, data, and concurrent users. Last but not least, performance evaluation can be measured across the

project, programs, and enterprise. The data processes help to collect, analyze, and emphasize the report findings of the measurement of execution by component, project, group, organization, system, program, or portfolio. PRISM aims to keep its reputation as one of the most robust project management software available in the market [40]. Although the market shows great demand for PM Softwares that target other methodologies that will benefit the industry, this software can generally cover matters that support QS and QTO's calculation and tendering, beneficial for both parties, and any third co-parties of the project.

3.3.2 Win QS

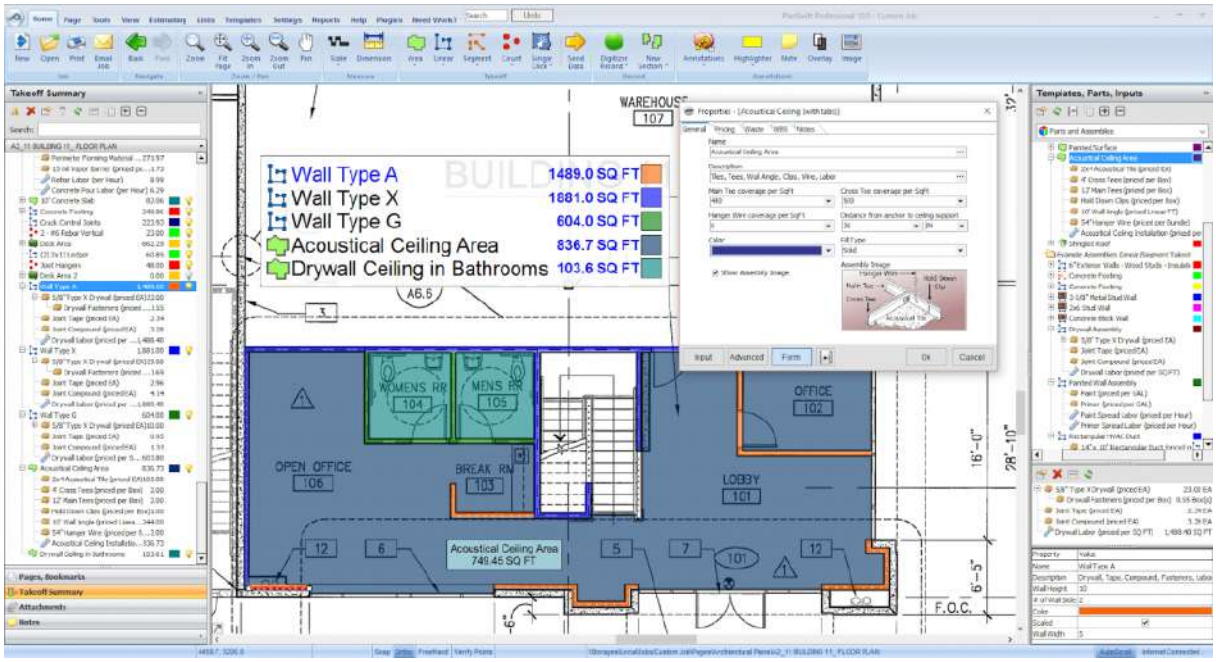


Figure 50. WIN QS user interface

WIN QS is a professional software, it provides Quantity Surveying services that are optimized for the industry. First among these services is the calculation and generation of BOQ documents; whether they are trials or final products for the projects' submission. Second is the production of estimate documents that check for errors to be enhanced and modified. The third is the function of monthly evaluation calculation and cost analysis of the projects different phases when requested by big or governmental projects supervised by private construction firms [32]. Forth is the provision of certifications that are needed like the JBCC and Engineering unions for the project locations. The fifth is another feature for contract price adjustment calculations that can be requested by the client in case of budget-cutting of unexpected economical crises with the firm or country. The software offers many other important features that will be needed for the project to stay on track.

A visual view of the document generification such as the Bill of Quantity is offered by the software where it does not require printing or previewing - the information that is inserted is not viewed and

modified on-screen, but with the full additional trial that is reserved to view who generated an item [33]. Several sets of trials are sorted for all projects, they can be duplicated, multiplied, and picked for BOQ and estimation usage.

Moreover, the printing and exporting of data is another beneficial feature in the software - items and page numbering, summary, and finalizing work can be all generated and done directly with no errors or manual intervention by a regular user since it is automatically generated by the system [34]. The software contains a standardized library featuring ASAQS model bills, JBCC principals and preliminaries, electrical work, mechanical work (Eg., HVAC/Refrigiration/ Air-Conditioning/ Ventilation), and other features can all be found in a standard library.

In conclusion, this software is mostly adapted by Quantity Surveying firms in The United Kingdom, as it is recognized and highly recommended to be used by the RICS association, to produce documents. Although it did not have international recognition it is found to be highly used in Europe, with the UK specifically showing great interest [35].

3.3.3 Dimension X

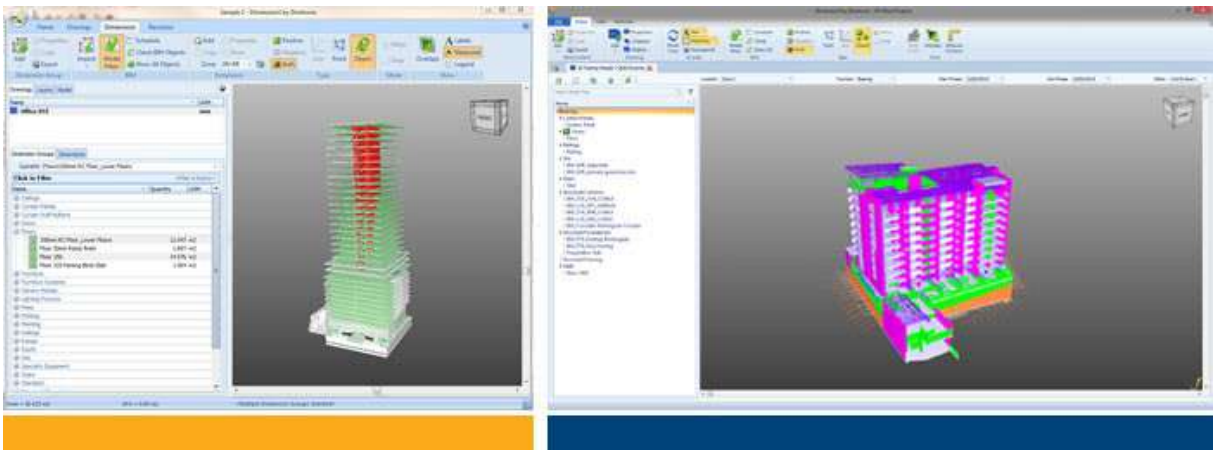


Figure 51. Dimension X CAD folder running

Dimension X is a software aiming to reduce the use of any hard copies, reducing printing costs and paper usage. This software produces an estimate/BQ, making redundant the acquisition of paper drawings which makes the process longer and results in the need for revisions that might not be marked up properly [36]. Based on the surveys generated by dimension X, it is clearly shown that using CAD drawings to generate readings and calculations is time-consuming, thus making it unreliable in the industry.

Within the last six years, the software updates have allowed easy, accurate, and fast measurement operations without the need for hardcopy drawings and documents. The developers secured efficient output of the project documents as a soft copy, in CAD format, or PDF format through Dimension X to

integrate those measurements within WIN QS that allows those directly [37]. Currently, formates are loaded and measurements are “Taken off“ with the triangular goal of accuracy, efficiency, and price tagging, noting that these goals do not require CAD intervention.

The pros outweigh the cons of modern used interventions. Even though third party CAD software requires licenses to be updated, it has several advantages [38]. For one, it has easy access and interfaces for users. Second, it is designed by certified and experienced Quantity surveyors for a high-end quality product, taking into consideration authentication and marking up to be printed in the header as a reference when needed. Third, it is capable of processing measurements and defining perimeters including “in No. of“ count, as well as modification in the work for later review and revising. Last, and comprehensive screen help support. All in all, these features along with others that can make the process easier and simpler for experienced and recent Quantity Surveyors alike [38].

3.3.4 Cost X

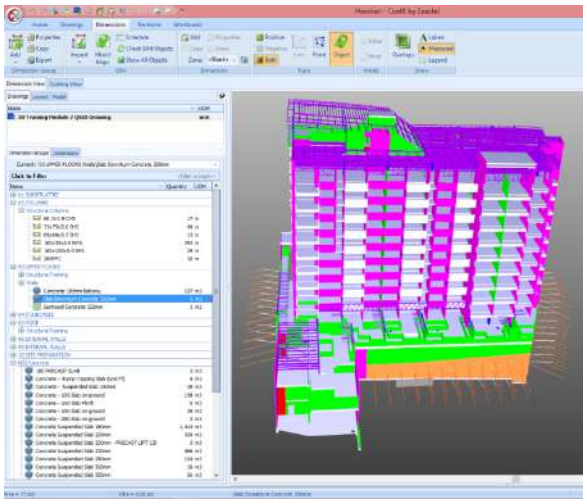


Figure 52. Cost X evaluation

Cost X is the most recognized software locally and regionally. It is used by contractors to provide an integrated model in one environment, to observe dimensions with managerial control that is associated with cost control, making it easier for engineers working on a construction project. It is a safe and reliable source of digital storage for the projects’ data, having the ability to benefit from all CAD features without having the software installed on the computer. Its advantages include minimizing data errors and providing precise readings of measurements and prices via alternate drawings of the project [41]. Cost X will extract all information from the drawings, and allow the user to work on the data without altering the original and master plan, which, if it were to happen, would compromise the integrity of the design.

The user starts by setting dimensions for the last revision and getting approval of the client and firm, all the while keeping accurate and clean track of variations, based on the full implementation of a digital workflow; this eliminates the usage of hardcopy documents for the project. Taking accountability of simplified projects, full projects, and buildings will be easily sorted and aligned with all interested parties. It is stated that the software offers a free viewer for that purpose, that assists the engineers in launching their Quantity Take-off in DWG, DXF, and DWF folders. The lines recognized in the drawing (Poly-lines) used for area, length measurements, and automatic object counts, are an excellent tool to collect the information per layer off of the second dimension drawings [41]. Support for PDF folders

and graphic files such as JPG and BMP is also taken into account. The drawing, when inserted into the software, will generate an intellectual identification of readings that will be traced, and used to the advantage of the project to measure and identify BOQ related data.

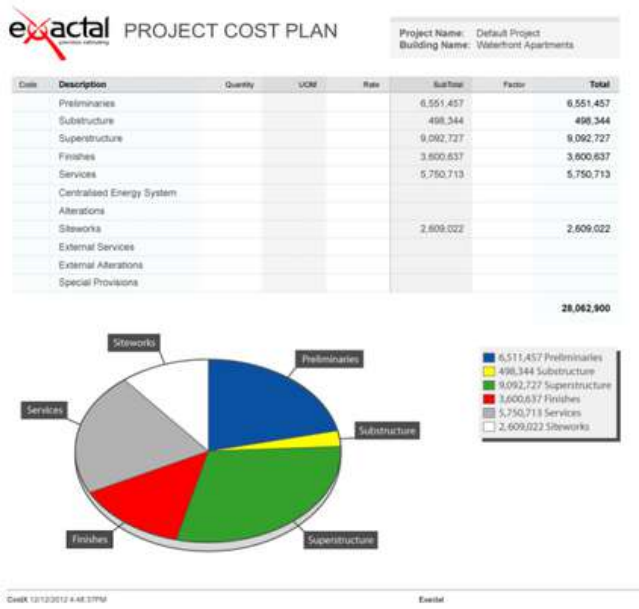


Figure 53. Costx Project Cost Plan

In regards to tendering reduction of time and cost, Cost X creates plans in minutes and even seconds, with the help of intelligent technology that identifies and understands the drawings to perfect the accuracy of the quantity surveying practices. Efficiency is drastically improved since CAD drawing folders are linked directly to offer viable and affordable parallel alternatives for design modifications, while eliminating time-consuming tasks and manual measurements that are not as accurate as digitized reading, for use in the take-offs. Cost X has a well-designed interface with a modern look view on updated Windows Softwares [41]. It is custom-built by awarded engineers that meet specific standards to fulfill Quantity Surveying and estimating engineers' practices. The program's design suffices the estimation technology to be a fast and efficient process, that leads to less time spent while simultaneously improving accurate measuring and other important matters, In conclusion, cost-based software if used in the project can be a tool to save time, help with paper reduction, storage, estimation, mobility, output time and error margins.

All in all, Cost X is often approached as a semi-traditional procedure, since it has advanced technology in comparison to the other analyzed software. It was highly recommended by other firms based on statistical readings and interviews conducted by advanced research facilities around the globe.

3.4 BIM and BOQ merge trails

Figure 54. BIM BOQ Quantifier

There were multiple trials and studies to merge the BIM and QS worlds as plugin support. One successful trial, which still needs modification and update on its prior version, was implemented in Greece under CCT international. The plugin is created to generate BOQ and QTO's with all international standards, except RICS standards and layout. The quantifier is powered and endorsed by Revit. The add-in is used to generate QS data when a model of a high level of detail is available. A highly experienced developer worked on the plug-in's trial phase to ensure better standards for the software's success [42]. It passed the standards of ICMS, CIQS, SMM7, and POMI. The developer mentioned its addition and modification in the newer version of NRM.

The new version is expected to be launched in 2021 with additional features, it will be updated with all international standards such as MEP, Architecture, and Structural Bills [42]. Based on NRM II standards and regulations it shows that the accuracy rate should be less than 5%. The expert stated that based on the LOD the accuracy rate shows as follows:

Table 2. Accuracy Rate per LOD

Level of Detail (LOD)	Accuracy Rate (%)
LOD 100	8.7%
LOD 150	8.1%
LOD 200	7.3%
LOD 250	6.9%
LOD 300	4.5%
LOD 350	4.1%
LOD 400	2,5%
LOD 450	1.1%
LOD 500	0.3%

4 PROGRAMMING AND SCRIPTING

Programing language selection was and still is a debatable matter that needs to match the aims and goals needed to be executed at the end of the project, where the prototype or group of commands is to deliver a bigger task [43]. Several types of research have been conducted and revealed that the selection of the language should be based on the aim/target, outcome, and interface that will be connected to the language, in other words, the application programming interface API will determine the process matter of the project.

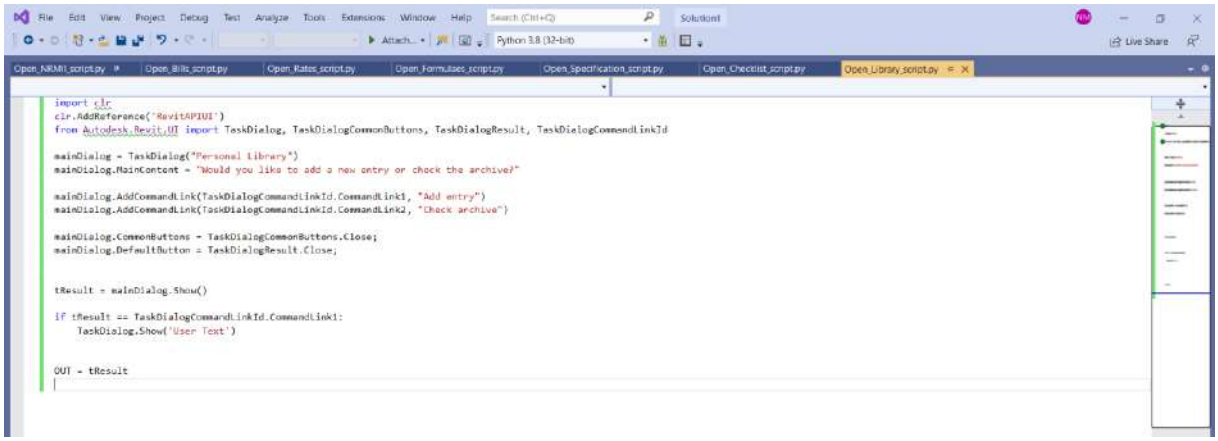


Figure 55. Visual studio python scripts

API stands for application programming interface and is the intermediary between software that will give access to two applications to communicate with each other [8]. For example, using an application like Facebook, checking the news, or the weather. The usage of API takes place when an application is used on the mobile phone, where it will connect to the internet and send data to the server that will be retrieved and interpreted later on. It will provide and present the data a user acquires in a relatable manner. This process is the API, usually defined as an algorithmic flow chart that solves and logically processes matters [8].

Based on the survey, the interview conducted, and the literature read and analyzed, it is evident that the most suitable language for the Plugin to be generated from is Python. Numerous successful tests and trials were approved and showed a lower percentage of errors when the first plug-in trial is launched. Some studies even showed that python will immediately point out the errors faced during launching and suggest solutions and guidance correct said errors.

4.1 BIM and programming

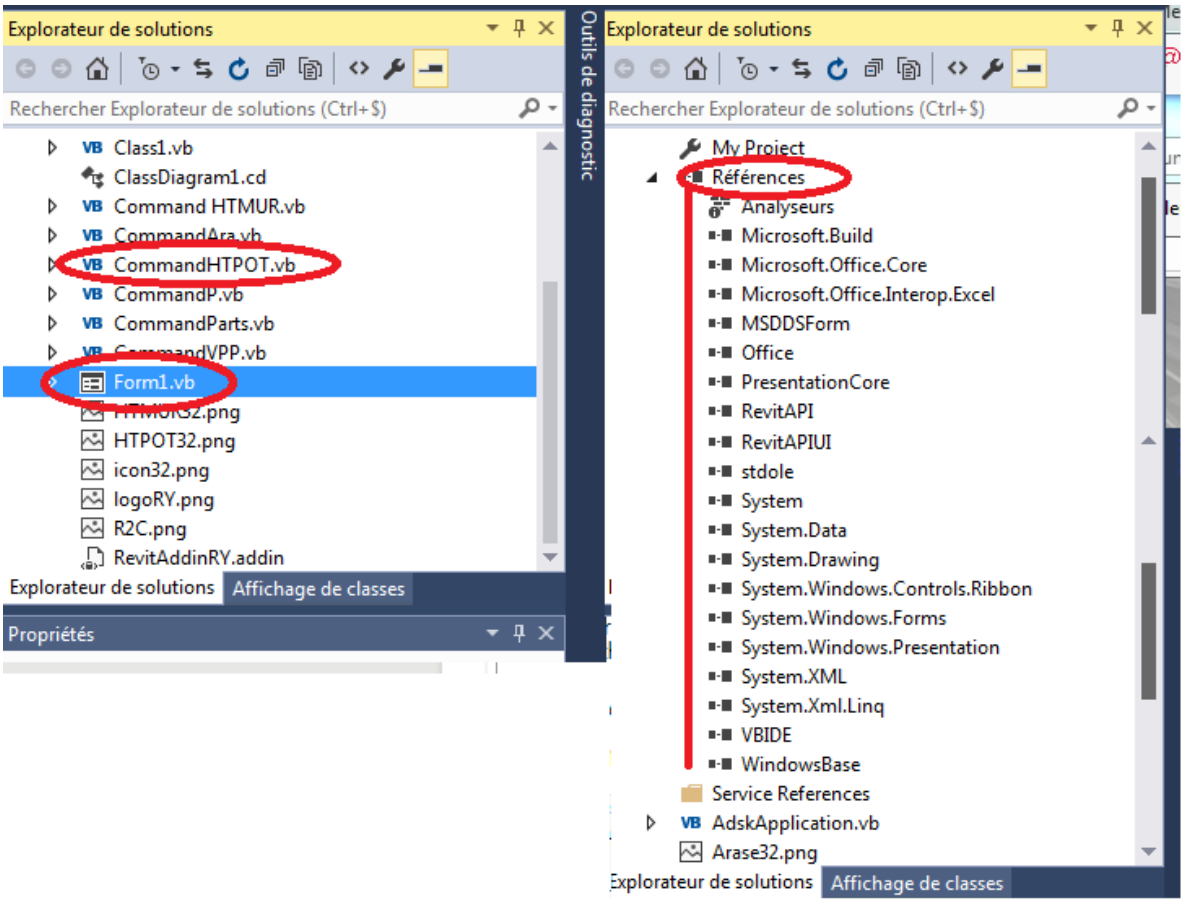


Figure 56. Revit API resources

There are several available resources on the internet that can teach and guide through Revit API, but these resources are usually intended for users with prior knowledge of programming. The guide developed for the presented plugin is different since it needs no prior knowledge of programming. Getting familiarized with this guide would be an added benefit that will help build the first plugin quickly. The program guidance will be reviewed to the advantage of tailoring Autodesk software. The lessons will primarily start by executing a functional plug-in before providing more detailed elaboration on the underlying principles, and further developing the functionality of the application. In the current market, it is prioritized to be more practical, which is key to customization. Working on the software used daily to process the workflows makes it more efficient. Autodesk provides a powerful API and a reliable software development kit 'SDK', this will authorize a greater gain value by software investment that is specific to the need of the business.

Autodesk Revit is well known for its rich API that can be used to establish a customized product with existing features or even adding entirely new ones [8]. Automation, repetition, and time-consuming tasks are some of the extended features. API is used to generate a custom tool and features that can be plugged directly to Revit, thus extending their functionality.

The interface for the software was developed by the visual studio and it took a lot of time to process and understand the whole language from scratch. Autodesk forge was a good source of support for that process since it helped in the interface development and the generation of the software as a prototype for developers to work on [44].

4.2 Python

As was formerly explained, Python language will be used in developing the plug-in, based on the outcomes of the primary trial [45]. The testing showed many positive outcomes, that are beneficial to the plugin; such as, easy to learn software, matureness, support, an extensive library, versatility, big data storage, flexibility, academic support, and automation.

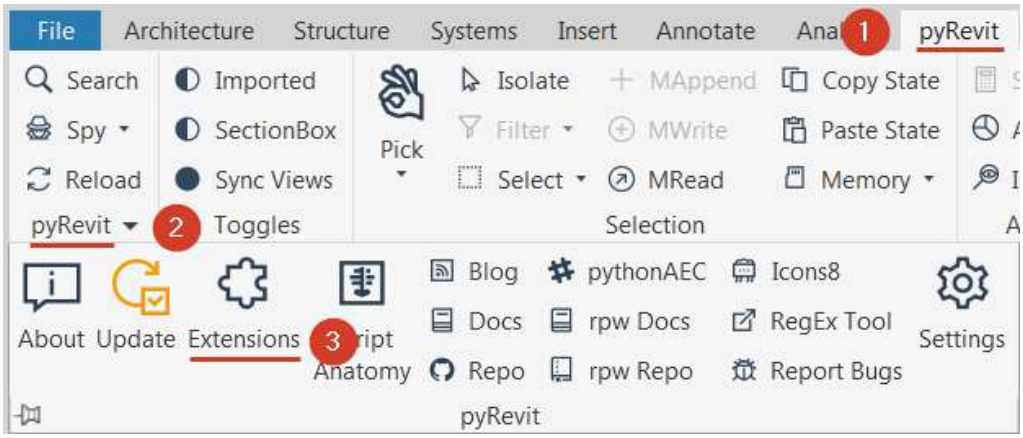


Figure 57. Pyrevit interface

Firstly, the language is easy to use and learn within a short period, both for beginners and experts in the field. Python is an accessible programming language since it simplified syntax programming language. Python codes are more easily written and implemented than all other languages proposed by the industry. Secondly, the language is over 30 years old and has taken many years to be analyzed and processed, reaching a point where the language has grown and become mature enough to support users from beginner to expert levels [45]. All scenarios and problems are documented in the form of videos, in which detailed solutions are available to the public for viewing and learning. The program has been evolving quickly, especially since it was sponsored by interested corporations. For example, PHP is sponsored by Facebook, Java is sponsored by oracle, C# is sponsored by Microsoft, and Python is sponsored by all those firms and more, such as Amazon, Google, and Twitter. It was recently stated by the board of Autodesk that Python is the number one language recommended to be used in any additional enhancements for any software under their scope [46].

