THE EFFECTIVENESS OF BUILDING INFORMATION MODELING IN SRI LANKA CONSTRUCTION INDUSTRY

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Declaration

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Dedication

I would like to dedicate

This thesis,

To my Parents, Husband and Son,

For their eternal love, affection and encouragement

Which strive me to

Make my dream a reality,

And the teachers, who lead me

To the path of success and honour.

Without their inspiration and guidance

I would not be able

To pass through the tiring process of this research.

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Abstract

Building Information Modeling (BIM) is one of the latest emerging technologies in the Architecture, Engineering, and Construction (AEC) industry. It is an application to reproduce the real building process facilitating to manage projects conveniently. This can be developed from 2D drawing up to 7D as modelling, scheduling, estimating, sustainability and facility management respectively. It is vastly used to handle complex projects in order to its enormous benefits namely faster project delivery, reduction of risk, time and material waste, enhancing sustainability and better building life cycle performance and more likely to become an industrial standard worldwide in future.

However, BIM is not much popular in local construction industry yet. Mostly, the top management is on the horns of dilemma in view of adopting BIM in their projects. This research addresses this contemporary need of figuring out whether a developing country like Sri Lanka is beneficial by adopting this technology in construction.

The study strived to investigate the BIM awareness and adoption level of Sri Lankan Construction Industry, the potential of BIM to solve common construction issues and the barriers to adopt BIM locally and last of all, concluded recommendations for proper BIM implementation. Data was collected via a questionnaire survey targeting the stakeholders of top tier construction projects. It was analysed applying hypothesis testing using Mann Whitney U test values and relative