There is a big supportive community of python users that provides an outstanding and excellent library. The library is very helpful with resources such as the optimization of time, effort, and accuracy; not to mention the broadened cloud media services that offer support through the library [47]. It is especially

focused and available for natural language processing and in good machine learning applications. To be specific, Python is considered the first option for the majority of programmers and developers, since it is marked as high demand in the development market, and is undoubtedly the best language offered in the market now. Another positive aspect is its flexibility, which gives the developer a chance to try something new, since it is similar to other languages, for them to try and make something unique. Last but not least, it can help in the automation of tasks in a synchronized manner, making it much more comfortable to deal with. It is also known to reach advanced levels of automation easily by using codes to boost the performance of the software [45].

4.3 Process programming

The process of generating the plug-in has several trials and comparisons made, it is done to run tests and reach a reliable conclusion to not be only theoretically proven. The solutions were analyzed, processed, and then implemented to a practically reliable prototype [48], and a backed-up proof was created for the plug-in.

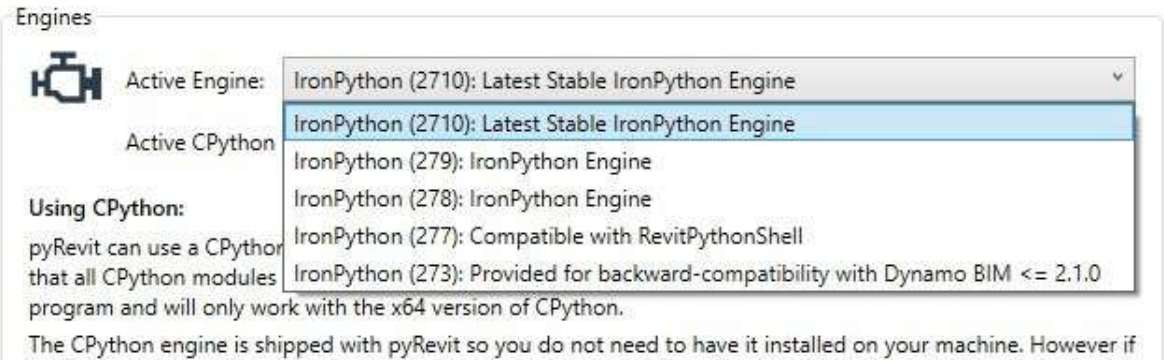


Figure 58. Iron python active enginer trail for plugin

Firstly, a primary Autodesk plugin for copying groups was created, the plug-ins' location was determined by the user, then the scripts were saved under the Revit API folder, which can be accessed on the main drive, where the software is saved and installed [48]. It took time for the scripting process, to make ensure that when executed, it would work without any errors to back up the launch failure. Secondly, it was recommended to pay attention to what will happen when the saved path launches, and when the execution of the plugin code took action, in an exploratory test of the visual C# express environment [49].

After the script launches succeeded on the Autodesk Revit API, a deeper look was taken at the API itself – the aim was for the lines of the script to be fully comprehended, and an exploration of its concepts and its potential as Object-Oriented Programming (OOP) was undertaken. Learning of the proper purpose of the Visual Studio debugger continued [48], to get through the codes line by line, follow the program execution, and observe the value of the variables as they change by the input of the RICS plugin.

The next step was to improve the plug-ins' selection process and its functionality for Revit. Research and development were made to make it an easy tool for the user to select the group, and to guarantee that the plugin anticipates the probability of launch failures; this specific test took time because it was needed to identify all the 3D items in the model, and segment them based on the layout of the bill given and published by the RICS. Exploring further the APIs and their potentials for the plugin, where concepts and statements are proposed about filtering with Filtered Element Collector (FEC) [49].

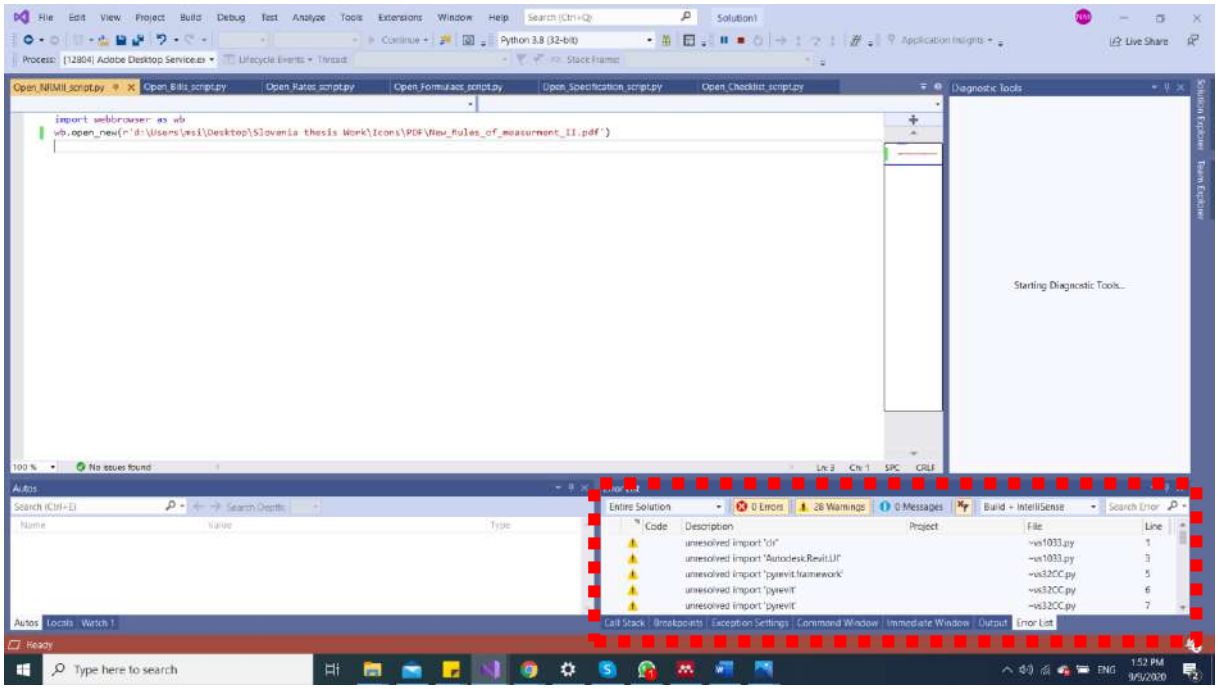


Figure 59. Errors occured when script run

Finally, the testing and running of the final plugin were done, showing what minor modification was needed [49]. The prototype is prepared to be developed and the interface concept and target are set. It is only the professional programmer obligation to add a secondary script, that will identify the items in the model, regardless of the LOD of the 3D item, sort it in the bill, and extract all the measurements and calculations. Last but not least, learning more and getting additional information would optimize the plugin, when the developer fully finalizes the software, increasing the understanding of the API and its documentation and what is needed to change and redirect the commands, smartly and practically that will benefit any engineer in the future interested to proceed with the concept [49].

4.4 Issues and errors occurred

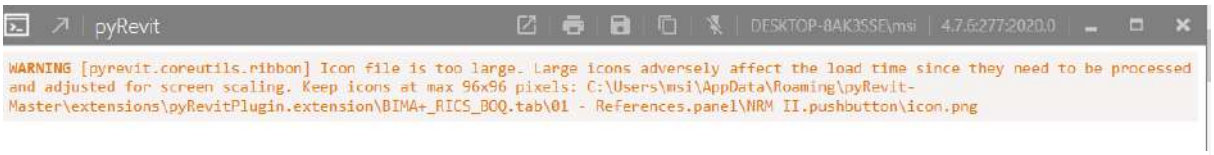


Figure 60. Pyrevit errors when launched

Programming takes time to be processed and analyzed properly. In Python, some disadvantages and obstacles hindered the process of generating the plugin, such as the quality of the laptop and the availability of the features in the surrounding environment [50].

Based on the personal performance and outcome of the prototype plugin, it was concluded that some issues were not beneficial for processing data, language, and generation. Moreover, the speed of Python programming was similar to prior trials on C or. However, since Python is a high-level language property, it is not closer to hardware, unlike C and. These issues were mitigated by the fact that the work was managed by professional experts in the language [51].

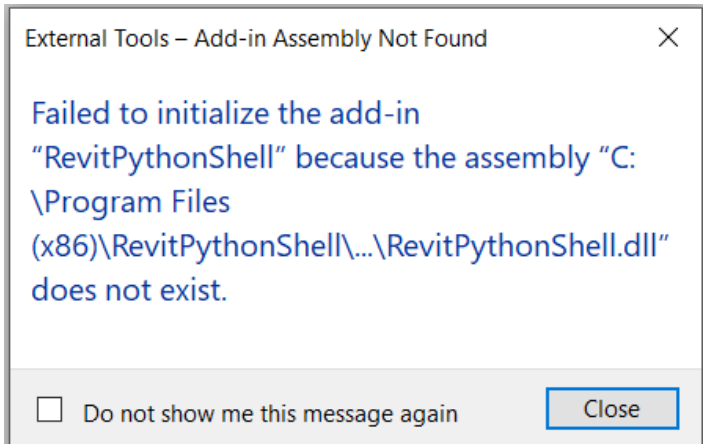


Figure 61. pop up massage when plugin launched.

Memory and storage were noticeable issues during the plugin development process. It was not a good choice for memory-intensive tasks, such as the BOQ generation plugin on Revit, so as a result, the laptop underwent several crashes, due to the lack of memory space and huge command processes which a regular computer cannot handle. Another issue is the limitation of Python database access. In comparison with technologies that are internationally recognized such as JDBC and ODBC, the Python database is considered to be underdeveloped, in some situations, it might not be able to be applied in the enterprises that require smooth interaction of complex data [52]. Last but not least, python records show sighted issues with the design of the language, that is because the language is dynamically written. It is reasonable to assume that more testing is required to have fewer errors that only show up at runtime [51][50].

4.5 Suggestions and proposed solution for enhancements

Several solutions and proposals were suggested for the optimization of those scripts, to avoid common issues such as storage, performance, and speed. The first aim is to make the script more computationally efficient, creating lists instead of a traditional look [48], which takes more lines in scripting and storage as in the same path location, it is advised to have a binary feature vector that would list the numbers as data points, while the negative numbers will be allocated and the rest will be assigned [53].

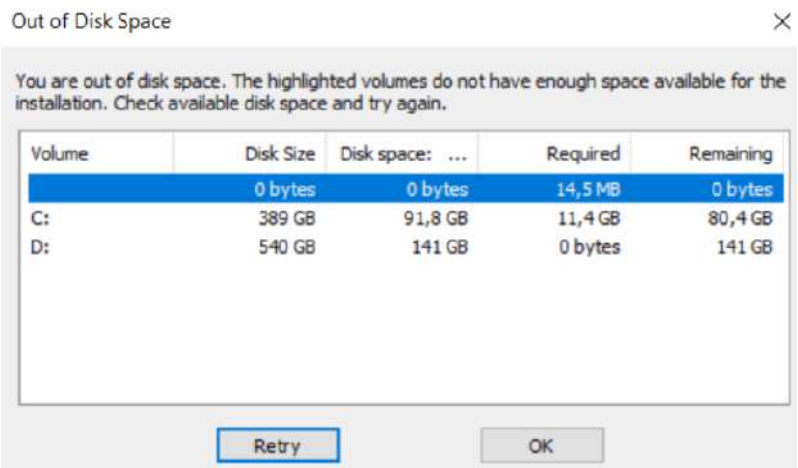


Figure 62. storage error when folder saved

Avoiding loops and comprehension lists would be enforced where possible, that is if vectors were created with one initialization value instead of using inefficient loops. For example, adding the lists and then plotting the XYZ plots. Additionally, the use of unnecessary functions should be avoided, to help cut out a significant amount of the running time and complexity, but it is important to exercise care when making these changes since not all commands have an alternative replacement [54]. Some recommend to not take the risk because it might not work and would result in losing prior script. Fewer functions might lead to less testable code, but by opting for built-in functions such as max, sum, map, it is possible to mitigate these issues. Instead of having to write the computations manually with longer scripts, they are commonly written in C# language, which will optimize the speed of the script with no errors if executed correctly. This process will reduce code-writing lines that can be used for other commands.

Knowing the data structure and how it works in Python will play a major role in optimizing the script and setting plans and goals, as well as avoiding duplications and future errors that will be faced in the project. It is proposed on how Python data structures are piloted and can be saved in the memory. For instance, referencing may be redundant when looking for a key in a dictionary. An extra list of the keys can be created, for example, so less time is needed for the script to look for the references [54]. If there is a list of items and processes proposing the lookup in a set, it might be elicited to turn the list into a set, in other words, if the script is looking up one of the items in the list, it will make things more complicated. However, if the list is turned into a set first behind the scenes, Python will iterate over the list and add the items on to a new list. The creation of the overhead set will make it a disadvantage otherwise. Therefore, removing duplicates from the list and casting it will be a very good option as an optimizing command feature [54].

5 RICS REVIT PROTOTYPE PLUGIN

Figure 63. BIMA+_RICS_BOQ

The prototype was generated and divided based on the survey and the interview formerly conducted. The outcome and additional comments from companies were generic and all focused on several matters in regards to the generation and security of the documents generated from the BIM model such as QTO and BOQ.

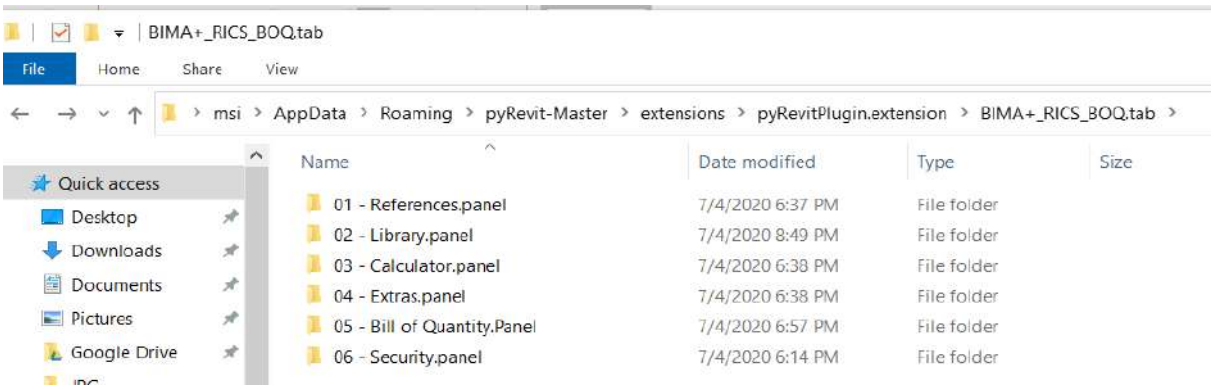


Figure 64. folder path for plugin prototype

The prototype is produced by creating a folder in the programming folders of Revit, under (*This_PC/Appdata/Roaming/Pyrevit/Master/Extensions/Pyrevitplugin*). To insert a tab, it is necessary to first establish a folder with the title being the designated tab label, for instance, BIMA+_RICS_BOQ, and then add a *(.tab)* extension so the computer will understand the language and translate it into a tab plugin on Revit.

After establishing the tab, it is important to generate panels, these are subtitles for the features of the plugin. In this package, there will be six panels that will be powering the features which are: References, Library, Calculator, Extras, Bill of Quantity, and Security. Every panel will focus on one matter that will be serving and supporting a field that is important for the generation of the BOQ. These panels will be generated when the user creates a new folder inside the tab folder followed with a (.panel) extension for instance (*References.panel*) [53].

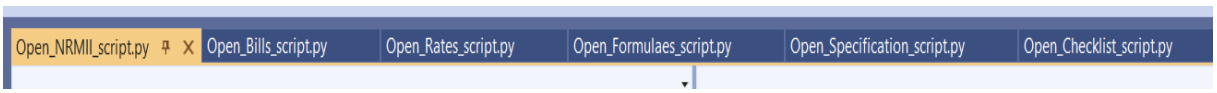


Figure 65. Python scripts powering plugin

In the last part of the ribbon development a push-button is designed, this is done by inserting a new folder with the title and then followed by the *(.pushbutton)* extension, for instance *(appendix.pushbutton)* [54]. Lastly, inside the folder, the script needed will be available for the button, the script is simply saved as a python script with *(_script)* so the computer will recognize it as a script, this way it would run when the pushbutton is pushed. For instance, *(Open_Appendix_script)* For the icon on the pushbutton to be presented on the ribbon you must insert the icon logo and name (*icon).* The prototype is generated and processed when the Pyrevit is refreshed and opened.

5.1 References

Figure 66. 01 Reference plugin panel

The reference panel is dedicated to providing the user with documents that support the generation of BOQ, such as the appendix of NRM II, which contains the templates that are summarised and extended based on the project requirements and work process, as well as a whole PDF copy of the NRM II book, which can be used by the users to read and expand their knowledge on the standards without risking unreliable sources of BOQ generation [54]. The folders contain the icon of the push button with the python script commands that request opening the PDF folder of the appendix or the NRM II book.

5.2 Library

Figure 67. 02 Library plugin panel

The library panel focuses on storing and showing all the BIM-related terminologies when the user requests so. There will be a push button in this panel - a link to the BIMe initiative dictionary. BIM dictionary contains hundreds of dictionary terms and descriptions that are used in construction and design projects. It will show a detailed description, synonyms, and abbreviations of that dictionary. The objectives of the dictionary are several and include promoting digital innovation, providing a research-driven description, and translated terminologies to all languages around the globe, providing reliable data sources that engineers can trust.

Another pushbutton will be a customized library. The user will be free to add any terminologies or definitions they cannot find easily online especially if the terminologies or abbreviations are used frequently in the project [54]. The feature was recommended by construction companies since they usually face obstacles when an engineer joins the team in a late phase of the project, time will be lost time in getting the engineer up to speed with all the different perspectives, such as the process and terminologies used in the project.

5.3 Calculators

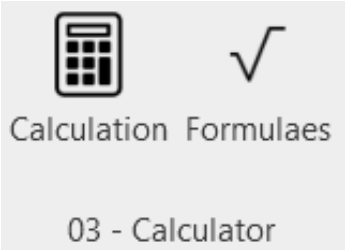


Figure 68. Calculator plugin panel

The calculation part will focus on the formulas used and processed by the software to work the plugin. There would be two parts for the panel, one to check manual calculations if needed for any referencing at the site or the department, and another to be used as storage for any additional formulas inserted and used later in the project. Such formulas can vary from one country to another.

The calculations will be customizable since, as stated above, some measurements vary from one country or region to another, in addition to the standards and specifications needed by the client. For instance, the United Arab Emirates will be focusing more on generalizing standards under government law by their personalized standards that are influenced by POMI, while some British investors in the UAE force the usage of RICS NRM II standards in their projects and investments [4].

The commands will record all the required data and information by the user or the project team, providing a point of reference for all users. These formulas can be linked to the model by identifying all the denominators and linking them to the areas needed, as well as using a default list of formulas that are published and authenticated by the British Board of RICS, and the NRM II to be more specific.

5.4 Extras

Figure 69. Extras plugin panel

Extras are unstable references that are updated by the hour and (in certain situations) per minute and per country. These vary from one region to another. The numbers are predetermined by governmental heads and representatives. One such element is the construction rate - these changes are labeled by the ministry of labor and sometimes proposed by the Engineering/Construction labor union.

The construction rate is shown on the website, the readings are up to date, these readings are taken for the BOQ generation, whereas the calls of statistics for quarterly indices on the cost of construction of a new project. All rates are inserted manually into the BOQ, taking into consideration the unknown data for some specific regions, such matters can use the construction producer price indices (construction output price index CPPI). This link will constantly be updated with all the information given and published by governments. It would benefit the BIM user since they would not need to check manually every time for a reliable source to work on the BOQ.

The specification button will be focusing on providing reliable specific documentation that would benefit the user. The push-button would specify the general standards of materials and workmanship required per capita and according to the department, this would also include the type of the building

such as small residential buildings, commercial buildings, or medical facilities. This applies to all types of works as well, such as refurbishment, new work, restoration, and maintenance [55].

The tax pushbutton will show the updated website with all the construction output tax rates. This will help the user with all matters related to tax calculation depending on the country, showing the important level of the indication on how the construction economy in the country is performing and linked to the Gross Domestic Product (GDP) of the country [48], [56].

5.5 Bill of Quantity

Figure 70. Bill of Quantity plugin panel

This panel will focus on the generation of the BOQ automatically, it contains four push buttons and they are the bills, BOQ, checklist, and export. The pushbuttons are designed to either generate a whole BOQ or a separate bill in case one is needed for internal work or referencing for the contractor, as well as checking prices and finding ways to reduce costs.

The bills can be generated individually if needed or if the tasks are distributed between the team, optimizing work, and team performance without having to rely on the other party to finish their tasks. The structure provided by NRM II would be implemented in the pushbutton, prompting the user to specify which bill they would be working on [27]. After the bills are finished, a pushbutton under the name of BOQ will merge all the bills to form one BOQ for the whole project. The Bills are divided into 45 sections where the bills that are wanted will be used:

Table 3. NRM II Bills

Bill	Title of the Bill
1	Main contractor's preliminaries.
2	Off-site manufactured materials, components, and buildings.
3	Demolitions.
4	Alterations, repairs, and conservation.
5	Excavating and filling.
6	Ground remediation and soil stabilization.
7	Piling.
8	Underpinning.
9	Diaphragm walls and embedded retaining walls.
10	Crib walls, gabions, and reinforced earth.
11	In-situ concrete works.
12	Precast/composite concrete.
13	Precast concrete.
14	Masonry.

15	Structural metalwork.
16	Carpentry.
17	Sheet roof coverings.
18	Tile and slate roof and wall coverings.
19	Waterproofing.
20	Proprietary linings and partitions.
21	Cladding and covering.
22	General joinery.
23	Windows, screens, and lights.
24	Doors, shutters and hatches.
25	Stairs, walkways and balustrades.
26	Metalwork.
27	Glazing.
28	Floor, wall, ceiling, and roof finishings.
29	Decoration.
30	Suspended ceilings.
31	Insulation, fire stopping and fire protection.
32	Furniture, fittings, and equipment.
33	Drainage above ground.
34	Drainage below ground.
35	Site works.
36	Fencing.
37	Soft landscaping.
38	Mechanical services.
39	Electrical services.
40	Transport.
41	Builder’s work in connection with mechanical, electrical, and transportation installations.
42	Risks.
43	Provisional sums.
44	Credits.
45	Daywork (Provisional).

The checklist pushbutton is an additional feature that will help the users determine which bills are done and which ones need additional work or corrections, as noted from the team. Especially if any other matters need to be addressed and pointed out, whether they are unidentified or clash with one another, which would affect the project as a whole and create risks within the calculations [54].

Last but not least, the export button will offer the type of folders the final BOQ can be exported to. Based on the survey formerly mentioned, most of the companies export to PDF, Excel sheet, or even JPEG. So an option will be available to the users to decide what format to export to and submit on.

5.6 Security

Figure 71. Security plugin panel

BIM security measures are considered to be added to the plugin for the confidentiality and security of the project. The panel will contain two main elements that will make sure the BOQ export is not leaked or stolen by competitors [57]. The importance of security in such matters is paramount since there are financial and reputational risks involved in the process. Making sure that no forgery that might lead to corruption, or any data theft or leak by the user, whether intended or not, for sale to competitors in case the data ended up in the wrong hands.

The first push-button will provide a watermark. It will request to upload the watermark and then insert it on the final export folder for authentication, or to make sure that the copy is not used for other purposes such as official documents if not warranted or permitted, or simply ensuring that copyrights are not breached [27]. The second pushbutton will be used for hiding the project's identity. Some project that is governmental based tries their best to maximize the privacy by hiring representatives to do the calculation without giving the name, location, and purpose of the project for the engineer. The push-button will assist with this matter by removing any titles, companies, and client names or logos to hide such information from outside parties.

6 CASE STUDY TESTING AND TRIAL

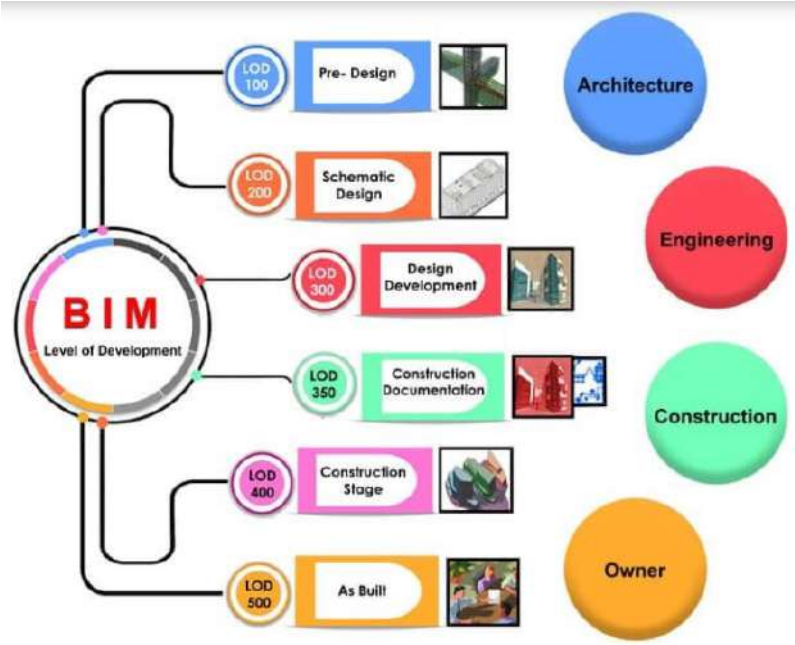


Figure 72. LOD determination diagram [67]

The case study was carefully prepared for the research, it was observed and analyzed properly in a real-life scenario. The model of the project was done on a BIM-based software (ArchiCAD), it showed a high level of detail that is essential for the BOQ process [58]. The IFC folder required a supercomputer to be opened and see all the details to start the analysis.

Two IFC models are used, one labeled as old, and the other is labeled as new. The models show the current situation of the building and then the new proposed refurbished project. The primary target is to spot the difference between the two models, and then record the new installments on the sheets of the quantity takeoff, with all the measurements and the necessary specifications needed for the study. This data is later transferred onto the BOQ format that accounted for forty-five bills, each of which has a different area of focus.

For the calculation process, the model must be imported to Revit to specify unidentified items and then run the entire model through the plugin. For the semi-traditional BOQ style, the model needed to be imported into a software that has two features which are an IFC interface and an exporting folder feature. The plans should be exported to the DWG format and then into PDF format. These matters will take a considerable amount of time due to the high level of detail.

The three BOQ generation approaches (Plugin, cost x, and traditional style) are analyzed and compared with regards to their efficiency, accuracy, and most importantly time consumption and level of experience needed to generate the BOQ [27]. The conclusions will reveal the most suitable approach and the most efficient for the professional and the project in general.

The model is provided by Styria Architects, The architecture firm had a very important landmark in the European architecture market. Allot of important facilities were built after plans created by Styria Architects, such as the Cultural Center of Arnold Tovornik, the emergency center of Novo Mesto, and many more [59]. The model of the kazina building is modeled with high standards and levels of details that meet the plugin criteria. Thus it was granted to be used for the case study to set a margin of accuracy.

6.1 Generic project briefing

Figure 73. Kazina Building

Kazina building in Slovenian translates to a casino building, it is an important historical building located in the capital city of Slovenia, Ljubljana. [60] The building has a Neoclassical architecture style. It is located in the northwestern corner of the Congress Square of Ljubljana, next to the crossroad of the main central street of the capital. Historically, it was considered a meeting place of the city's upper classes. In current days, the casino building adapts several institutions, such as the institution of modern history [61], Slovenia archive, France Marolt academic folklore society, and the tone Tomsic academic choir.

The building was erected in 1837 to serve as the city's high society social club. It contains a well-stocked library that is open to the public and a hosting venue for a variety of historical, social, and other important events in the city. Currently, the building is undergoing a transitional phase to add other features, with demolition and refurbishment actions set to generate area for the new faculty of music that will be integrated into the casino building [60].

Kazina Palace took 2 years (1835-1837) to built after the architect Benedikt Muller designed the building for the upper-class citizens of Ljubljana [62]. The building is 59 meters long and 29 meters wide. The building contains three stories and a basement. The basement walls consist of a solid mass made out of stone masonry. In the south part of the building, there is a big hall that was used as a large dancing hall back then. This hall is located on the first floor with high slender piers and stone columns. Based on research there were no damages recorded for the building following the earthquake in Ljublijana back in 1985 [62].

The model for the Kazina building was analyzed and it was determined that the LOD level is expected to be 350 or 400 based on the software, and the information provided in the model. Some items are not identified accurately, this will be resolved by setting a replacement or identifying the item without leaving it blank, which would affect the accuracy of the BOQ. There are two models for the project: one is the old building without intervention, and the other is with the new installments and refurbishment works [60]. The objective is to compare the plans and spot the new installment such as new interior walls and furniture. This process is documented through the QTO and then processed to the BOQ.

6.2 Quantity take-off analysis

Quantity take-off varies from one style to another, the generation of this folder would be vital because it is considered the base of the final BOQ [60]. It is also indicated by Quantity Surveyors that when an error occasionally occurs with the calculations, the quantity take-off is considered as a starting benchmark instead of starting over again. The three levels of technology intervention vary based on how old the chosen process is.

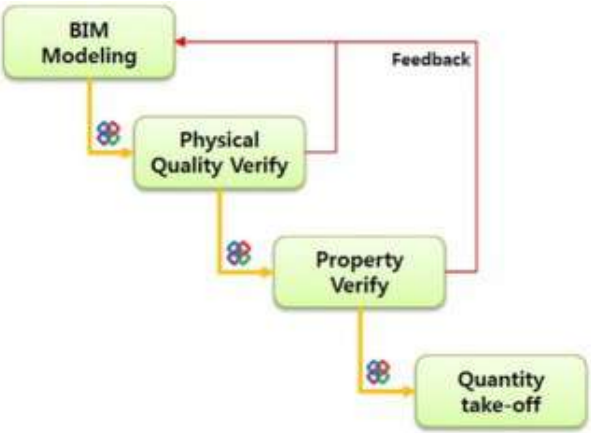


Figure 74. Quantity Take Off waterfall flow chart [63]

The traditional style is the least interactive with technology, as it was established long before the revolution of the computer. Quantity surveyors are given hand-drawn plans with detailed readings to extract and generate the bill of quantity. Engineering instruments are used to extract accurate measurements such as rulers, compasses, etc. [60]. The QS is provided sheets of papers that are called the Quantity takeoffs in which they have all the reading measurements and their locations. All this data is organized and assembled in the BOQ as a final product.

Cost X intervention can be approached regardless of whether the project has two dimensions or three. For this research, it was selected to be observed the second dimension was selected to see that is due to how much time it would require and, be compared with the final plugin output [63]. as a final. PDFs were extracted and then imported to the software. Measurements are taken from the software and recorded after all the reading is done [63]. An excel sheet is generated with all the measurements. Forever items a new sheet is formed and therefore the final QTO was used to process the BOQ.

In BIM, 5D connects a 3D object and its parts for the entire assembly of the model. It is established that whenever changes in the model occur, the calculations are changed based on those changes. QTO in the BIM platform is created based on the primary QTO, which is linked to the BOQ, making a huge impact on time efficiency and cost [63]. The QTO can be extracted to an Excel sheet or any type of format needed when necessary. It showed a reduction in the iteration for estimation, approximation, bidding, and accuracy. It is also believed that the QTO in the BIM project brings certainty in planning logistics and scheduling.

6.3 Traditional BOQ template style summary

The traditional style requires time since every reading and measurement is taken manually. This process takes place before the technology intervention and the accuracy is based on several factors, such as the level of experience of the quantity surveyor, as well as the time given to deliver such a proposal with no flaws and errors [64]. Furthermore, the chance of getting a high risk of errors, if not checked multiple times, if there was an error in the reading and calculations, the user is expected to repeat the procedure at least twice and then given to another team member to repeat the procedure and the measurements and final calculations should be identical to pass to the next step.

For this case study, great care was taken to ensure that the bills of quantity are prepared based on NRM II, which is a widely known methodology. It helped prevent common ambiguities and misunderstandings that would take time when other engineers attempt to read it. Not to mention avoiding disputes that would take up even more time. The extracted plans of the building are printed into sheets and then analyzed by comparing the plans and reviewing what is added and what is not. This matter is later documented manually ahead of the next steps taken [29].

Table 4. Traditional BOQ checklist and bills

Section	Title	Included in Project
A	Preliminaries and general conditions.	Not Included
B	Complete buildings, structures, and units	Not Included
C	The existing site, buildings, and services.	Not Included
D	Groundwork.	Not Included
E	In situ concrete and large precast concrete.	Not Included
F	Masonry.	Included
G	Structural carcassing, metal, and timber	Not Included
H	Cladding and covering.	Not Included
I	Waterproofing.	Not Included
J	Linings, sheathing, and dry partitioning.	Not Included
K	Windows, doors, and stairs.	Included
L	Surface finishes	Included
M	Furniture and equipment.	Included
N	Building fabric sundries.	Not Included
O	Paving, planting, fencing, and site furniture.	Included
P	Disposal systems.	Not Included
Q	Piped supply systems.	Not Included
R	Mechanical heating, cooling, and refrigeration systems.	Not Included
S	Ventilation and air conditioning systems.	Not Included
T	Electrical systems.	Not Included
U	Communications, security, safety, and protection systems.	Not Included
V	Transport systems.	Not Included
W	General engineering services.	Not Included
X	Building fabric reference specification.	Not Included

Based on the Civil Engineering Methode of Measurement (CESMM) and Common Arrangement of Work Sections (CAWS), the standard categorizing procedure for the works is based on the following steps that are to be adopted fully in the process.

The QTO is then generated based on the items that are needed to be inserted in the bill. After the QTO procedure, the project is labeled and segmented per bill, and then all the final calculations and specifications are added by the engineer [24]. Notably, this system is passing through a considerable change, NRM and CAWS are rapidly changing because the procedure is getting harder, and it is becoming more reliant on modern technology to procure the results more efficiently.

6.4 Cost X BOQ template style summary

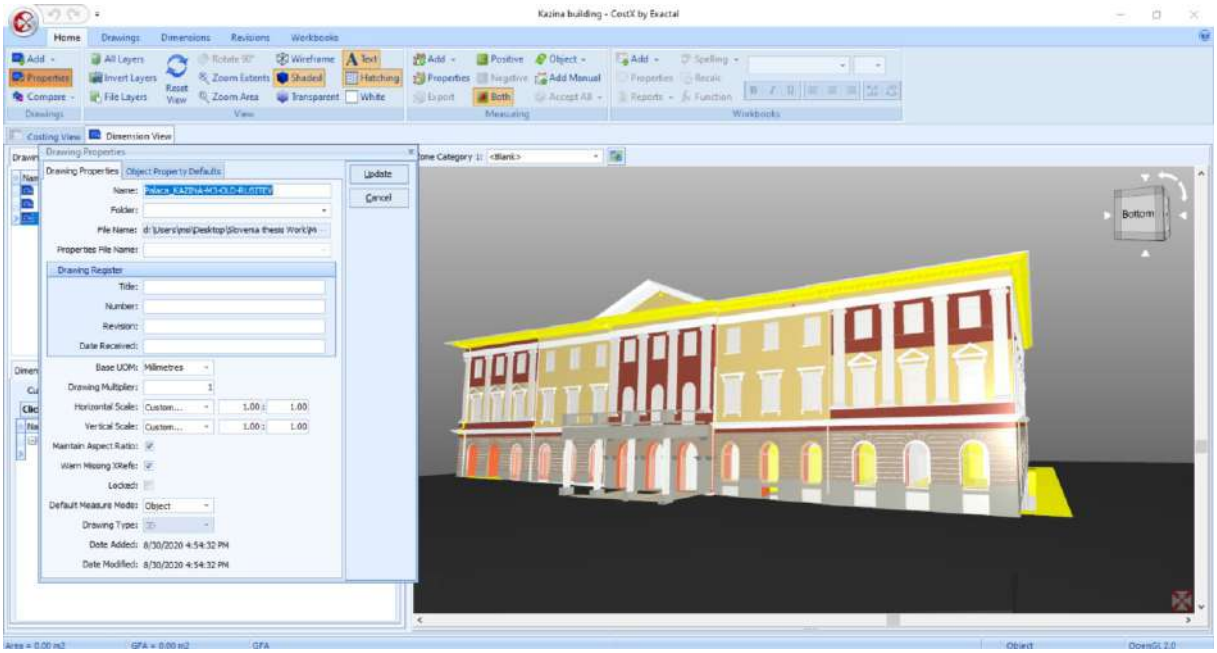


Figure 75. CostX- IFC model import Model: Styria Arhitektura

The IFC model is used to extract 2D drawings to be imported into Cost X. It is commonly advised to import the 2D drawings in PDF format to proceed with the measurement calculation. The IFC model was a challenge to be imported into a BIM technology software, where the plans can be extracted as a DWG folder and then, later on, exported once again from AutoCAD to PDF [41]. Before the project's starting process, a minor analysis was formed to compare both models and determine the scope of the project for the new installments. This process is done by comparing the old kazina building IFC folder with the new model, the installments are finally marked and the project is ready to be launched.

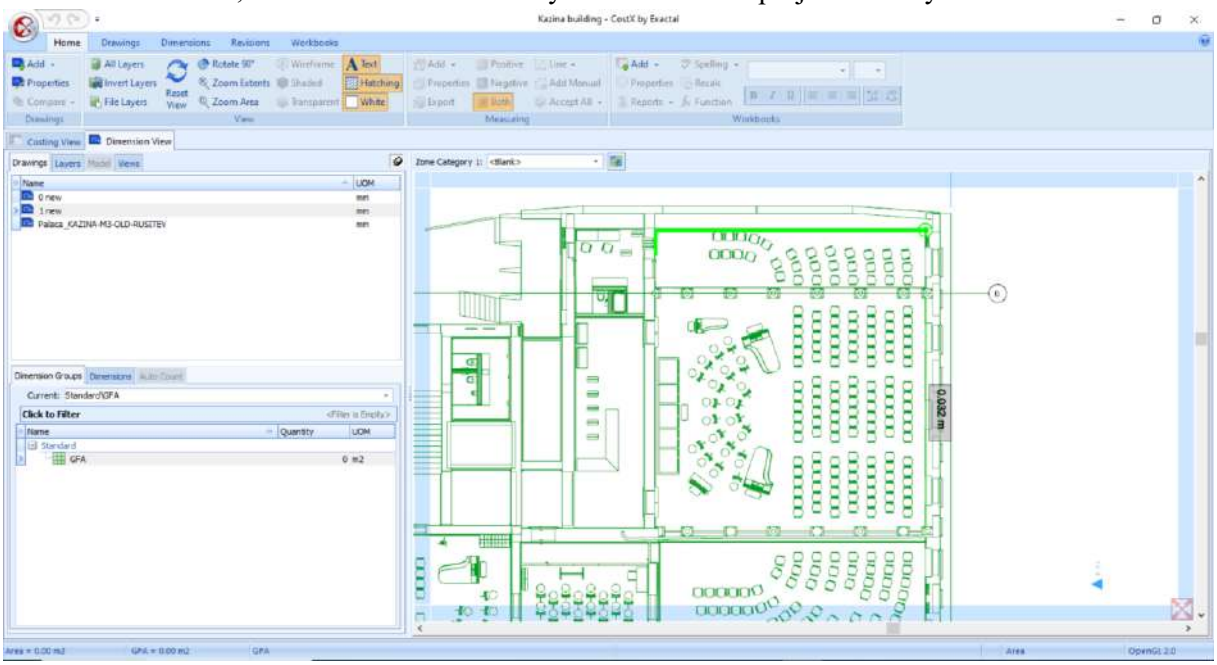


Figure 76. Cost X measurment extraction Plans extracted from model: Styria Arhitektura

The quotation process was readily documented since all the information is provided in the IFC model, this saved time and analysis on the project since this information was accessible and all questions were answered. The process is usually done when a formal offer to carry out the job or certain tasks for a specific price is negotiated [27]. The exceptions would be if there is a specific and accurate allowance for the different variations that change the prices of certain materials. The process is progressing under careful supervision, where the quotation documents are prepared for the client to view, based on the forms of the contract which both parties signed upon the client's approval [65].

The plan is then inserted into Cost X and rescaled based on the generic measurements extracted from the building, meaning that all the lines are in the same proportions as the original plan. The data is then exported to a CAD drawing, which is completed using a computer if time is available to have a final professional outcome. The proposed sketch is verified to be feasible and proportional if drawn properly if a line in the plan measures to 100 mm in real life the scale will be as follows:

10 mm (on the plan) = 100 mm (in real life), which is a ratio of 1:20

The scale rule allows drawing lines up to a specific scale without the requirement of a grid. Other scales most commonly used in this field are 1:5, 1:20. 1:50 and 1:100. The building floor plans are commonly proposed in a 1:100 scale, to show the whole scope of the building on one building plan up to scale and on one sheet of paper instead of several. Some drawings might require bigger plans where the scale used would be 1:50, this would show more details needed for the project. The final selection on Cost X will depend on the number of details needed to be worked on.

After the plan is understood and imported in the right scale and proper way. The Quantity take-off will take action, where all the measurements will be calculated and filled in the sheets and then analyzed to start forming the documents, which will conclude the BOQ. Some readings are revised in case of illogical readings, or if any changes occurred in the main model, or if budget cuts arise in the project. The group of quantity, cost, and value engineers will check the work, and all the readings are proofed and corrected with every new item identified in the BOQ, the process will then start again and all the data obtained in the Quantity take-off phase will be transferred to the pre-final draft of the BOQ.

The BOQ template is formed on an organizational software, most engineers use an Excel sheet. The new rule of measurement division and templates are used for this case, and the sheets will have a specified title on the top with the logo, the bill number, and any subdivisions. The BOQ is divided into 45 bills which are available in the appendix (Refer to appendix A2), every bill will have a specific field that will be covered. Since the case study adapted is a refurbishment project, it mainly focused on the floor, wall, and furniture installments, which limited the bills needed to be generated for the project.

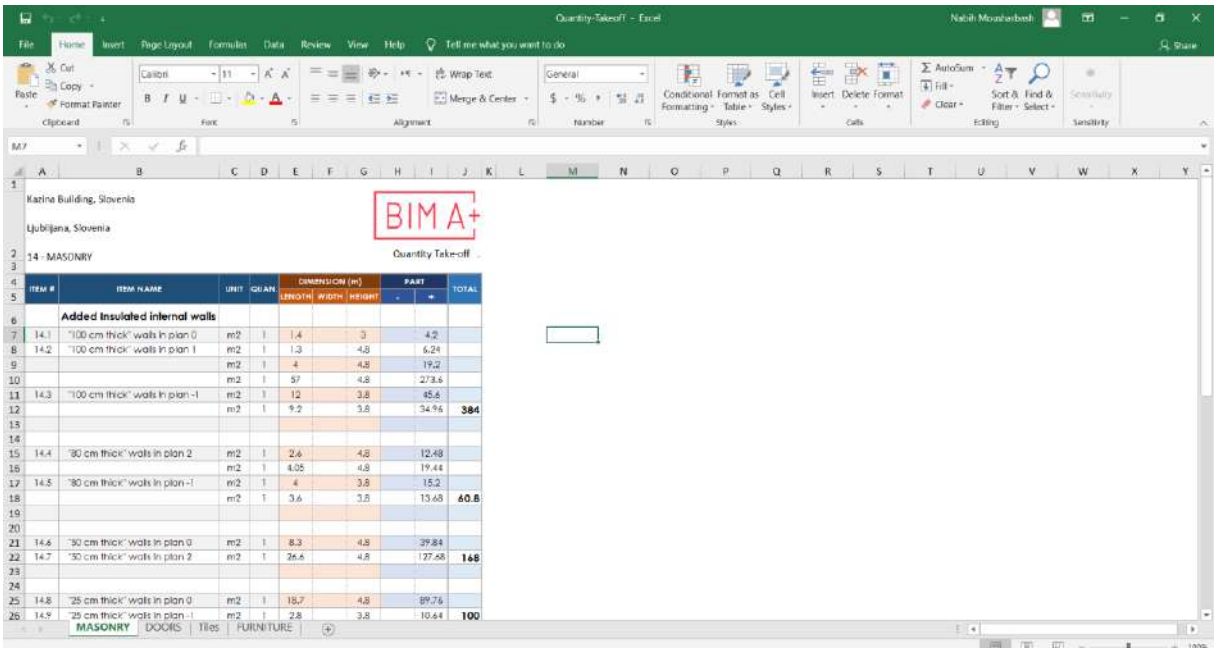


Figure 77. Exported Quantity Take Off readings taken from model: Styria Arhitektura

The bills are generated in Excel and all the measurements and specifications are priorly done. Even if some of the bills are not mentioned in the BOQ, they must be inserted and crossed out as N/A to meet the RICS NRM II common standards, this BOQ is later given to the client, and they are asked if the process is to be kept anonymous or made public [27]. Based on that it is then decided whether the bill should cross out data that is related to the building identity or not.

6.5 Plug-in BOQ template style summary

The generation of BOQ through the plugin is a sensitive and accurate process. The model should be well detailed before running it through the commands [66]. As mentioned prior, the model is imported in IFC format. The first task is to import the model and then explore it on Revit so the API would identify the items and proceed with the work.

Many cases require the model to be rebuilt, and the items are replaced with missing data from the original IFC model, to avoid loss of identification in the specifications. The model used for the case study did not face this issue and had a successful outcome. The exterior facades were unidentified during the import of the project but had no actual effect on the trial since it is a refurbishment project. Therefore,

the IFC model was exploded and some adjustments were made to meet the minimum level of detail that is required for the plugin [66].

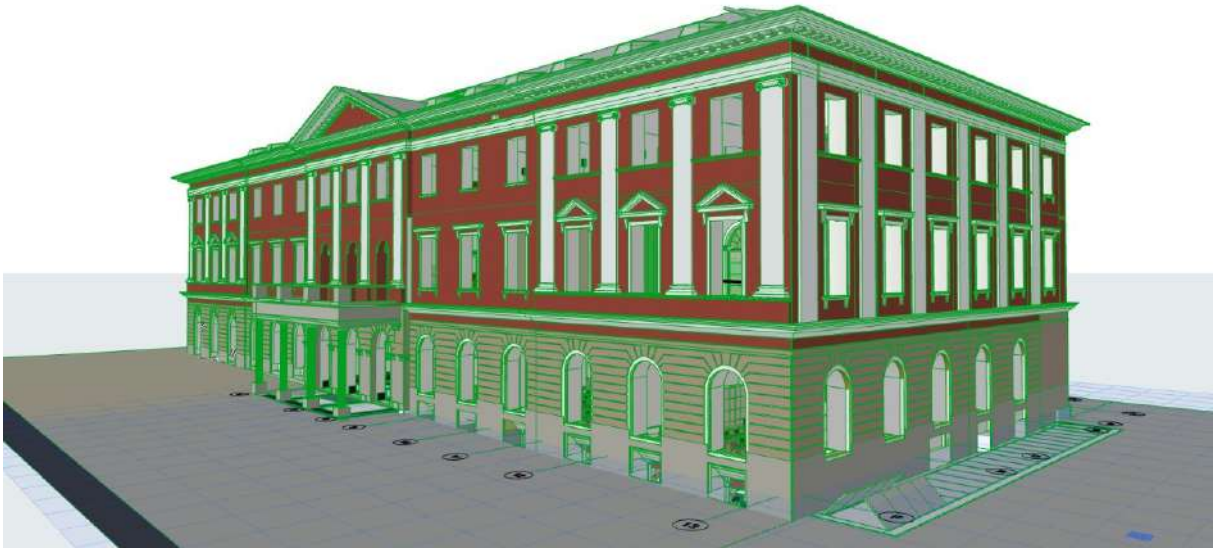


Figure 78. Imported IFC model to revit: Styria Arhitektura

After the specifications were created and if meeting the LOD specifications, the model is run through the plug-in where it would first identify the model items [67]. This process takes based on the scope of the project, in this case, study, the process took around 5 – 10 minutes to identify all the items and their specifications. If any errors or missing items occur during the identification process, the bill of quantity if specified, and measures and documents the data without any specifications or title.

The issue was resolved by checking the BOQ manually and spotting the unidentified items and running the script again, the script was run three times to meet the accuracy rate and identify all the items together. After the third run, the BOQ is 99.6% accurate, passing the NRM II standards which set the accuracy range at 5%. [27].

Table 5. Plugin trial error rate

Trial Number	Items identified (%)	BOQ error rate (%)
1	90.6%	+9%
2	98.2%	+4.2%
3	100%	+0.4%

The calculations of the script start with counting all the identified items and then dividing them by all the items in the project. The calculation of the BOQ is then done by comparing both BOQs and subtracting the difference, the result is then divided with the average of both readings.

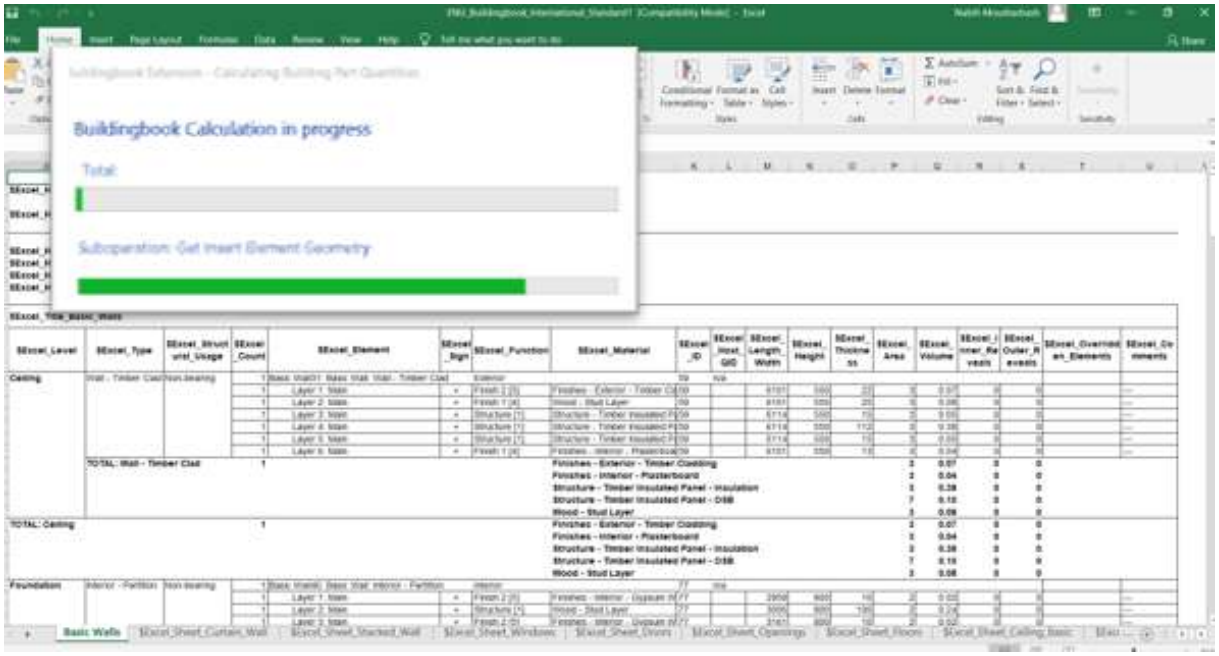


Figure 79. QTO reading extracted from imported IFC model on Revit

The final readings BOQ produced by the script are then exported into an Excel sheet, and if needed could be saved in PDF format to submit for the client and the team, for pricing or as a reference for the tender selection process of the project. The extracted BOQ of this project's case study is used only for educational purposes since it is generated by a student researcher and not an expert.

6.6 Experts comments and regards

A group of experts was requested to evaluate all three exported data sets and readings from the case study, (traditional, semi-traditional, and plug-in). Four groups of experts were formed for the feedback. They were labeled (A, B, C, D), divided as follows: 'A' - Civil and construction engineers, 'B' - Architects, 'C' - Quantity Surveyors, and 'D' - Project Managers. In addition to giving all the data generated and given by all three methodologies such as report builder in costx, manual and automatic Quantity take-off… etc

Table 6. Evaluation experts grouping

Groups	Specialty	Number	Level of experience
Group A	Civil and construction engineers	1	Medium
Group B	Architects	2	Medium
Group C	Quantity Surveyors	1	Expert
Group D	Project managers	2	Experts

The groups investigated the exported BOQ data outputs generated from all three methods done on the case study. They were given the data without the project's information, ie. (site, location, function.... etc). The evaluation is based on five main milestones: the template, accuracy, standards implemented, time, and quality of the BOQ. The groups were asked to evaluate every milestone of each style separately on a scale from one to five, where one denotes the lowest grade and five denotes the highest.

6.6.1 Traditional style

Table 7. Traditional style groups evaluation

Groups	A (1-5)	B (1-5)	C (1-5)	D (1-5)
Template	5	4	5	3
Accuracy	4	3	5	4
Standards	4	3	4	4
Time	1	2	1	1
Overall review	3.50	3.00	3.75	3.00

The traditional style was the first matter of discussion within the groups. Quantity surveyors (Group C) stated that, although this process is time-consuming when generating the BOQ, it is optimal to reflect on other milestones within the project such as the accuracy, standards, and templates. However, The architects (Group B) and the civil engineers (Group A) noted that this process could have less beneficial readings since the outcome could include inaccurate readings and need to be repeated.

The template was presented to all the groups. The exported template was checked by experts before it was delivered, removing all occurring errors. The project managers (Group D) emphasized that time would be the biggest issue in this process as the project managers would face obstacles within the timeframe, thus increasing disputes between both parties.

6.6.2 Cost X style

Table 8. Cost X – BOQ evaluation

Groups	A (1-5)	B (1-5)	C (1-5)	D (1-5)
Template	4	4	3	3
Accuracy	4	4	4	4
Standards	3	3	2	4
Time	3	3	3	4
Overall review	3.50	3.50	3.00	3.75

The semi-traditional style is the most preferred by all groups. It balances between all the milestones proposed, making it is faster and more accurate in procuring the final readings. Some groups, on the other hand, pointed out how the templates and standards of the BOQ generated in this process (using Cost X) are not as good as the other templates in the construction industry. The readings and the template generation were done manually. Quantity surveyors (Group C) mentioned several times that those standards would not be accepted if the standards and measurements do not match. Therefore it does not wrap up the BOQ as a whole.

In conclusion, all groups agreed that this approach may be acceptable depending on whether the financial condition meets the budget and the cost of generating the project on this software, as well as the availability of experts with good and rigid knowledge of the software to generate a proper and accurate quantity take-off, to make the BOQ and measurement process easier.

6.6.3 Plug-in style

Table 9. Plugin evaluation

Groups	A (1-5)	B (1-5)	C (1-5)	D (1-5)
Template	4	3	3	5
Accuracy	5	5	4	5
Standards	4	4	4	4
Time	5	5	5	5
Overall review	4.50	4.25	4.00	4.75

The plugin prototype was the most notable approach for all the groups, its outcomes covered all the important aspects, such as time, accuracy, and standards. The project managers (Group D) state that it is the best approach from all three. Some comments were made regarding the standards of numbering, which had errors, and the group expressed their expectation to see these modified and enhanced in the next stages of development of the plug-in, should development continue.

Architects (Group B) and Quantity surveyors (Groups C) did not give feedback on the template of the final exported folder since it had numerous debugs, such as the alignment of the texts and the insertion of the header on each bill. Furthermore, it was debated how much can be resolved, and in conclusion, it was suggested that the header be edited before exporting to a PDF format, which, although time-consuming, would take less time in the long run than generating the whole BOQ from scratch traditionally or by Cost X.

The construction and civil engineers group (Group A) stated that the main concern of the project is the unidentified specifications and objects that occurred in the first draft of the BOQ. It was noted that it would take time to check the BOQ before exporting and remodifying the items in the project before the script is rerun, finding the missing details in a big project would be challenging for the BIM modeler and managers, hence it was advised that for the newer version to contain a popup highlighter to optimize the time usage.

6.7 Summary conclusion of feedback

Overall, the Kazina building is a challenging building to generate BOQ for, since it is not processed from scratch. It was a challenge to ensure that all the data is modified and elaborated upon before processing any of the three approaches. Furthermore, the importing process of the model was a huge challenge as well, especially in terms of extracting data and processing the information. A machine with strong computational power should be used in such a project and process.

The traditional style was the most time consuming among the three, as it was required to do a Quantity take off that is written manually, by hand. The readings and measurements should be taken in a very accurate matter to avoid any errors in the process. The drawing was exported from Revit to AutoCAD and then to PDF and finally printed to perform the full traditional style trial with no technology intervention in the process.

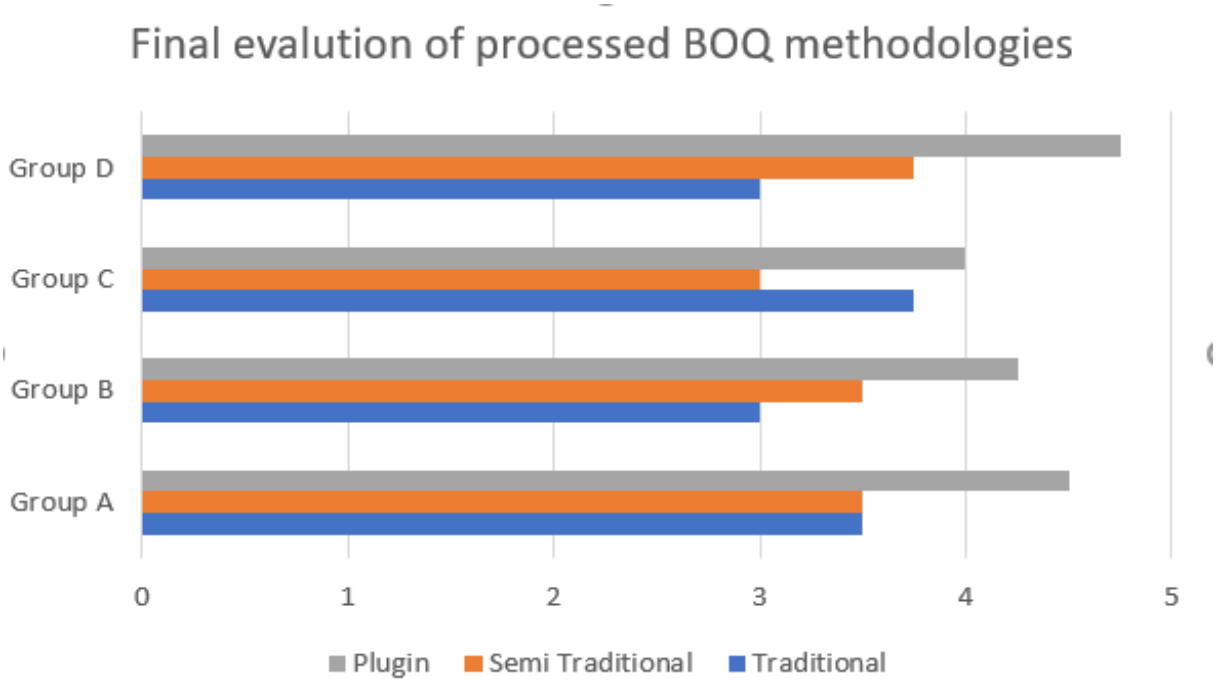


Figure 80. Final evaluation of processed BOQ methodologies chart

Cost X was ranked as the second-best after the plugin. However, it is recommended by experts to keep this style of BOQ for the time being, before switching to BIM. This is mostly because a quantity surveyor will be checking the readings manually and use Cost X to extract the accurate readings, which will then be added in the quantity take-off and located in the bill of quantity with full NRM II standards and template.

The plug-in was considered a recommended feature but still needs some modifications regarding its interface, such as highlighting unknown and unspecified items in the bill and introducing a solid and accurate template, that does not have unaligned headers and columns, thus matching the output of the project.

Table 10. The average evaluation of BOQ templates in different approaches

Groups	A (1-5)	B (1-5)	C (1-5)	D (1-5)
Traditional	3.50	3.00	3.75	3.00
Semi Traditional	3.50	3.50	3.00	3.75
Plugin	4.50	4.25	4.00	4.75

Experts highlighted the potential of the plug-in and highly advised that it should be tested in several offices and different types of projects to expose it to all the aspects and wide variety of items and specifications the industry offers. And based on the comprehensive test outcomes, the plug-in would then have to be modified and tested again until it perfectly meets the standards for the industry.

7 DISCUSSION AND SWOT ANALYSIS

The plug-in has many conceivable advantages but is naturally not without disadvantages. The final aim is to produce a plug-in that will help out with time-consuming processes to help move the profession and industry forward. Several matters presented big obstacles in the generation of the plug-in, and it must be a long-term goal for the plug-in, if adopted, to aim to satisfy the needs of workers in all fields of the industry, whether in high managerial positions or junior staff any given project. The survey certainly helped in that regard, since it sculpted all the additional features and matters that were not initially addressed.

In terms of the language, Python proved a perfect match for the project to be executed with, even though the script was complicated to adapt, and the time needed for it to be read and reprocessed to make sure it is running smoothly and no setbacks affect the model, computer, and the software. To sum up, Python rose above other languages in this task and consulting with programming experts verified this conclusion.

The case study adapted had several levels that needed to be resolved to pass the plug-in software. Firstly, the format folder needed to be explored to make the file transferable and then reassembled to pass through the plug-in. Secondly, the LOD did not originally match the plug-in criteria, where errors were found in the first trial run of the plug-in. While this process still takes time, it will not take as much time in the long run as the prior traditional style approach.

7.1 Strengths

At the primary layer of the 4th and 5th dimensions, this plug-in can be beneficial in various ways, should engineers come to use the tool and their usage lead to further developments on the plug-in. For instance, leveraging from the references will help ensure that all the information is correct and prevent any errors. Likewise, an extra section is present to provide updated platforms where the engineer can find rates, specifications, and tax readings per week, per location, and per country.

Another benefit is the library feature, where you can use an extensive and well recognized BIM dictionary that is powered and generated by the BIMe initiative. The feature will help out with all construction technology terminologies that users would face during the project execution phase. An offline feature is added as well where the user can store his personalized library and write down the definitions manually in his style to understand.

Security being a very important matter for the model, it was highly advised to have a protected system to avoid risks to the model and the hub. Several beneficial features were considered and tested to be part of the plug-in, such as watermarking any exported data to avoid fraud, plagiarism, and information leakage. Moreover, in cases where the project required discretion, regardless of the reason

(governmental, military....etc) and the project is to be proposed to construction firms in the public sector forbidding, the pushbutton will erase all information that is generically related to the project and keep only the items and the bill format so the construction engineers can place their bids without knowing the project until the selection is made.

The most important aspect is the BOQ generation. When all the requirements are fulfilled, the script will be run, as this occurs, the items are identified and prepared to be exported into the format desired by the users and the client. The time needed for the process to extract the full readings is a fraction of the time to export data from any different approach. All in all, the conceptual approach of the idea is rigid and strong and has great potential going forward.

7.2 Weaknesses

even though the pros of the plug-in outweigh its cons, some matters would pose a risk or lead to problems in the plug-in if they are not addressed and resolved in the future, should the plugin be published and made accessible to interested users. For instance, the script folder transformation presents an issue that would weaken the plug-in if it is not plotted and spotted properly. Also, API configuration updates should be addressed, especially the prior requirements needed before the plug-in processes the data.

The Script path and location must be configured accurately to be recognized by the Revit interface once labeled correctly. If the folder is moved or the title is changed by mistake or when the computer is formatted, the push button would lose the interface and thus disable features in the plugin. This equally applies to all push buttons (Reference, Library, Formulae.....etc).

Revit API and version updates would also be an issue if the plug-in is not updated parallelwise and new versions developed whenever possible. Autodesk is well known for its rapid change and modification that makes all plug-ins and software that are powered by Autodesk need at least yearly updates. Should these be neglected, the plug-in will not be up to date and if any API system folder of scripting language would change the plug-in would no longer be functional for users.

Lastly, requirement tasks needed before running the plug-in on the project would limit the availability and sources as a whole. The level of detail should be defined to get the proper readings and pass the estimated error rate of 5%. Moreover, the folder format would be limited if it was IFC and required to be exploded and reassembled so all the data in the main model can be specified and rebuilt with no errors whatsoever.

7.3 Opportunities

Expert analysis from all different fields related to the construction, engineering, and tendering document phase indicated that the idea could help revolutionize the principals of generating BOQ within the current field. Many suggestions were offered to improve the software and make it more reliable and user friendly, these opportunities are related to time, accuracy, and BOQ enhancements.

Time efficiency was the main concern and purpose to be achieved in this plug-in. Tests and trials showed impressive results for the readings as well as the generating process which came at a fraction of the time compared to other methods. Based on the studies, surveys, and evaluation, it was highly advised that separating the bills in the BOQ would be beneficial since more than one person can work on the bills. In this manner, errors could be eliminated without the need for further corrections.

Essentially, optimizing time in any way possible is a key for an efficient, accurate, and reliable plug-in. Some items that are not specified or recognized may cause issues with the BOQ. However, they can be simply changed by adding more specifications, and the plug-in restarted within a click. The matter would take more time since the items should be searched for manually without any popup or notification, but one area of opportunity would be to add a highlighting feature where the item will be spotted by the modeler and marked to be resolved.

7.4 Threats

Several threats are taken into consideration for the plug-in. These include matters that affect the project directly or affect the main purpose or even the user himself. These risks and threats, however, can be avoided by setting precautions and making preparations to be dealt with when needed or if any prior foreseen symptoms occur on the occasion.

Cost-wise, the plugin would be expensive to be implemented in the firms since the plug-in is linked per license, this matter would be based on the price that will be plotted for this plug-in. Big companies with low cash flow might not be able to purchase full access for this plug-in as that would cost too much money to process, so the company should be sure and confident to take this step and transform the methodology in the office and provide computers and the right environment for the plug-in.

Experienced workers should be involved in implementing plug-ins to make sure that the execution of the plug-in is flawless and will have no negative effects on the model, server, and the work done up to that point. It is recommended to let people who specialize in quantity surveying take charge of this task. Some minor experience in BIM interface software and RICS (NRM II) bill templates and standards would be an added advantage, of course. The more experience the user has, the more accurate and precise the output would be. Otherwise, certain negative matters might be faced, such as wrong price

and measurements reading, failure to match BOQ RICS standards, and most importantly of all clash errors which could lead to all current live modifications to be erased.

7.5 Closing remarks

Table 11. SWOT analysis for the plugin

Strengths		Weakness	
1-	Fast to generate BOQ	1-	Path location
2-	Accurate BOQ readings	2-	Updated versions
3-	RICS standards	3-	Folder format
4-	Additional features support		
Opportunities		**Threats**	
1-	Make every bill generate individually	1-	Running cost
2-	Highlight pop up feature for unknown	2-	Software, not responding (data loss)
		3-	Experience workers

The work proved the benefits of the plug-in in general, as well as the risks it indicated. Although some matter needs to be modified such template and layout. These matters can be taken into account in the newer version of the plug-in is updated. Another matter that needs to be addressed is the folder path movement where if moved the scripts cannot work. Securing the folder path within the Revit API path to avoid launch failures.

Some investigation should be directed towards the folder formatting and unifying all BIM models more effectively. The matter is open for debate by experts, and the IFC format is leading to many issues where it requires time to modify and make sure all the items within the model are defined and have no issues whatsoever. Also, there are opportunities that the software can offer additionally such as splitting the bills in more detail and generating them separately, making these processes more feasible and optimizing time. Finally, emphasis should be placed on highlighting unidentified items when needed to let the user know where the item lies in the model, as well as how this should be achieved through Python scripting, and what procedures would need to be taken to do so.

8 CONCLUSION

All in all, a lot of matters were learned in the thesis. Firstly, programming was a challenge at first and still is somehow. Languages varied and it showed their strength and weaknesses. The survey and interview showed the importance of the small details that companies pointed out as obstacles such as security and template accuracy. It was also observed that to produce a plug-in that is powered by Revit it is recommended to use python or dynamo instead of other languages since the API recognizes such commands and it heavily supports it.

The feedback on the three BOQ outcomes is beneficial since it showed from an educational point of aspect how engineers and managers think and approach the problems and evaluate the output. It showed every profession what do they prioritize and what they don't. In conclusion, BIM is considered the key to future construction and such trials and approaches would be done in real-life case studies where it would revolutionize the whole industry and take it to the next level.

All in all, generating a Plugin for BIM models was a challenge since it showed matters that traditional style faced and tried to get it over with. The programming showed how the API interface works on Revit and how it defines the items within the model. The prototype concluded how the matter is taken within steps to achieve the goal of data process optimization.

8.1 Summary

In conclusion, the information and terminologies were well understood and defined concerning the related history of development, this leads to today's proposed alternatives for a new dimension in the BIM model. RICS standards have a specified procedure that was tailored to the needs of both parties saving time from unresolved disputes and issues.

Taking into account all three approaches that were done to generate the BOQ of the building, the concept expanded, and features that were added upon a greater understanding of those specifications. Several factors were critical in the processing of the project, which hopefully is resolved but might have formed a small obstacle for the user to process the plug-in.

The survey was a great source of information since it was very diversified with ideas and approaches that the current world of construction technology is dealing with. Additional comments were pointed out that were addressed and added to the plug-in content. Noting concerns regarding matters that would lift and revolutionize the thinking approach of BOQ was duly prioritized throughout this process.

The programming language used for the plug-in was selected based on a careful study on Revit and its API, which needed some training and consulting to be done apriori. After understanding the language, commands were organized and scripted within the software.

The prototype was generated to provide the interface to the user. The plug-in was divided into sections, and the sections were then divided into push buttons, where each had a script and a purpose that serves engineers and BIM modelers during the project. The icons and the scripts are then linked to the push buttons that are assigned specific tasks, and finally, a trial is launched on Revit to observe the given results.

The Case Study is used to test the three BOQ approaches, where all three went through the regular process of a QTO, whether it was made manually, through Cost X, or QTO analysis for the model. A final BOQ is generated and made with the main four bills of focus out of 45 that NRM proposes for each project to have. Between project type, folder recognition, and items output, several errors have encountered that lead to switching the process path into an alternative that was beneficial for the conclusion of the case study and helped crystalize ideas for the new version of the plug-in that shows even greater potential.

Feedback was requested from experts who weighed in with their point of view and their evaluation of the outcome that was contended within the groups due to the different areas of expertise and depending on the features of each profession. All this data is recorded and documented for research purposes and future reference if needed for all experts around the globe.

8.2 Future work

The plugin managed to be done has a lot of potentials, the time process of data within the plugin can be optimized and achieve other related time-consuming tasks. Experts suggested that time expenditure could be reduced if the plug-in had a feature where it would generate measurements per bill and item, and not just per building. It was argued that this would give more space for other engineers to join and work parallel with each other.

Problems and issues that occurred in the research or were brought up through the expert feedback will be taken into consideration and reviewed for solutions and alternatives to improve the experience for all users of this plug-in moving forward. Expanding formats of exports to fit all the engineers and their companies' needs would require additional time, as the most common formats to be added for the future plug-in would have to be thoroughly considered. This could be done after conducting another survey when proceeding with the work.

Future versions of the plug-in should be focused on the security and data forgery issues of the BOQ output. This will enable that the work is not stolen by competitors and effect the procedure of contractors selection for the project based on the tender documents. Fort his issue, there are several proposed solutions but all of them need to be further investigated and proposed to experts for valuable feedback.

9 APPENDIX

9.1 Appendix A: Quantity Takeoff and preparation of bill of quantities

9.1.1 Appendix A1: Elemental BQ breakdown structures for a simple building project

Elemental breakdown structure	
Bill No 1:	Preliminaries (main contract)
Bill No 2:	Facilitating Works
Bill No 3:	Substructure
Bill No 4:	Superstructure
Bill No 5:	Internal Finishes
Bill No 6:	Fittings, Furnishings and Equipment
Bill No 7:	Services
Bill No 8:	External Works
Bill No 9:	Risks
Bill No 10:	Provisional Sums
Bill No 11:	Credits
Bill No 12:	Daywork (provisional)

9.1.2 Appendix A2: Work Section BQ breakdown structures for a simple building project

Work section breakdown structure	
Bill No 1:	Main contractor's preliminaries
Bill No 2:	Off-site manufactured materials. components and buildings
Bill No 3:	Demolitions
Bill No 4:	Alterations, repairs and conservation
Bill No 5:	Excavating and filling

Bill No 6:	Ground remediation and soil stabilization
Bill No 7:	Piling
Bill No 8:	Underpinning
Bill No 9:	Diaphragm walls and embedded retaining walls
Bill No 10:	Crib walls, gabions and reinforced earth
Bill No 11:	In-situ concrete works
Bill No 12:	Precast/composite concrete
Bill No 13:	Precast concrete
Bill No 14:	Masonry
Bill No 15:	Structural metalwork
Bill No 16:	Carpentry
Bill No 17:	Sheet roof coverings
Bill No 18:	Tile and slate roof and wall coverings
Bill No 19:	Waterproofing
Bill No 20:	Proprietary linings and partitions
Bill No 21:	Cladding and covering
Bill No 22:	General joinery
Bill No 23:	Windows, screens and lights
Bill No 24:	Doors, shutters and hatches
Bill No 25:	Stairs, walkways and balustrades
Bill No 26:	Metalwork
Bill No 27:	Glazing
Bill No 28:	Floor, wall, ceiling, and roof finishings

Bill No 29:	Decoration
Bill No 30:	Suspended ceilings
Bill No 31:	Insulation, fire stopping and fire protection
Bill No 32:	Furniture, fittings and equipment
Bill No 33:	Drainage above ground
Bill No 34:	Drainage below ground
Bill No 35:	Site works
Bill No 36:	Fencing
Bill No 37:	Soft landscaping
Bill No 38:	Mechanical Service
Bill No 39:	Electrical Service
Bill No 40:	Transport
Bill No 41:	Builders work in connection with mechanical, electrical, and transportation installations
Bill No 42:	Risks
Bill No 43:	Provisional sums
Bill No 44:	Credits
Bill No 45:	Daywork (Provisional)

9.1.3 Appendix A3: Typical BQ breakdown structure for discrete work package

Work section breakdown structure	
Bill No 1:	Main contractor's preliminaries
Bill No 2:	Intrusive investigation
Bill No 3:	Demolition works
Bill No 4:	Groundworks
Bill No 5:	Piling
Bill No 6:	Concrete works
Bill No 7:	Roof coverings and roof drainage
Bill No 8:	External and internal structural walls
Bill No 9:	Cladding
Bill No 10:	Windows and external doors
Bill No 11:	Mastic
Bill No 12:	Non-structural walls and partitions
Bill No 13:	Joinery
Bill No 14:	Suspended ceilings
Bill No 15:	Architectural metalwork
Bill No 16:	Tiling
Bill No 17:	Painting and decorating
Bill No 18:	Floor covering
Bill No 19:	Fittings, furnishings and equipment
Bill No 20:	Combined mechanical and electrical engineering services
Bill No 21:	Lifts and escalators

Bill No 22:	Facade access equipment
Bill No 23:	External works and drainage
Bill No 24:	Risks
Bill No 25:	Provisional sums
Bill No 26:	Credits
Bill No 27:	Daywork (provisional)

9.1.4 Appendix A4: Typical BQ format for a work section bill of quantity

Bill No. 2 Superstructure						
2.14 Masonry						
2.14.1	BRICK/BLOCK WALLING					
2.14.1.1	Common brickwork in cement: lime moetar (1:1:6)					
2.14.1.1.1	Walls 102.5mm thick, brickwork; built againt other work	196	m^2			
2.14.1.1.2	Walls 215mm thick, brickwork	302	m^2			

9.1.5 Appendix A5: Typical of how to total pages

		Carried forward		£		

The top of the following bill page is completed as follows:

Bill No. 3 SUPERSTRUCTURE					
2.5 EXTERNAL WALLS					
		Brought Forward	£		

To end each bill section, the section is completed as follows:

	TOTAL carried to main summary		£		

9.2 Appendix B: Template for preliminaries (main contract) pricing schedule (condensed)

Cost Centre	Component	Time-Related Charges	Fixed Charges	Total Charges
		£ p	£ p	£ p
1	PRELIMINARIES			
1.1	EMPLOYER'S REQUIREMENTS			
1.1.1	Site accommodation			
1.1.2	Site records			
1.1.3	Completion and post-completion requirements			
1.2	MAIN CONTRACTOR'S COST ITEMS			
1.2.1	Managment and staff			

1.2.2	Site establishment			
1.2.3	Temporary services			
1.2.4	Safety and enviromental protection			
1.2.5	Control and protection			
1.2.6	Mechanical plant			
1.2.7	Temporary works			
1.2.8	Site records			
1.2.9	Completion and post-completion requirments			
1.2.10	Cleaning			
1.2.11	Fees and charges			
1.2.12	Site services			
1.2.13	Insurance, bonds, guarantees and warranties			
	Totals £			
	TOTAL CARRIED TO MAIN SUMMARY £			

9.3 Appendix C: Template for preliminaries (main contract) pricing schedule (expanded)

Cost Centre	Component	Time-Related Charges	Fixed Charges	Total Charges
		£ p	£ p	£ p
1.1	EMPLOYER'S REQUIRMENT			
1.1.1	Site accommodation			
1.1.1.1	Site accommodation			
1.1.1.2	Furniture and equipment			

1.1.1.3	Telecommunication and IT system			
1.1.2	Site records			
1.1.2.1	Site records			
1.1.3	Completion and post-completion requirement			
1.1.3.1	Handover requirments			
1.1.3.2	Operation and maintanance services			
1.2	MAIN CONTRACTOR'S COST ITEMS			
1.2.1	Managment and staff			
1.2.1.1	Project specific managment and staff			
1.2.1.2	Visiting managment and staff			
1.2.1.3	Extraordinary support cost			
1.2.1.4	Staff travel			
1.2.2	Site establishment			
1.2.2.1	Site accomedation			
1.2.2.2	Temporary works in connection with the site establishment			
1.2.2.3	Furniture and equipment			
1.2.2.4	IT systems			
1.2.2.5	Consumables and services			
1.2.2.6	Brought-in services			
1.2.2.7	Sundries			
1.2.3	Temporary services			
1.2.3.1	Temporary water supply			
1.2.3.2	Temporary gas supply			

1.2.3.3	Temporary electricity			
1.2.3.4	Temporary telecommunication			
1.2.3.5	Temporary drainage			
1.2.4	Security			
1.2.4.1	Security staff			
1.2.4.2	Security equipment			
1.2.4.3	Hoarding, fences and gates			
1.2.5	Safety and enviromental protection			
1.2.5.1	Safety programme			
1.2.5.2	Barriers and safety scaffolding			
1.2.5.3	Enviromental protection measures			
1.2.6	Control and protection			
1.2.6.1	Survay, inspections and monitoring			
1.2.6.2	Setting out			
1.2.6.3	Protection of works			
1.2.6.4	Samples			
1.2.6.5	Enviromental control of building			
1.2.7	Mechanical plant			
1.2.7.1	Generally			
1.2.7.2	Tower cranes			
1.2.7.3	Mobile cranes			
1.2.7.4	Hoists			
1.2.7.5	Access plant			

1.2.7.6	Concrete plant			
1.2.7.7	Other plant			
1.2.8	Temporary works			
1.2.8.1	Access scaffolding			
1.2.8.2	Temporary works			
1.2.9	Site records			
1.2.9.1	Site records			
1.2.10	Completion and post-completion requirement			
1.2.10.1	Testing and commissioning plan			
1.2.10.2	Handover			
1.2.10.3	Post-completion services			
1.2.11	Cleaning			
1.2.11.1	Site tidy			
1.2.11.2	Maintanance of roads, paths and paving			
1.2.11.3	Building clean			
1.2.12	Fees and charges			
1.2.12.1	Fees			
1.2.12.2	Charges			
1.2.13	Site services			
1.2.13.1	Temporary works			
1.2.13.2	Multi-service gang			
1.2.14	Insurance, bonds gurantees and warranties			
1.2.14.1	Works insurance			

1.2.14.2	Public liability insurance			
1.2.14.3	Employer's (main contractor's) liability insurance			
1.2.14.4	Other insurance			
1.2.14.5	Bonds			
1.2.14.6	Gurantees			
1.2.14.7	Warranties			
	Totals £			
	TOTAL CARRIED TO MAIN SUMMARY £			

9.4 Appendix D: Template for pricing summary for elemental bill of quantities (condensed)

Cost Centre	Element	£/p	£/p
0.0	**Facilitating works**		**£0.00**
1.0	**Substructure**		**£0.00**
2.0	**Superstructure**		**£0.00**
3.0	**Internal finishes**		**£0.00**
4.0	**Fitting, furnishings and equipment**		**£0.00**
5.0	**Services**		**£0.00**
6.0	**Prefabricated buildings and building units**		**£0.00**
7.0	**Work to existing building**		**£0.00**
8.0	**External works**		**£0.00**
	TOTAL (Building works, including M&E engineering services)		**£0.00**
9.0	**Main contractor's preliminaries**		**£0.00**
	Sub-total		£0.00

10.0	**Provisional sums:**		**£0.00**
10.1	Defined provisional sums	£0.00	
10.2	Undefined provisional sums	£0.00	
10.3	Works to be carried out by statutory undertakers	£0.00	
	Sub-total		£0.00
11.0	**Risks**		**£0.00**
11.1	Sub-total		£0.00
12.0	**Main contractor's overheads and profits (insert required % adjustment)**	**0.00%**	**£0.00**
	Sub-total		£0.00
13.0	**Credit (for retained arising)**		**£(0.00)**
	Sub-total		£0.00
14.0	**Main contractor's fixed price adjustment (insert required % adjustment)**	**0.00%**	**£0.00**
	Sub-total		£0.00
15.0	**Director's adjustment (insert required adjustment (+/-))**		**£0.00 or £(0.00)**
	Sub-total		£0.00
16.0	**Dayworks (provisional)**		**£0.00**
	TOTAL TENDER PRICE, exclusive to VAT (Carried to form of Tender)		**£0.00**

9.5 Appendix E: Template for pricing summary for elemental bill of quantities (expanded)

Cost Centre	Element	£/p	£/p
0.0	**Facilitating works**		**£0.00**

0.1	Toxic/hazardous/contaminated material treatment	£0.00	
0.2	Major demolition works	£0.00	
0.3	Specialist ground works	£0.00	
0.4	Temporary diversion works	£0.00	
0.5	Extraordinary site investigation works	£0.00	
1.0	**Substructure**		**£0.00**
1.1	Substucture	£0.00	
2.0	**Superstructure**		**£0.00**
2.1	Frame	£0.00	
2.2	Upper Floors	£0.00	
2.3	Roof	£0.00	
2.4	Stairs and ramps	£0.00	
2.5	External walls	£0.00	
2.6	Windows and external doors	£0.00	
2.7	Internal walls and partitions	£0.00	
2.8	Internal doors	£0.00	
3.0	**Internal finishes**		**£0.00**
3.1	Wall finishes	£0.00	
3.2	Floor finishes	£0.00	
3.3	Ceiling finishes	£0.00	
4.0	**Fitting, furnishings and equipment**		**£0.00**
4.1	Fitting, furnishings and equipment	£0.00	
5.0	**Services**		**£0.00**

5.1	Sanitary installation	£0.00	
5.2	Services equipement	£0.00	
5.3	Disposal installation	£0.00	
5.4	Water installation	£0.00	
5.5	Heat source	£0.00	
5.6	Space heating and air conditioning	£0.00	
5.7	Ventilation	£0.00	
5.8	Electrical installation	£0.00	
5.9	Fuel installation/system	£0.00	
5.10	Lift and conveyor installations/systems	£0.00	
5.11	Fire and lighting protection	£0.00	
5.12	Communication, security and control systems	£0.00	
5.13	Spacial installations/systems	£0.00	
5.14	Builder's work in connection with services	£0.00	
6.0	**Complete buildings**		**£0.00**
6.1	Pre-fabricated buildings	£0.00	
7.0	**Work to existing building**		**£0.00**
7.1	Minor demolition works and alteration works	£0.00	
7.2	Repairs to existing service	£0.00	
7.3	Damp proof courses/fungus and beetle eradication	£0.00	
7.4	Facade retention	£0.00	
7.5	Cleaning existing surfaces	£0.00	
7.6	Renovation works	£0.00	

8.0	**External works**		**£0.00**
8.1	Site preparation works	£0.00	
8.2	Roads paths and pavings	£0.00	
8.3	Soft landscaping, planting and irrigation systems	£0.00	
8.4	Fancing, railings and walls	£0.00	
8.5	Site/street furniture and equipment	£0.00	
8.6	External drainage	£0.00	
8.7	External services	£0.00	
8.8	Minor building works and ancillary building	£0.00	
	TOTAL (Building works, including M&E engineering services)		**£0.00**
9.0	**Main contractors preliminaries**		£0.00
	Sub-total		£0.00
10.0	**Risks**		£0.00
	Sub-total		£0.00
11.0	**Provisional sums:**		£0.00
11.1	Defined provisional sums	£0.00	
11.2	Undefined provisional sums	£0.00	
11.3	Works to be carried out by statutory undertakers	£0.00	
	Sub-total		£0.00
12.0	**Main contractors overheads and profits** (insert required % adjustment)	0.00%	**£0.00**
	Sub-total		£0.00
13.0	**Credit (for retained arising)**		**£(0.00)**
	Sub-total		£0.00

14.0	**Main contractor's fixed price adjustment** (insert required % adjustment)	0.00%	**£0.00**
	Sub-total		£0.00
15.0	**Directors adjustments (insert required adjustment (+/-))**		**£0.00 or £(0.00)**
	Sub-total		£0.00
16.0	**Dayworks (Provisional)**		**£0.00**
	TOTAL TENDER PRICE, exclusive of VAT (Carried to form of Tender)		**£0.00**

9.6 Appendix F: Python Script trials

```
import os
import datetime
import sys
itemname=[]
amount=[]
qty=[]
rate=[]
ch='y'
x =
'+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+++++++++++++++++++++++++++++'
y = ' '

os.system("title Bill Generator")

d_date = datetime.datetime.now()
reg_format_date = d_date.strftime("  %d-%m-%Y {} Bill {}  %I:%M:%S
%p".format(40*y,40*y))
print (x)
print (reg_format_date)
print (x)

def show():
        print ('\nItemname\t\t\t\t'+'\tRate\t'+'Qty\t'+'Amount')

for i in range(0,len(itemname)):
        print
('{0}\t\t\t\t\t{1}\t{2}\t{3}'.format(itemname[i],rate[i],qty[i],amount[i]))
print ('\nSub Total :\t\t\t\t\t\t\t{0}'.format(sum(amount)))
print ('\nTAX: 7%')
tax=((sum(amount))*0.07)
print ('Total Amount:\t\t\t\t\t\t\t{0}'.format(sum(amount)+tax))

from rpw.ui.forms import TextInput

while ch=='y' or ch=='Y':
        tempitemname = TextInput('\nEnter item name (max 8 character): ')
        tempitemname = tempitemname[0:15]
        if len(tempitemname)<8:
                tempitemname=tempitemname+'        '
        itemname.append(tempitemname)
        tempamount=0
        tempqty=0
        tempa=0
        tempq=0

        try:
                tempamount=int(TextInput('Enter rate: '))
                tempa=tempamount
        except:
                print('Please Enter Rate')

        try:
                tempqty=int(TextInput('Enter quantity: '))
                tempq=tempqty
        except:
                print('Please Enter quantity')
```

```
        ch= TextInput('\nDo you want to add more(y for yes and n for no): ')
        amount.append(tempq*tempa)
        qty.append(tempq)
        rate.append(tempa)
        show()


print (x)
print (reg_format_date)
print (x)
print ('\nItemname\t\t\t\t'+'\tRate\t'+'Qty\t'+'Amount')
for i in range(0,len(itemname)):
        print
('{0}\t\t\t\t\t{1}\t{2}\t{3}'.format(itemname[i],rate[i],qty[i],amount[i]))
print ('\nSub Total :\t\t\t\t\t\t\t{0}'.format(sum(amount)))
print ('\nTAX: 7%')
tax=((sum(amount))*0.07)
print ('Total Amount:\t\t\t\t\t\t\t{0}'.format(sum(amount)+tax))
```

9.7 Appendix G: Python tax and rate calculator

```
quan = int(input("Enter the quantity of product: "))
pric = int(input("Enter the price of product: "))
disc = int(input("Enter discount percentage: "))
taxx = int(input("Enter TAX percentage: "))

amount = quan*pric
discount = amount*disc/100
sub = amount - discount
tax = sub*taxx/100
total = sub+tax

print('\n')
print('*********BILL**********')
print('Quantity Sold: ',quan)
print('Price: ',pric)
print('------------------------')
print('Amount: ' ,amount)
print('Discount: ' ,discount)
print('------------------------')
print('Discounted Total: ' ,sub)
print('TAX: ' ,tax)
print('------------------------')
print('Total Amount To Be Paid:' ,total)
input()
```

9.8 Appendix H: Area and Volume Extraction

```
#pylint: disable=E0401,C0103
import math
from collections import namedtuple

from pyrevit.framework import List
from pyrevit import revit, DB
from pyrevit import forms
from pyrevit import script

import clr
import math
```

```
clr.AddReference('ProtoGeometry')
from Autodesk.DesignScript import Geometry as dg

# EXTENSION Enable ToDSType
clr.AddReference('RevitNodes')
import Revit
clr.ImportExtensions(Revit.Elements)

# Enable Revit Elements
from Revit.Elements import *

# EXTENSION Enable Geometry Conversion Methods
clr.ImportExtensions(Revit.GeometryConversion)

# Enable Revit API
clr.AddReference('RevitAPI')
from Autodesk.Revit.DB import *

# Enable DocumentManager and TransactionManager
clr.AddReference('RevitServices')
from RevitServices.Persistence import DocumentManager
from RevitServices.Transactions import TransactionManager

# Enable ICollection List Translate
clr.AddReference("System")
import System.Collections.Generic
from System.Collections.Generic import List
from itertools import compress
from itertools import combinations
#The inputs to this node will be stored as a list in the IN variables.

clr.AddReference('RevitAPIUI')
from Autodesk.Revit.UI import TaskDialog, TaskDialogCommonButtons, TaskDialogResult,
TaskDialogCommandLinkId


doc = DocumentManager.Instance.CurrentDBDocument

result = []
result.append(FilteredElementCollector(doc).OfCategory(BuiltInCategory.OST_Walls).Wher
eElementIsNotElementType().ToElements())
fixedresult = []
for e in result:
	fixedresult = e
	break

volumes = []
areas = []
for each in fixedresult:
	tmp = []
	tmp2 = []
	for matid in each.GetMaterialIds(False):
		tmp.append(each.GetMaterialVolume(matid))
		tmp2.append(each.GetMaterialArea(matid,False))
	volumes.append(round(sum(tmp),3))
	areas.append(round(sum(tmp2),3))

totalvolumes = sum(volumes)
totalareas = sum(areas)

mainDialog = TaskDialog("Total Volumes and Area")
```

```
mainDialog.MainContent = "Volumes:" + str(totalvolumes) + " | Areas: " +
str(totalareas)


mainDialog.CommonButtons = TaskDialogCommonButtons.Close;
mainDialog.DefaultButton = TaskDialogResult.Close;


tResult = mainDialog.Show()

if tResult == TaskDialogCommandLinkId.CommandLink1:
       TaskDialog.Show('User Text')


OUT = tResult
```

9.9 Appendix I: Survey Questionnaire

BIMA+ Royal Institution of Chartered Surveyors (RICS), Bill of Quantity (BOQ) Plug-in generator

This part is to plot generic data of the company

* Required

1. Company name (Optional)

   Note: the name will not be publish and is not obligatory

2. Company location

   Mark only one oval.

   - Oceania
   - Asia
   - Africa
   - Europe
   - North America
   - South America

3. Company size

   Mark only one oval.

   - Small Firm (10 - 20 employees)
   - Medium Firm (20 - 100 employees)
   - Big Firm (100 + employees)

4. Company operations

   Mark only one oval.

   - Local Firm
   - Regional Firm
   - National Firm
   - International Firm

5. Company BIM assessment

   Mark only one oval.

   - Beginners
   - Intermediate
   - Advanced

6. Do you ...

Mark only one oval per row.

	Yes	No
use RICS standards ?	◯	◯
use BIM tools for QS ?	◯	◯
use 5D in BIM ?	◯	◯

7. Would your company...

Mark only one oval per row.

	Yes	No
use BIM in construction stage ?	◯	◯
use Revit layout template ?	◯	◯
use Autodesk BIM 360 ?	◯	◯

8. Would your Company...

Mark only one oval per row.

	Yes	No
Revit add-in to generate BOQ according to Rics ?	◯	◯
Use Revit Add-In that generates BOQ by RICS NRM2?	◯	◯

9. What inputs and outputs do you use for Quantity Surveying (QS) ? *

Mark only one oval.

- ◯ PDF
- ◯ JPEG
- ◯ CAD
- ◯ BIM
- ◯ Excel
- ◯ Other: _____

10. Please explain what is the most time consuming task of the Bill of Quantities (BOQ) generation process

11. Would you recommend any special features for the Quantity Surveying (QS) plug-in?

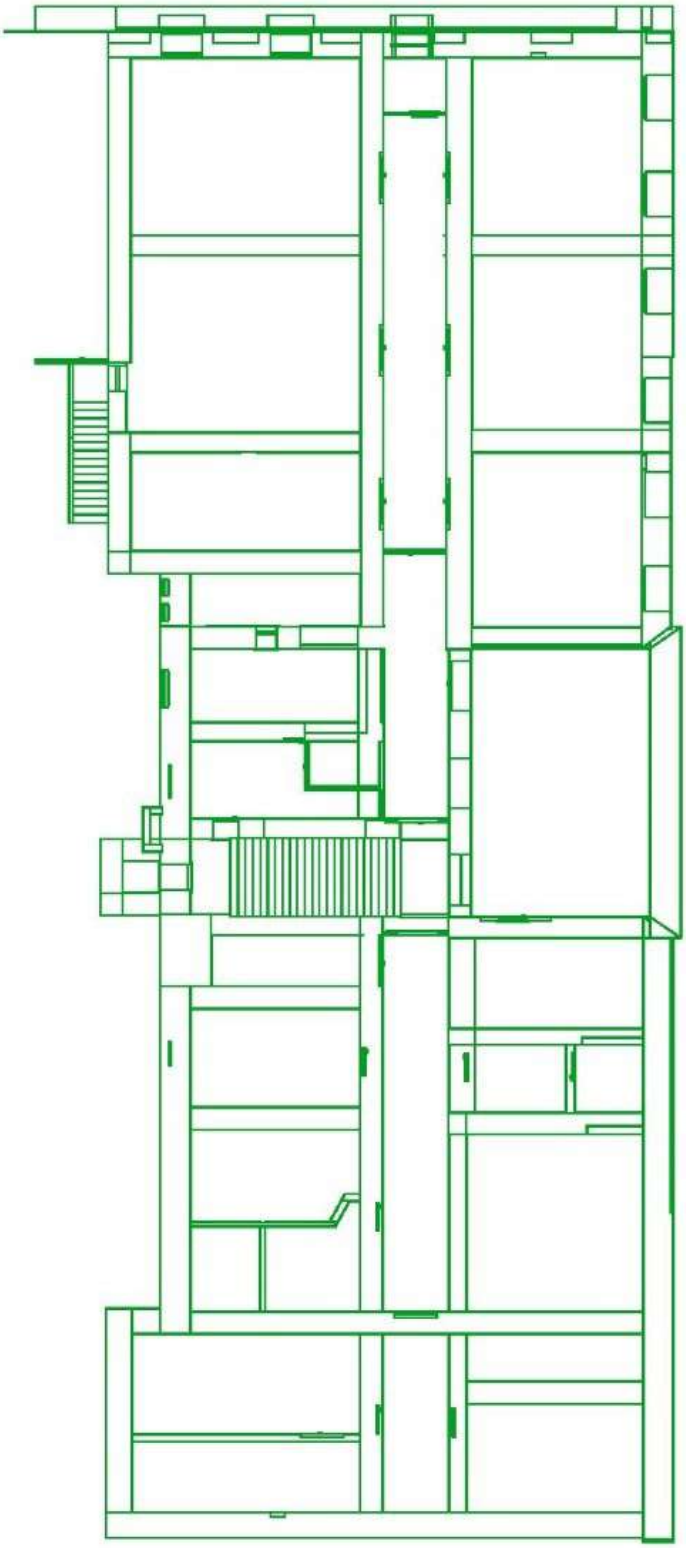
12. Would you :

Mark only one oval per row.

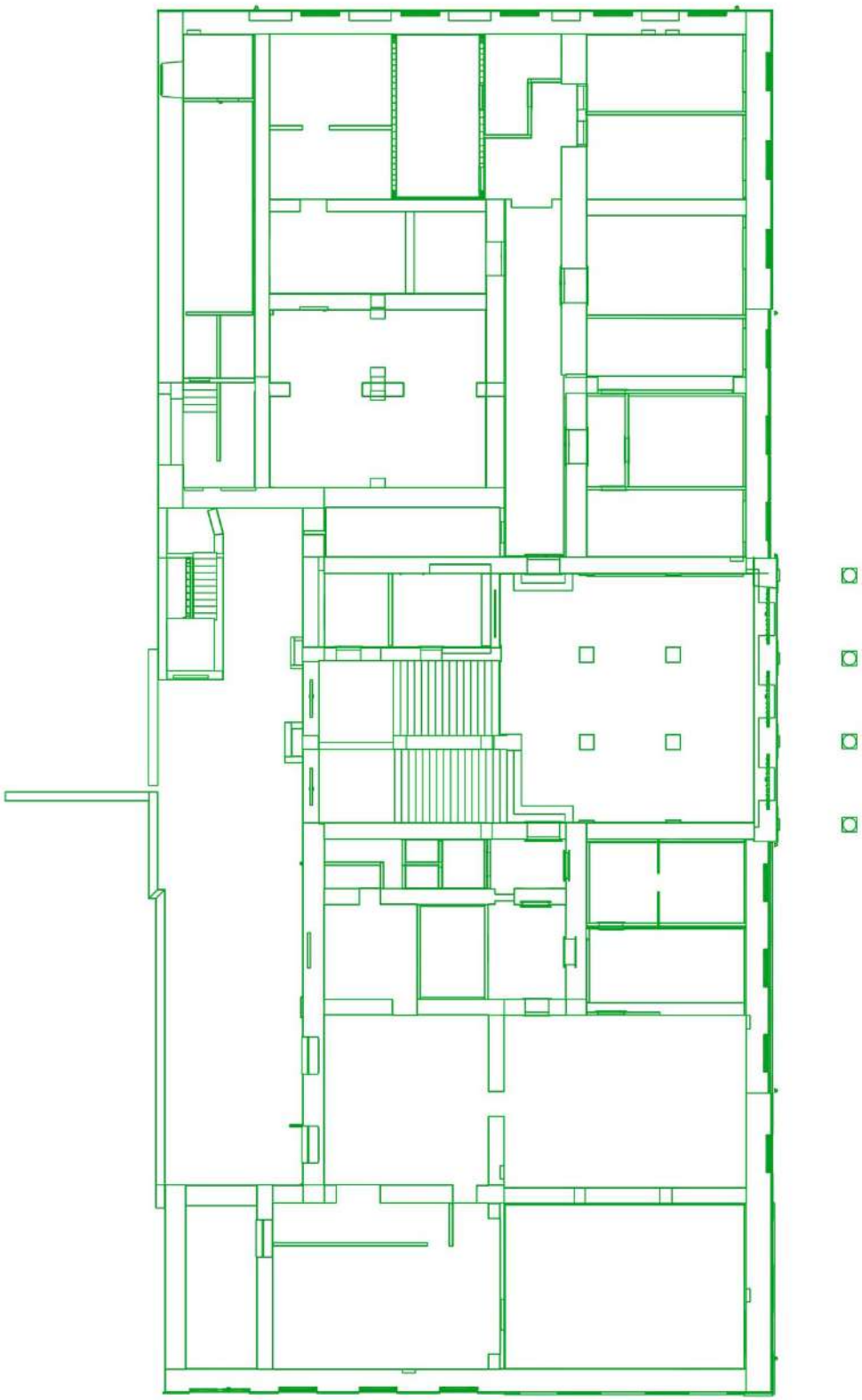
	Yes	No
Share models for education trial purposes ?		
set a Skype call for further information ?		

13. Do you have any closing remarks ?

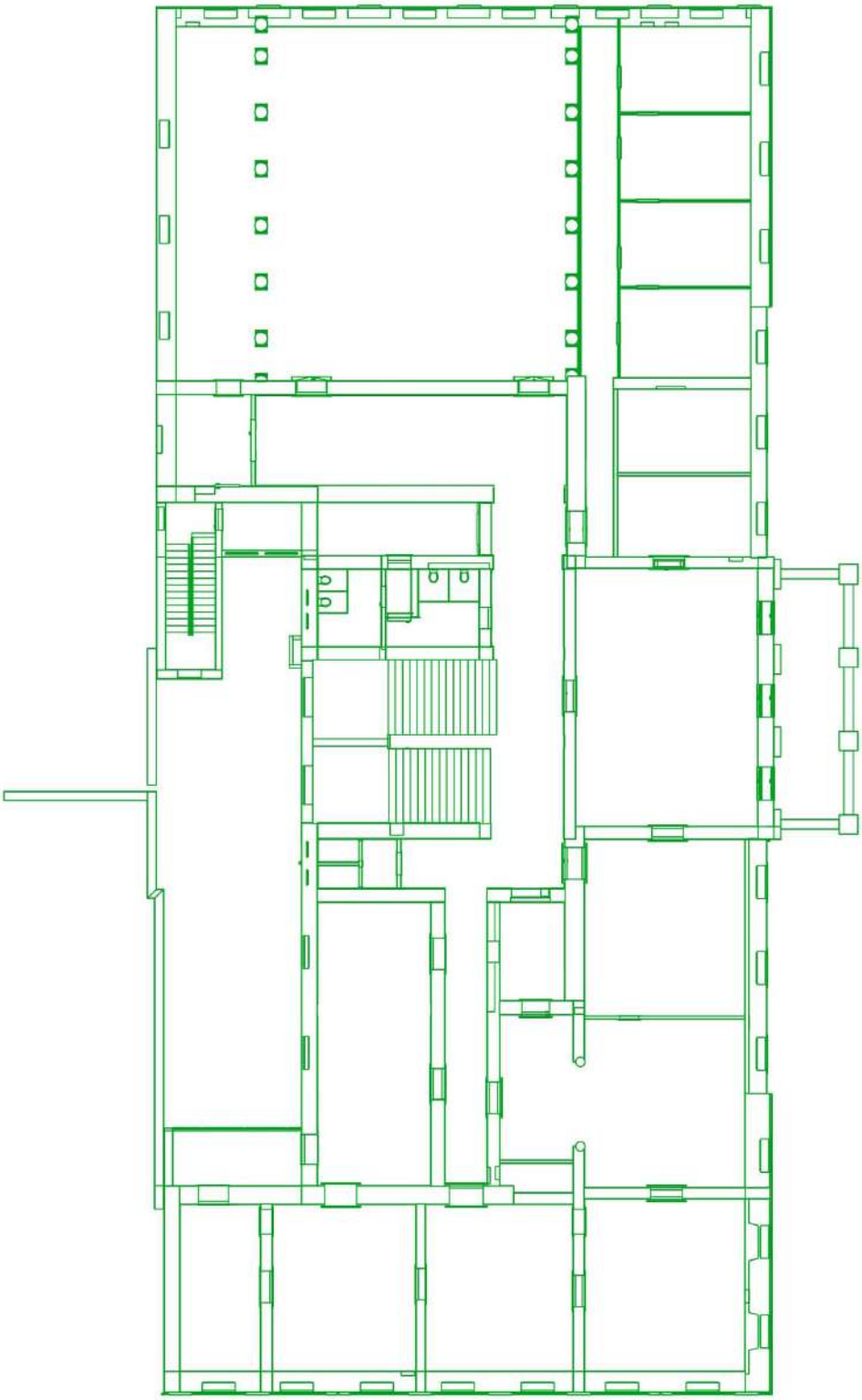
9.10 Appendix J: Kazina building Old plans



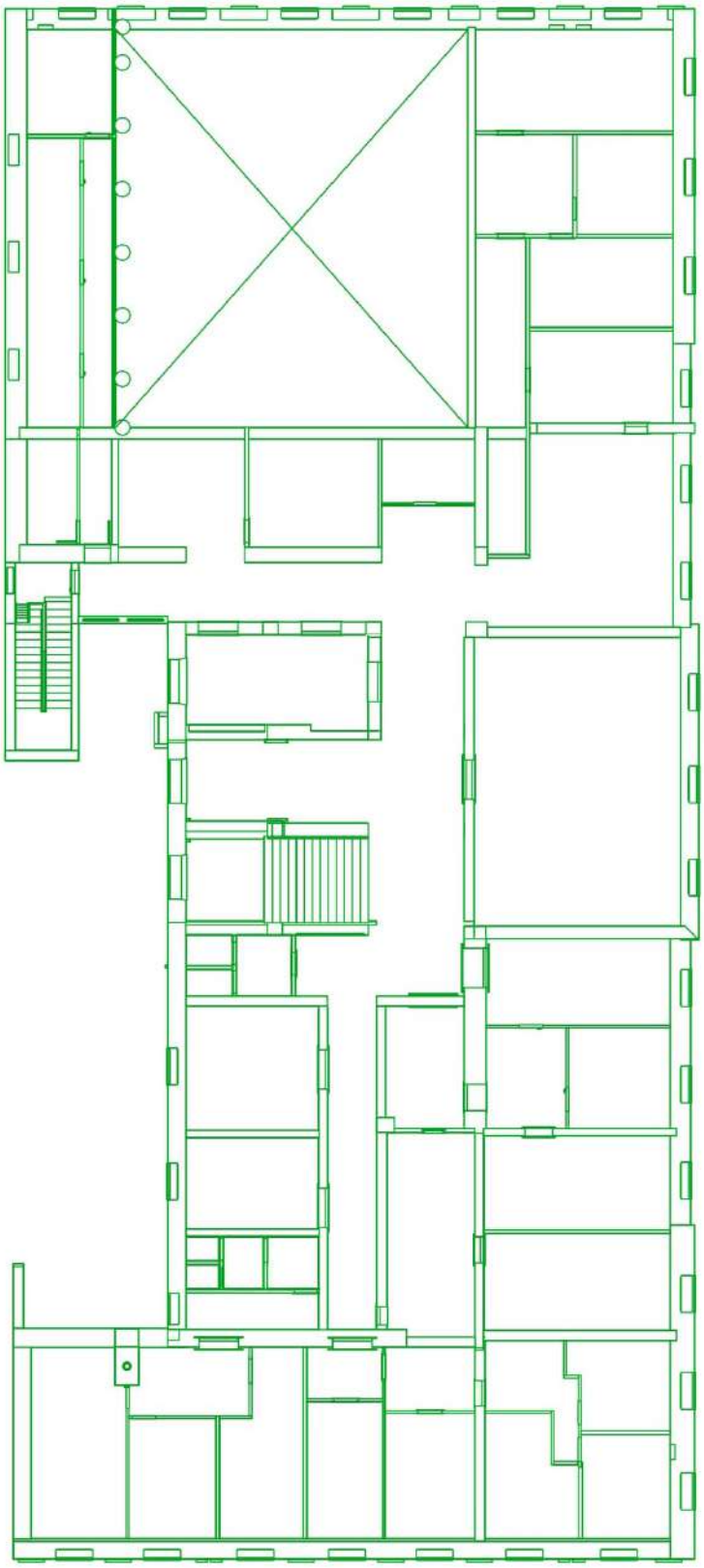
Kazina Building Old Plan (Level -1)



Kazina Building Old Plan (Level 0)



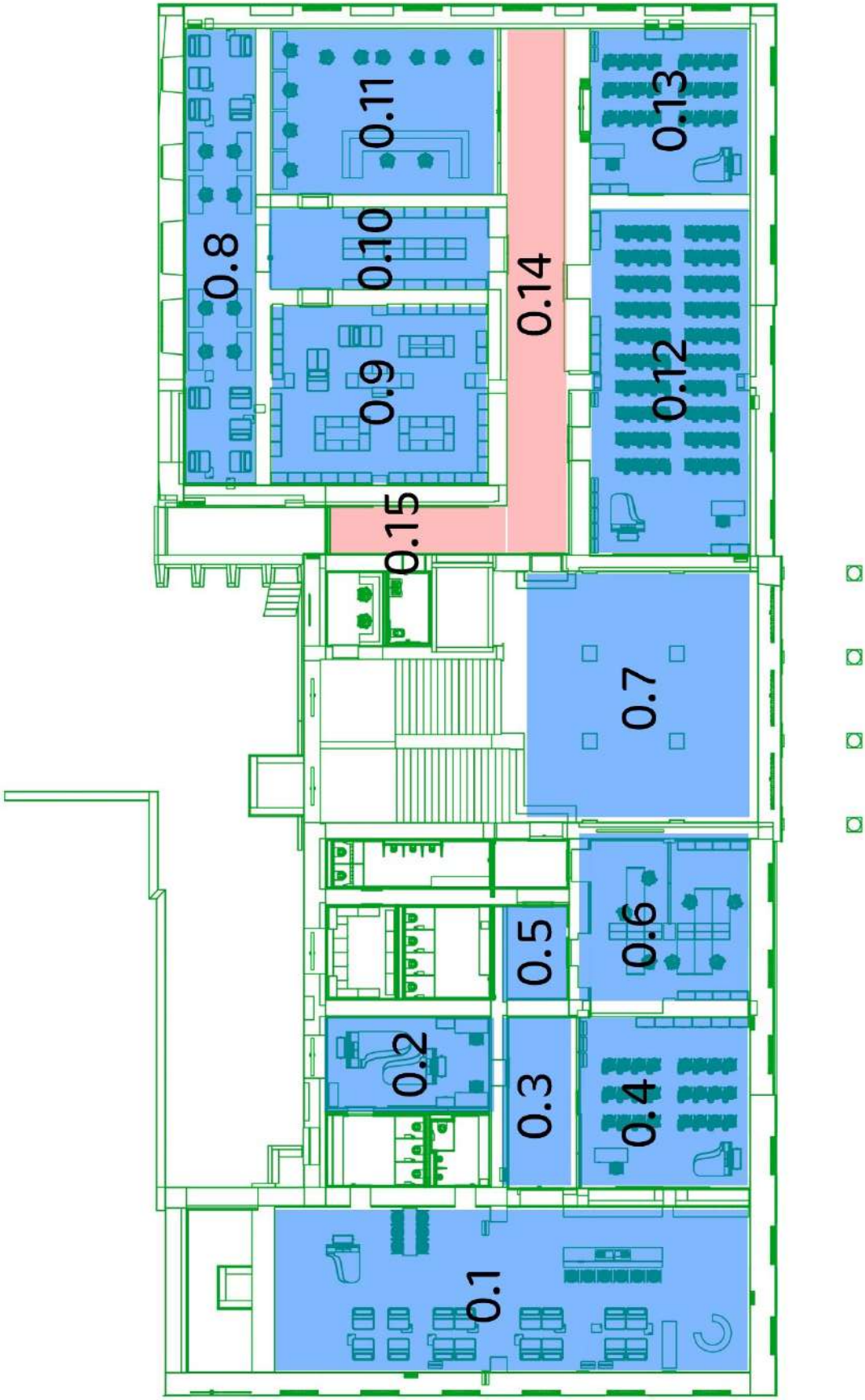
Kazina Building Old Plan (Level 1)



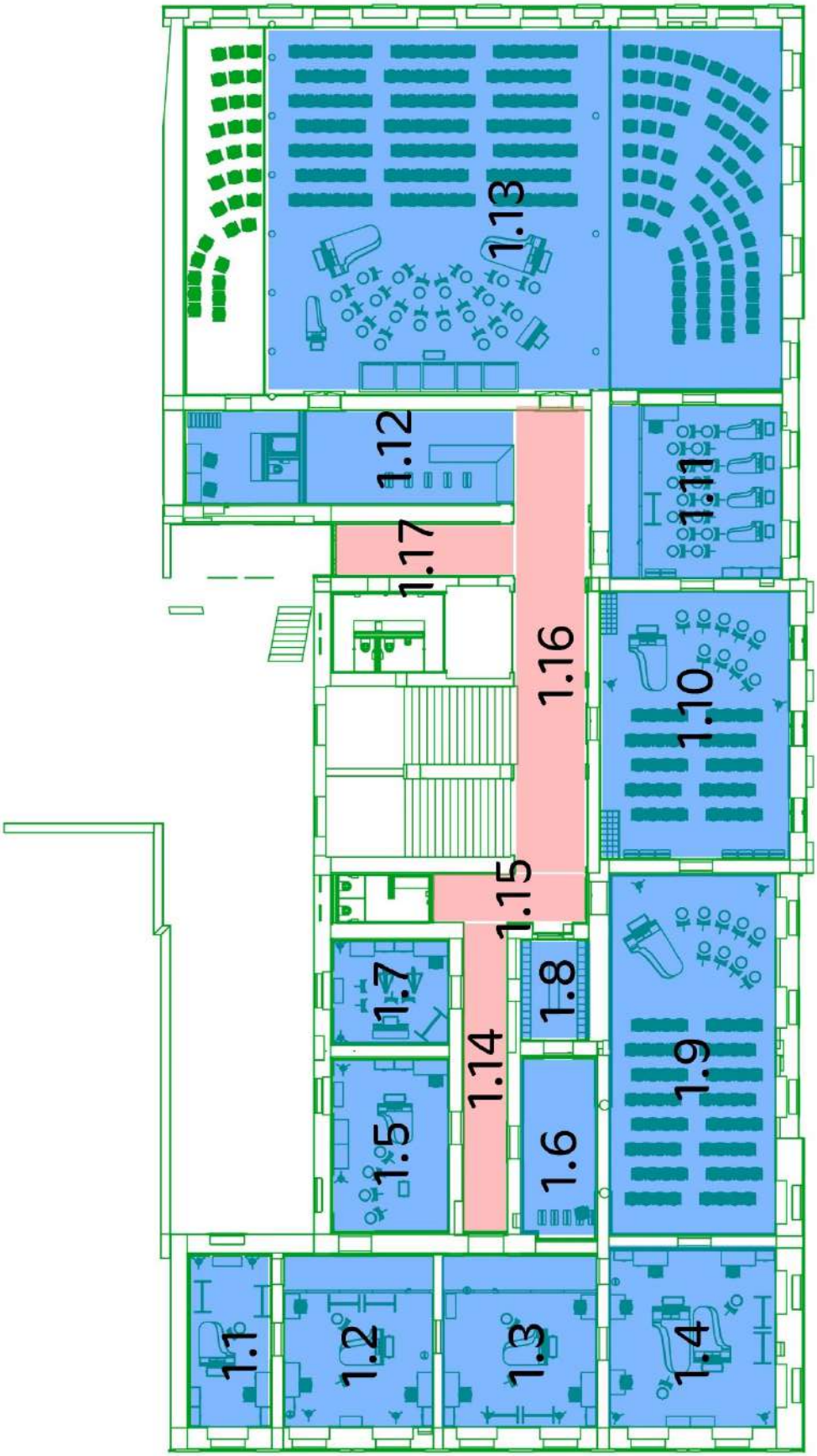
Kazina Building Old Plan (Level 2)

9.11 Appendix K: Kazina building New plan

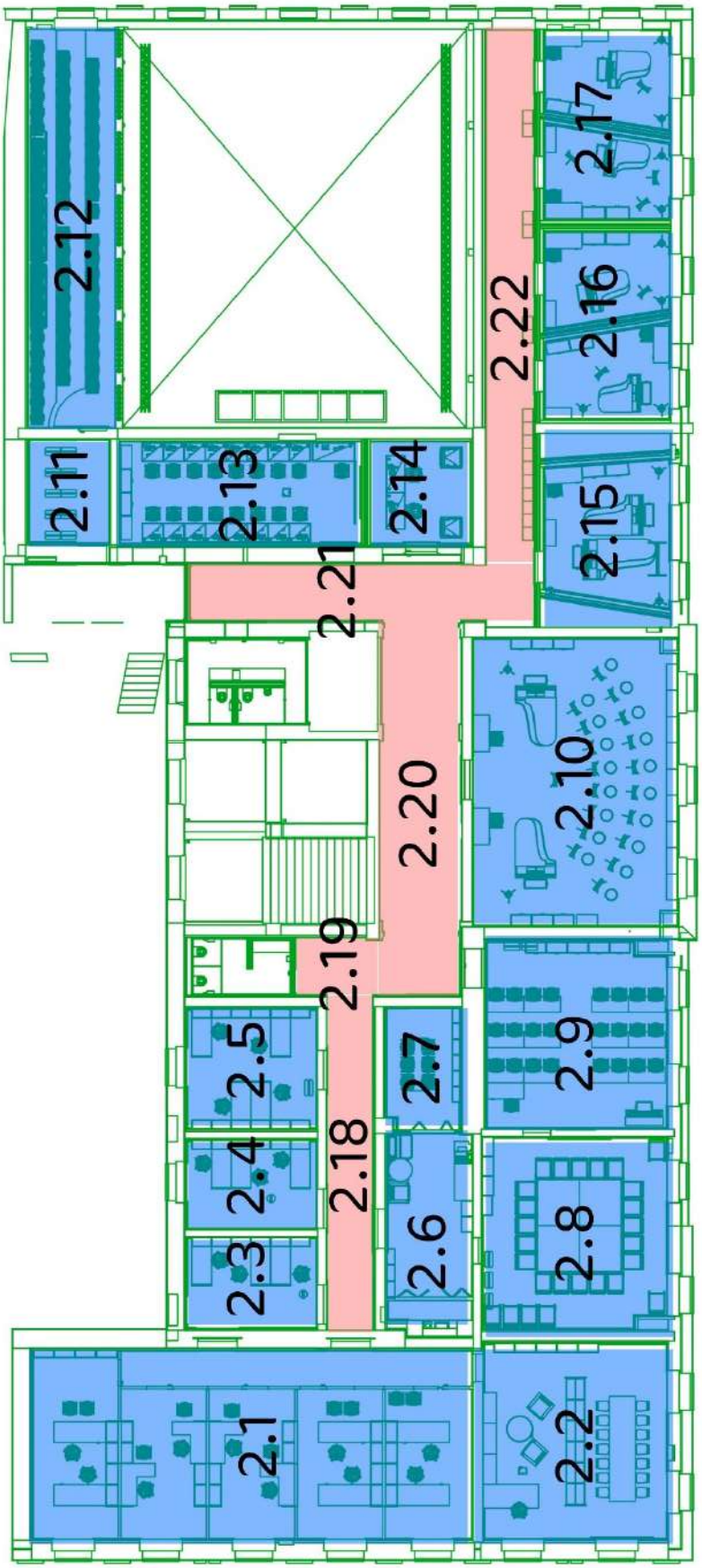
Kazina Building New Plan (Level -1)



Kazina Building New Plan (Level 0)



Kazina Building New Plan (Level 1)



Kazina Building New Plan (Level 2)

9.12 Appendix L: Quantity take-off sheets

Kazina Building, Slovenia

Ljubljana, Slovenia

14 - MASONRY

BIM A+

Quantity Take-off .

ITEM #	ITEM NAME	UNIT	QUAN.	DIMENSION (m)			PART		TOTAL
				LENGTH	WIDTH	HEIGHT	-	+	
	Added Insulated internal walls								
14.1	"100 cm thick" walls in plan 0	m2	1	1.4		3		4.2	
14.2	"100 cm thick" walls in plan 1	m2	1	1.3		4.8		6.24	
		m2	1	4		4.8		19.2	
		m2	1	57		4.8		273.6	
14.3	"100 cm thick" walls in plan -1	m2	1	12		3.8		45.6	
		m2	1	9.2		3.8		34.96	**383.8**
14.4	"80 cm thick" walls in plan 2	m2	1	2.6		4.8		12.48	
		m2	1	4.05		4.8		19.44	
14.5	"80 cm thick" walls in plan -1	m2	1	4		3.8		15.2	
		m2	1	3.6		3.8		13.68	**60.8**
14.6	"50 cm thick" walls in plan 0	m2	1	8.3		4.8		39.84	
14.7	"50 cm thick" walls in plan 2	m2	1	26.6		4.8		127.68	**167.52**
14.8	"25 cm thick" walls in plan 0	m2	1	18.7		4.8		89.76	
14.9	"25 cm thick" walls in plan -1	m2	1	2.8		3.8		10.64	**100.4**
	Demolished internal walls								
14.10	"85 cm thick" walls in plan 0	m2	1	8		4.8		38.4	
		m2	1	2.6		4.8		12.48	
14.11	"85 cm thick" walls in plan -1	m2	1	4		3.8		15.2	**66.08**
14.12	"125 cm thick" walls in plan 0	m2	1	1.6		3		4.8	**4.8**
14.13	"100 cm thick" walls in plan 0	m2	1	1.4		3		4.2	**4.2**
14.14	"20 cm thick" walls in plan 0	m2	1	8.5		4.8		40.8	
		m2	4	8		4.8		153.6	
14.15	"20 cm thick" walls in plan 1	m2	2	16.4		4.8		157.44	
		m2	4	6.5		4.8		124.8	
		m2	1	8		4.8		38.4	
14.16	"20 cm thick" walls in plan 2	m2	1	3.8		4.8		18.24	
		m2	1	12.9		4.8		61.92	
		m2	2	8.8		4.8		84.48	
		m2	3	4.5		4.8		64.8	
		m2	1	14.1		4.8		67.68	
		m2	1	8.5		4.8		40.8	
		m2	3	4.2		4.8		60.48	

14.17	"20 cm thick" walls in plan -1	m2	1	3.8		3.8		14.44	
		m2	1	4		3.8		15.2	**943.08**

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

24 - DOORS, SHUTTERS AND HATCHES

BIM A+

Quantity Take-off .

ITEM #	ITEM NAME	UNIT	QUAN.	DIMENSION (m)			PART		TOTAL
				LENGTH	WIDTH	HEIGHT	-	+	
	INTERNAL WOOD DOOR								
24.1	"240cm" doors in plan 0	p	1	2.4	0.1	3		1	**1**
24.2	"140cm" doors in plan 0	p	1	1.4	0.1	3		1	
24.3	"140cm" doors in plan 2	p	3	1.4	0.1	3		3	
24.4	"140cm" doors in plan -1	p	3	1.4	0.1	3		3	**7**
	INTERNAL INSULATED DOOR								
24.5	"170cm" doors in plan 0	p	2	1.7	0.2	3		2	**2**
24.6	"130cm" doors in plan 0	p	1	1.3	0.2	3		1	
24.7	"130cm" doors in plan 1	p	11	1.3	0.2	3		11	
24.8	"130cm" doors in plan 1	p	8	1.3	0.2	3		8	**20**
24.9	"100cm" doors in plan 0	p	2	1	0.2	3		2	**2**
24.10	"260cm" doors in plan -1	p	2	2.6	0.2	3		2	**2**
24.11	"240cm" doors in plan -1	p	5	2.4	0.1	3		5	**5**
	INTERNAL CURTAIN DOOR								
24.12	"240cm" doors in plan 0	p	1	2.4	0.05	3		1	**1**

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

28 - FLOOR WALL, CEILING AND ROOF FINISHING

BIM A+

Quantity Take-off .

ITEM #	ITEM NAME	UNIT	QUAN.	DIMENSION (m)			PART		TOTAL
				LENGTH	WIDTH	HEIGHT	-	+	
	Tiles scour								
28.1	Tiles scour room 0.1		m2	8.1	24.5			198.45	
28.2	Tiles scour room 0.2		m2	4.8	8.2			39.36	
28.3	Tiles scour room 0.3		m2	8.4	3.3			27.72	
28.4	Tiles scour room 0.4		m2	8.4	8.4			70.56	
28.5	Tiles scour room 0.5		m2	4.6	4.1			18.86	
28.6	Tiles scour room 0.6		m2	8	8			64	
28.7	Tiles scour room 0.7		m2	11.1	12.1			134.31	
28.8	Tiles scour room 0.8		m2	14.6	3.5			51.1	
28.9	Tiles scour room 0.9		m2	9	11			99	
28.10	Tiles scour room 0.10		m2	4	11			44	
28.11	Tiles scour room 0.11		m2	8.2	11.1			91.02	
28.12	Tiles scour room 0.12		m2	8	9.2			73.6	
28.13	Tiles scour room 0.13		m2	8	9.2			73.6	
28.14	Tiles scour room 0.14		m2	2.9	18			52.2	
28.15	Tiles scour room 0.15		m2	2.3	8.8			20.24	**1058**
28.16	Tiles scour room 1.1		m2	8.2	4			32.8	
28.17	Tiles scour room 1.2		m2	8.2	7.1			58.22	
28.18	Tiles scour room 1.3		m2	8.2	7.2			59.04	
28.19	Tiles scour room 1.4		m2	8.4	8			67.2	
28.20	Tiles scour room 1.5		m2	8.2	5.5			45.1	
28.21	Tiles scour room 1.6		m2	8.3	3.4			28.22	
28.22	Tiles scour room 1.7		m2	5	5.5			27.5	
28.23	Tiles scour room 1.8		m2	4.8	3.4			16.32	
28.24	Tiles scour room 1.9		m2	8	17.2			137.6	
28.25	Tiles scour room 1.10		m2	12.8	9			115.2	
28.26	Tiles scour room 1.11		m2	8.3	9			74.7	
28.27	Tiles scour room 1.12		m2	4.4	15.8			69.52	
28.28	Tiles scour room 1.13		m2	24.8	17.2			426.56	
28.29	Tiles scour room 1.14		m2	15	2.1			31.5	
28.30	Tiles scour room 1.15		m2	7.1	2.1			14.91	
28.31	Tiles scour room 1.16		m2	3.4	22.2			75.48	
28.32	Tiles scour room 1.17		m2	8.4	2.4			20.16	**1300**
28.33	Tiles scour room 2.1		m2	8.2	19.6			160.72	
28.34	Tiles scour room 2.2		m2	8.2	4.2			34.44	
28.35	Tiles scour room 2.3		m2	4	6			24	
28.36	Tiles scour room 2.4		m2	4	6			24	
28.37	Tiles scour room 2.5		m2	5.3	6			31.8	
28.38	Tiles scour room 2.6		m2	4	8.6			34.4	
28.39	Tiles scour room 2.7		m2	4	5.2			20.8	
28.40	Tiles scour room 2.8		m2	8.3	8.6			71.38	
28.41	Tiles scour room 2.9		m2	8.3	8.3			68.89	

28.42	Tiles scour room 2.10		m2	9	12.8			115.2	
28.43	Tiles scour room 2.11		m2	4.6	3.6			16.56	
28.44	Tiles scour room 2.12		m2	17.8	3.6			64.08	
28.45	Tiles scour room 2.13		m2	4.6	10.8			49.68	
28.46	Tiles scour room 2.14		m2	4.6	4.4			20.24	
28.47	Tiles scour room 2.15		m2	5.8	8.5			49.3	
28.48	Tiles scour room 2.16		m2	5.8	8.3			48.14	
28.49	Tiles scour room 2.17		m2	5.8	8.3			48.14	
28.50	Tiles scour room 2.18		m2	14.8	2.1			31.08	
28.51	Tiles scour room 2.19		m2	3.7	2.3			8.51	
28.52	Tiles scour room 2.20		m2	16.5	3.5			57.75	
28.53	Tiles scour room 2.21		m2	15.2	2.3			34.96	
28.54	Tiles scour room 2.22		m2	23.8	2.1			49.98	**1064.1**
28.55	Tiles scour room -1.1		m2	9.8	7.6			74.48	
28.56	Tiles scour room -1.2		m2	7.6	7.6			57.76	
28.57	Tiles scour room -1.3		m2	7.1	7.8			55.38	
28.58	Tiles scour room -1.4		m2	7.1	4			28.4	
28.59	Tiles scour room -1.5		m2	7.6	6.9			52.44	
28.60	Tiles scour room -1.6		m2	7.6	6.9			52.44	
28.61	Tiles scour room -1.7		m2	19	7.9			150.1	
28.62	Tiles scour room -1.8		m2	7.3	7.3			53.29	
28.63	Tiles scour room -1.9		m2	7.5	7.3			54.75	
28.64	Tiles scour room -1.10		m2	7.7	7.3			56.21	
28.65	Tiles scour room -1.11		m2	10	4.1			41	
28.66	Tiles scour room -1.12		m2	10.2	2.9			29.58	
28.67	Tiles scour room -1.13		m2	10	3.6			36	
28.68	Tiles scour room -1.14		m2	10	7.2			72	
28.69	Tiles scour room -1.15		m2	24.3	2.5			60.75	
28.70	Tiles scour room -1.16		m2	9.6	2			19.2	
28.71	Tiles scour room -1.17		m2	8.1	2.8			22.68	
28.72	Tiles scour room -1.18		m2	4.4	2.8			12.32	**928.78**

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

32 - FURNITURE, FITTING AND EQUIPMENTS

Quantity Take-off .

ITEM #	ITEM NAME	UNIT	QUAN.	DIMENSION (m)			PART		TOTAL
				LENGTH	WIDTH	HEIGHT	-	+	
	Tables								
32.1	"200*70cm" table in plan 0	p	24	2	0.7	0.7		24	
32.2	"200*70cm" table in plan 1	p	10	2	0.7	0.7		10	
32.3	"200*70cm" table in plan 2	p	23	2	0.7	0.7		23	
32.4	"200*70cm" table in plan -1	p	18	2	0.7	0.7		18	**75**
32.4	"240*110cm" table in plan 2	p	21	2.4	1.1	0.7		21	
32.5	"240*110cm" table in plan -1	p	8	2.4	1.1	0.7		8	**29**
32.6	"460*120cm" Meeting Table in plan 2	p	1	4.6	1.2	0.7		1	**1**
	Cabinet								
32.7	"100*50" Smal unites in floor 0	p	112	1	0.5	2		112	
32.8	"100*50" Smal unites in floor 1	p	15	1	0.5	2		15	
32.9	"100*50" Smal unites in floor 2	p	59	1	0.5	2		59	
32.10	"100*50" Smal unites in floor -1	p	23	1	0.5	2		23	**209**
	Seats								
32.11	"50*50cm chair" in plan 0	p	34	0.5	0.5	0.45		34	
32.12	"50*50cm chair" in plan 1	p	10	0.5	0.5	0.45		10	
32.13	"50*50cm chair" in plan 2	p	85	0.5	0.5	0.45		85	
32.14	"50*50cm chair" in plan -1	p	31	0.5	0.5	0.45		31	**160**
32.15	"100*100cm" Sofa in floor 0	p	30	1	1	0.45		30	**30**
32.16	"45*45cm" Theater chairs in floor 0	p	127	0.45	0.45	0.45		127	
32.17	"45*45cm" Theater chairs in floor 1	p	230	0.45	0.45	0.45		230	
32.18	"45*45cm" Theater chairs in floor 2	p	40	0.45	0.45	0.45		40	**397**
	Reciption Counter								
32.19	"640*240cm" Counter in floor 0	p	1	6.4	2.4	0.9		1	**1**
	Datashow Screen								
32.20	Screens in floor 1	p	10					10	**10**

	INSTRUMENTS						
32.21	Piano + seat in floor 0	p	6			6	
32.22	Piano + seat in floor 1	p	15			15	
32.23	Piano + seat in floor 2	p	8			8	
32.24	Piano + seat in floor -1	p	3			3	**32**
32.25	Music stand in floor 1	p	65			65	
32.26	Music stand in floor 2	p	30			30	
32.27	Music stand in floor -1	p	23			23	**118**
32.28	Org in floor 1	p	2			2	
32.29	Org in floor -1	p	5			5	**7**
32.30	lyre in floor 1	p	1			1	**1**
32.31	Droms in floor -1	p	5			5	**5**

These bills are generated and used
only for education purposes.

Faculty of Music

9.13 Appendix M: Bill of Quantity Sheets

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 1 - MAIN CONTRACTORS PRELIMINARIES

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	MAIN CONTRACTORS PRELIMINARIES (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 2 - OFF-SITE MANUFACTURED MATERIALS; COMPONENTS AND BUILDINGS

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	OFF-SITE MANUFACTURED MATERIALS; COMPONENTS AND BUILDINGS (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 3 - DEMOLITIONS

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	DEMOLITIONS (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 4 - ALTERATIONS, REPAIRS AND CONSERVATION

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	ALTERATIONS, REPAIRS AND CONSERVATION (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 5 - EXCAVATION AND FILLING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	EXCAVATION AND FILLING (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljubljana, Slovenia

BILL NO. 6 - GROUND REMEDIATION AND SOIL STABILISATION

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	GROUND REMEDIATION AND SOIL STABILISATION (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 7 - PILING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	PILING (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 8 - UNDERPINNING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	UNDERPINNING (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 9 - DIAPHRAGM WALLS AND EMBEDED RETAINING WALL

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	DIAPHRAGM WALLS AND EMBEDED RETAINING WALL (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 10 - CRIB WALLS, GABIONS AND REINFORCED EARTH

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	CRIB WALLS, GABIONS AND REINFORCED EARTH (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 11 - IN-SITU CONCRETE WORKS

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	IN-SITU CONCRETE WORKS (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 12 - PRECAST/COMPOSITE CONCRETE

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	PRECAST/COMPOSITE CONCRETE (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 13 - PRECAST CONCRETE

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	PRECAST CONCRETE (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 14 - MASONRY

BIM A+

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	Added Insulated internal wall				
NRM2.14.1.1	**"100 cm thick" walls** *Providing and constructing 100 cm brick thick size or more brick masonry work with sub class B bricks minimum compressive strength of 35kg/sq cm in cement mortar 1:6 (1 cement : 6 coarse sand) in straight or curved in plan at all heights and locations including scaffolding, staging ,curing etc., complete for internal walls*	383.8	m2	25	9595
NRM2.14.1.2	**80 cm thick walls** *Providing and constructing 80cm brick thick size or more brick masonry work with sub class B bricks minimum compressive strength of 35kg/sq cm in cement mortar 1:6 (1 cement : 6 coarse sand) in straight or curved in plan at all heights and locations including scaffolding, staging ,curing etc., complete for internal walls*	60.8	m2	20	1216
NRM2.14.1.3	**50 cm thick walls** *Providing and constructing 50 cm brick thick size or more brick masonry work with sub class B bricks minimum compressive strength of 35kg/sq cm in cement mortar 1:6 (1 cement : 6 coarse sand) in straight or curved in plan at all heights and locations including scaffolding, staging ,curing etc., complete for internal walls*	167.5	m2	13	2177.5
NRM2.14.1.4	**25 cm thick walls** *Providing and constructing 25 cm brick thick size or more brick masonry work with sub class B bricks minimum compressive strength of 35kg/sq cm in cement mortar 1:6 (1 cement : 6 coarse sand) in straight or curved in plan at all heights and locations including scaffolding, staging ,curing etc., complete for internal walls*	100.4	m2	6	602.4

	Demolished internal walls				
NRM2.14.2.5	**"85 cm thick" walls** *Providing utilities to demolish 85 cm tick interior wall*	66.1	m2	11	727.1
NRM2.14.2.6	**"125 cm thick" walls in plan 0** *Providing utilities to demolish 125 cm tick interior wall*	4.8	m2	16	76.8
NRM2.14.2.7	**"100 cm thick" walls in plan 0** *Providing utilities to demolish 100 cm tick interior wall*	4.2	m2	13	54.6
NRM2.14.2.8	**"20 cm thick" walls in plan 0** *Providing utilities to demolish 20cm tick interior wall*	943.1	m2	3	2829.3
Rev. 0				€	17,279

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 15 - STRUCTURAL METALWORK

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	STRUCTURAL METALWORK (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 16 - CARPENTRY

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	CARPENTRY (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 17 - SHEET ROOF COVERING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	SHEET ROOF COVERING (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 18 - TILE AND SLATE ROOF WALL COVERING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	TILE AND SLATE ROOF WALL COVERING (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 19 - WATERPROOFING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	WATERPROOFING (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 20 - PROPRIETARY LININGS AND PARTITIONS

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	PROPRIETARY LININGS AND PARTITIONS (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 21 - CLADDING AND COVERING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	CLADDING AND COVERING (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 22 - GENERAL JOINERY

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	GENERAL JOINERY (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 23 - WINDOW, SCREEN AND LIGHTS

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	WINDOW, SCREEN AND LIGHTS (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 24 - DOORS, SHUTTERS AND HATCHES

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	INTERNAL WOOD DOOR				
NRM2.24.1.9	**"240cm" doors** *Installation of interior door with 240 cm height and solid section*	1	Nr	240	240
NRM2.24.1.10	**"140cm" doors** *Installation of interior door with 140 cm height and solid section*	7	Nr	140	980
	INTERNAL INSULATED DOOR				
NRM2.24.2.11	**"170cm" doors** *Installation of insulated interior door with 170 cm height with insulating material in stuffing*	2	Nr	270	540
NRM2.24.2.12	**"130cm" doors** *Installation of insulated interior door with 130 cm height with insulating material in stuffing*	20	Nr	230	4600
NRM2.24.2.13	**"100cm" doors** *Installation of insulated interior door with 100 cm height with insulating material in stuffing*	2	Nr	200	400
NRM2.24.2.14	**"260cm" doors** *Installation of insulated interior door with 260 cm height with insulating material in stuffing*	2	Nr	360	720
NRM2.24.2.15	**"240cm" doors** *Installation of insulated interior door with 240 cm height with insulating material in stuffing*	5	Nr	340	1700
	INTERNAL CURTAIN DOOR				
NRM2.24.3.16	**"240cm" doors** *Installation of iinterior curtain door with 240 cm height with insulating material in stuffing*	1	Nr	400	400
Rev. 0				€	9,580

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 25 - STAIRS WALKWAYS AND BALUSTRADES

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	STAIRS WALKWAYS AND BALUSTRADES (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 26 - METAL WORK

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	METAL WORK (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 27 - GLAZING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	GLAZING (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 28 - FLOOR WALL, CEILING AND ROOF FINISHING

BIM A+

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	Tiles scour				
NRM2.28.1.17	**Tiles scour in floor 0** *Tiles and surface installement per are square meter include mortar tiles and equipmnent*	1058	m2	20	21160
NRM2.28.1.18	**Tiles scour in floor 1** *Tiles and surface installement per are square meter include mortar tiles and equipmnent*	1300	m2	20	26000
NRM2.28.1.19	**Tiles scour in floor 2** *Tiles and surface installement per are square meter include mortar tiles and equipmnent*	1064.1	m2	20	21282
NRM2.28.1.20	**Tiles scour in floor -1** *Tiles and surface installement per are square meter include mortar tiles and equipmnent*	928.8	m2	20	18576
Rev. 0				€	87,018

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 28 - FLOOR WALL, CEILING AND ROOF FINISHING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	Tiles Replacement				
NRM2.28.2.21	**Tiles scour in floor 0** *Tiles and surface installement per are square meter include mortar tiles and equipmnent*	1058	m2	100	105800
NRM2.28.2.22	**Tiles scour in floor 1** *Tiles and surface installement per are square meter include mortar tiles and equipmnent*	1300	m2	100	130000
NRM2.28.2.23	**Tiles scour in floor 2** *Tiles and surface installement per are square meter include mortar tiles and equipmnent*	1064.1	m2	100	106410
NRM2.28.2.24	**Tiles scour in floor -1** *Tiles and surface installement per are square meter include mortar tiles and equipmnent*	928.8	m2	100	92880
Rev. 0				€	435,090

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 29 - DECORATION

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	DECORATION (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 30 - SUSPENDED CEILING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	SUSPENDED CEILING (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 31 - INSULATION, FIRE STOPPING AND FIRE PROTECTION

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	INSULATION, FIRE STOPPING AND FIRE PROTECTION (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 32 - FURNITURE, FITTING AND EQUIPMENTS

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	Tables				
NRM2.32.1.25	**"200*70cm" table**	75	Nr	70	5250
	Vitra model Nr. 100V23C				
NRM2.32.1.26	**"240*110cm" table**	29	Nr	110	3190
	Steelcase model Code A467R				
NRM2.32.1.27	**"460*120cm" Meeting Table**	1	Nr	200	200
	Steelcase model Code A68BR				
	Cabinet				
NRM2.32.2.28	**"100*50" Smal unites**	209	Nr	150	31350
	Plank wood cabinet with which top coat				
	Seats				
NRM2.32.3.29	**"50*50cm chair"**	160	Nr	100	16000
	Steelcase model Code Ch23571				
NRM2.32.3.30	**"100*100cm" Sofa**	30	Nr	200	6000
	Vitra model Code Ch24525				
NRM2.32.3.31	**"45*45cm" Theater chairs**	397	Nr	90	35730
	Vitra model Custome chairs Code 242				
Rev. 0				€	97,720

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 32 - FURNITURE, FITTING AND EQUIPMENTS

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	Reciption Counter				
NRM2.32.4.32	**"640*240cm" Counter**	2	Nr	340	680
	Plankwood counter with white coat				
	Datashow Screen				
NRM2.32.5.33	**Screen projector**	10	Nr	70	700
	Samsung projector and screen display t200-40				
	INSTRUMENTS				
NRM2.32.6.34	**Classic piano set**	32	Nr	8000	256000
	Classic yamaha Piano smahogany black				
NRM2.32.6.35	**Sheet Score Stand**	118	Nr	100	11800
	Aluminum based coat perferatedwith stainless steel stem				
NRM2.32.6.36	**Electronic Piano (Organ)**	7	Nr	3000	21000
	Electric yamaha Piano electroo 4000				
NRM2.32.6.37	**Strings quartetter (Lyre)**	1	Nr	2000	2000
	Classic yamaha string set lilac brass lyre strings				
NRM2.32.6.38	**Percussion set (Drums)**	5	Nr	1000	5000
	Classic yamaha drums percussion set professional lilac				
Rev. 0				€	297,180

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljubljana, Slovenia

BILL NO. 33 - DRAINAGE ABOVE GROUND

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	DRAINAGE ABOVE GROUND (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 34 - DRAINAGE BELOW GROUND

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	DRAINAGE BELOW GROUND (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 35 - SITE WORKS

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	SITE WORKS (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 36 - FENCING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	FENCING (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 37 - SOFT LANDSCAPING

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	SOFT LANDSCAPING (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 38 - MECHANICAL SERVICES

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	MECHANICAL SERVICES (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 39 - ELECTRICAL SERVICES

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	ELECTRICAL SERVICES (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 40 - TRANSPORT

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	TRANSPORT (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia
BILL NO. 41 - BUILDERS WORK INCONNECTION WITH MECHANICAL, ELECTRICAL AND TRANSPORTATION INSTALLATION

BIM A+

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	BUILDERS WORK INCONNECTION WITH MECHANICAL, ELECTRICAL AND TRANSPORTATION INSTALLATION (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 42 - RISKS

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	RISKS (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 43 - PROVISIONAL SUMS

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	PROVISIONAL SUMS (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 44 - CREDITS

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	CREDITS (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

Kazina Building, Slovenia

Ljublijana, Slovenia

BILL NO. 45 - DAYWORK

BILLS OF QUANTITIES

Item	Description	Qty.	Unit	Rate	Amount
	DAYWORK (NOT USED)				0
					0
					0
					0
					0
					0
					0
					0
					0
					0
Rev. 0					0

These bills are generated and used
only for education purposes.

Faculty of Music

10 REFERENCES

[1] "RICS looks to certify 10,000 chartered surveyors in India by 2029," *Moneycontrol*.

[2] "What is BIM? | NBS." [Online]. Available: https://www.thenbs.com/knowledge/what-is-building-information-modelling-bim. [Accessed: 18-Jun-2020].

[3] "A history of BIM - LetsBuild." [Online]. Available: https://www.letsbuild.com/blog/a-history-of-bim. [Accessed: 27-Aug-2020].

[4] *History*. RICS, 2014.

[5] "The history of Quantity Surveying - Association of South African Quantity Surveyors (ASAQS)." [Online]. Available: https://www.asaqs.co.za/page/history. [Accessed: 29-Jun-2020].

[6] R. G. Kreider and J. I. Messner, "The Uses of BIM Classifying and Selecting BIM Uses," 2013.

[7] "Programming languages for the BIM industry you need to know in 2020." [Online]. Available: https://medium.com/@krel.svyatoslav/programming-languages-for-the-bim-industry-you-need-to-know-in-2020-1efd4d5be5d1. [Accessed: 29-Jun-2020].

[8] "What is an API? (Application Programming Interface) | MuleSoft." [Online]. Available: https://www.mulesoft.com/resources/api/what-is-an-api. [Accessed: 23-Aug-2020].

[9] "Vault Subscription | Get Prices & Buy Vault 2021 | Autodesk Store." [Online]. Available: https://www.autodesk.com.au/products/vault/subscribe?plc=VLTM&term=1-YEAR&support=ADVANCED&quantity=1. [Accessed: 18-Sep-2020].

[10] "Augmented Reality (AR) Consulting Services for BIM | Consultants." [Online]. Available: https://www.srinsofttech.com/augmented-reality-for-bim.html. [Accessed: 21-Sep-2020].

[11] "Rendering a BIM model and the PlayStructure view - BibLus." [Online]. Available: http://biblus.accasoftware.com/en/rendering-a-bim-model-and-the-playstructure-view/. [Accessed: 27-Aug-2020].

[12] "Royal Institute of British Architects RIBA - Designing Buildings Wiki." [Online]. Available: https://www.designingbuildings.co.uk/wiki/Royal_Institute_of_British_Architects_RIBA. [Accessed: 11-Jul-2020].

[13] L. S. B. University, "RIBA Professional Practice Part 3."

[14] "RICS: Royal Institution of Chartered Surveyors." [Online]. Available: https://www.rics.org/uk/.

[Accessed: 11-Jul-2020].

[15] "Royal Institution of Chartered Surveyors RICS - Designing Buildings Wiki." [Online]. Available: https://www.designingbuildings.co.uk/wiki/Royal_Institution_of_Chartered_Surveyors_RICS. [Accessed: 29-Jun-2020].

[16] "RICS: Upholding Professional Standards," *rics.org*.

[17] "RICS: Royal Institution of Chartered Surveyors." [Online]. Available: https://www.rics.org/eu/. [Accessed: 22-Jun-2020].

[18] "Becoming an RICS Member," *ricsrecruis.com*, Apr. 2016.

[19] "AssocRICS – the new grade," *RICS*, Jan. 2009.

[20] RICS, "Who we are and what we do," *rics.org*.

[21] *NRM 1: Order of cost estimating and cost planning for capital building works RICS new rules of measurement NRM 1: Order of cost estimating and cost planning for capital building works 2nd edition*. .

[22] *NRM 3: Order of cost estimating and cost planning for building maintenance works. RICS new rules of measurement RICS new rules of measurement Order of cost estimating and cost planning for building maintenance works RICS new rules of measurement NRM 3: Order of cost estimating and cost planning for building maintenance works 1st edition Acknowledgments of Copyright*. .

[23] H. Taherdoost, "Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research," *SSRN Electron. J.*, Aug. 2018.

[24] "CHAPTER 2 QUANTITY TAKE-OFF."

[25] "Quantity takeoff from 2D and 3D models | isurv." [Online]. Available: https://www.isurv.com/info/1405/quantity_takeoff_from_2d_and_3d_models. [Accessed: 21-Jul-2020].

[26] C. Khosakitchalert, N. Yabuki, and T. Fukuda, "Improving the accuracy of BIM-based quantity takeoff for compound elements," *Autom. Constr.*, vol. 106, p. 102891, Oct. 2019.

[27] *NRM 2: Detailed measurement for building works RICS NEW RULES OF MEASUREMENT NRM 2: Detailed measurement for building works 1st edition*. .

[28] "5 reasons why firms refuse to adopt BIM - The BIM Center." [Online]. Available: https://www.thebimcenter.com/2016/08/5-reasons-why-firms-refuse-to-adopt-bim.html. [Accessed: 18-Sep-2020].

[29] R. Bečvarovská and P. Matějka, "COMPARATIVE ANALYSIS OF CREATING TRADITIONAL QUANTITY TAKEOFF METHOD AND USING A BIM TOOL."

[30] A. Marques, "António Alexandre Fernandes Marques Universidade do Minho Escola de Engenharia."

[31] "Pesquisa mostra o avanço dos benefícios da adoção do BIM na America do Norte – Claudia Campos." [Online]. Available: https://claudiacamposlima.wordpress.com/2013/07/25/pesquisa-mostra-o-avanco-dos-beneficios-da-adocao-do-bim-na-america-do-norte/. [Accessed: 18-Sep-2020].

[32] "The lowdown on LODs: Bringing clarity to BIM | Building Design + Construction." [Online]. Available: https://www.bdcnetwork.com/blog/lowdown-lods-bringing-clarity-bim. [Accessed: 01-Aug-2020].

[33] "Forge Authentication API – The Field of View." [Online]. Available: https://fieldofviewblog.wordpress.com/2017/01/24/forge-authentication-api/. [Accessed: 18-Sep-2020].

[34] "Types of bill of quantities - Designing Buildings Wiki." [Online]. Available: https://www.designingbuildings.co.uk/wiki/Types_of_bill_of_quantities. [Accessed: 29-Jun-2020].

[35] "Billing of Quantities (BOQ) | Types | Example BOQ | Advantages and Limitations - EngineeringCivil.org." [Online]. Available: https://engineeringcivil.org/articles/billing-of-quantities-boq-types-example-boq-advantages-and-limitations/. [Accessed: 27-Aug-2020].

[36] P. Piroozfar, F. Pomponi, and E. R. P. Farr, "Life cycle assessment of domestic hot water systems: a comparative analysis," *Int. J. Constr. Manag.*, vol. 16, no. 2, pp. 109–125, Apr. 2016.

[37] H. P. M. Winchester, "Interviews and questionnaires as mixed methods in population geography: The case of lone fathers in Newcastle, Australia," *Professional Geographer*, vol. 51, no. 1. Routledge, pp. 60–67, 1999.

[38] "6 Steps To Conducting An Online Survey | SmartSurvey." [Online]. Available: https://www.smartsurvey.co.uk/articles/6-steps-to-conducting-an-online-survey. [Accessed: 27-Aug-2020].

[39] "ARES PRISM | Enterprise Project Controls Software." [Online]. Available: https://www.aresprism.com/. [Accessed: 27-Aug-2020].

[40] "Project Cost Estimating Software | ARES PRISM." [Online]. Available: https://www.aresprism.com/products/project-estimating-software/. [Accessed: 27-Aug-2020].

[41]: : "CostX ::" [Online]. Available: http://www.costx.co.za/why.php. [Accessed: 06-Aug-2020].

[42] "BIM BOQ Quantifier | Revit | Autodesk App Store." [Online]. Available: https://apps.autodesk.com/RVT/en/Detail/Index?id=8582772410282720734&appLang=en&os=Win64. [Accessed: 27-Aug-2020].

[43] "What is Programming? [Beginner's Guide]." [Online]. Available: https://hackr.io/blog/what-is-programming. [Accessed: 09-Sep-2020].

[44] "Revit Programming for Beginners: Easily Access the Revit API Using Free Tools | Autodesk University." [Online]. Available: https://www.autodesk.com/autodesk-university/class/Revit-Programming-Beginners-Easily-Access-Revit-API-Using-Free-Tools-2018. [Accessed: 09-Sep-2020].

[45] "Top 10 Reasons Why Python is So Popular With Developers in 2020 | upGrad blog." [Online]. Available: https://www.upgrad.com/blog/reasons-why-python-popular-with-developers/. [Accessed: 24-Aug-2020].

[46] "python - How to handle both `with open(...)` and `sys.stdout` nicely? - Stack Overflow." [Online]. Available: https://stackoverflow.com/questions/17602878/how-to-handle-both-with-open-and-sys-stdout-nicely. [Accessed: 11-Jul-2020].

[47] "Extensions and Commmands — pyRevit 4.5 documentation." [Online]. Available: https://pyrevit1.readthedocs.io/en/latest/creatingexts.html. [Accessed: 09-Sep-2020].

[48] "Introducing IronPython." [Online]. Available: https://www.codemag.com/Article/0809071/Introducing-IronPython. [Accessed: 09-Sep-2020].

[49] "1. Command line and environment — IronPython 2.7.2b1 documentation." [Online]. Available: https://ironpython-test.readthedocs.io/en/latest/using/cmdline.html. [Accessed: 09-Sep-2020].

[50] "Disadvantages of Python - GeeksforGeeks." [Online]. Available: https://www.geeksforgeeks.org/disadvantages-of-python/. [Accessed: 09-Sep-2020].

[51] "Python vs C++ Comparison: Compare Python vs C++ Speed and More." [Online]. Available: https://www.bitdegree.org/tutorials/python-vs-c-plus-plus/. [Accessed: 09-Sep-2020].

[52] "What are the disadvantages of the Python?" [Online]. Available: http://net-informations.com/python/iq/disadvantages.htm. [Accessed: 01-Sep-2020].

[53] "My First Revit Plug-in Overview | Revit Products | Autodesk Knowledge Network." [Online]. Available: https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/simplecontent/content/my-first-revit-plug-overview.html. [Accessed: 23-Aug-2020].

[54] "Optimizing Your Python Code. Essential tips for working with large… | by Anna Astori | Towards Data Science." [Online]. Available: https://towardsdatascience.com/optimizing-your-python-code-156d4b8f4a29. [Accessed: 01-Sep-2020].

[55] "Refurbishment - Designing Buildings Wiki." [Online]. Available: https://www.designingbuildings.co.uk/wiki/Refurbishment. [Accessed: 09-Sep-2020].

[56] "List of Countries by Corporate Tax Rate." [Online]. Available: https://tradingeconomics.com/country-list/corporate-tax-rate. [Accessed: 09-Sep-2020].

[57] "(No Title)." [Online]. Available: https://www.theiet.org/media/1222/bim-cyber.pdf. [Accessed: 27-Aug-2020].

[58] "Import IFC Model to ARCHICAD | User Guide Page | GRAPHISOFT Help Center." [Online]. Available: https://helpcenter.graphisoft.com/user-guide/65782/. [Accessed: 09-Sep-2020].

[59] "Studio | Styria Arhitektura." [Online]. Available: http://www.styria.si/studio/. [Accessed: 24-Sep-2020].

[60] "Casinos Team building." [Online]. Available: https://www.kazina.si/dodatna-ponudba/team-building/. [Accessed: 27-Aug-2020].

[61] "Casinos The world of dance." [Online]. Available: https://www.kazina.si/. [Accessed: 09-Sep-2020].

[62] V. Z. Bosiljkov, "MASONRY TODAY PERFORMANCE BASED ASSESSMENT OF CULTURAL HERITAGE BUILDINGS IN CENTRAL EUROPE - CASE STUDIES FROM SLOVENIA," 2018.

[63] J. Choi, H. Kim, and I. Kim, "Open BIM-based quantity take-off system for schematic estimation of building frame in early design stage," *J. Comput. Des. Eng.*, vol. 2, no. 1, pp. 16–25, Jan. 2015.

[64] "Αψίδα | Preparation of a bill of quantities using the traditional method." [Online]. Available:

https://apsida.cut.ac.cy/items/show/17098#?c=&m=&s=&cv=. [Accessed: 09-Sep-2020].

[65] "COSTX TIPS & TRICKS TUTORIAL - 3 APR 2019." [Online]. Available: https://www.evensi.com/costx-tips-tricks-tutorial-curtin-university/298516226. [Accessed: 09-Sep-2020].

[66] "What is IFC?" [Online]. Available: https://bimconnect.org/en/software/what-is-ifc/. [Accessed: 09-Sep-2020].

[67] "BIM Level of Development | LOD, 100, 200, 300, 350, 400, 500 | BIM Modeling Services | Architecture Engineering and Construction(AEC) | AEC Industry." [Online]. Available: https://www.srinsofttech.com/bim-level-of-development-lod-300-400-500.html. [Accessed: 09-Sep-2020].

[68] "Construction Estimating - BibLus." [Online]. Available: http://biblus.accasoftware.com/en/construction-estimating/. [Accessed: 18-Sep-2020].

[69] "Technology Archives - Page 4 of 9 - BibLus." [Online]. Available: http://biblus.accasoftware.com/en/category/technology/page/4/. [Accessed: 18-Sep-2020].

[70] "All 1 Studio | BIM Implementation - All 1 Studio." [Online]. Available: https://all1studio.com/bim-implementation/. [Accessed: 18-Sep-2020].

[71] "The Data Spectrum – The ODI." [Online]. Available: https://theodi.org/about-the-odi/the-data-spectrum/. [Accessed: 18-Sep-2020].

[72] "BIM and building properties | NBS." [Online]. Available: https://www.thenbs.com/knowledge/bim-and-building-properties. [Accessed: 18-Sep-2020].

[73] "BIM maturity Levels: from stage 0 to stage 3 - BibLus." [Online]. Available: http://biblus.accasoftware.com/en/bim-maturity-levels-from-stage-0-to-stage-3/. [Accessed: 18-Sep-2020].

[74] "BIM, Security and the Building Lifecycle." [Online]. Available: https://www.ascentor.co.uk/2017/11/bim-security-building-lifecycle/. [Accessed: 18-Sep-2020].

[75] "(798) Pinterest." [Online]. Available: https://www.pinterest.com/pin/506092076874615255/?autologin=true. [Accessed: 18-Sep-2020].

[76] "Flow Chart of Clash Inspection | Download Scientific Diagram." [Online]. Available:

https://www.researchgate.net/figure/Flow-Chart-of-Clash-Inspection_fig2_221510843. [Accessed: 18-Sep-2020].

[77] M. Begum and M. S. Uddin, "Digital Image Watermarking Techniques: A Review," *Information*, vol. 11, no. 2, p. 110, Feb. 2020.

[78] "Reactive optimization schedule for traditional refurbishment project vs... | Download Scientific Diagram." [Online]. Available: https://www.researchgate.net/figure/Reactive-optimization-schedule-for-traditional-refurbishment-project-vs-BIM-virtual_fig2_327756410. [Accessed: 18-Sep-2020].

[79] "Cost estimating process in a BIM-based cost estimating software. | Download Scientific Diagram." [Online]. Available: https://www.researchgate.net/figure/Cost-estimating-process-in-a-BIM-based-cost-estimating-software_fig1_314080434. [Accessed: 18-Sep-2020].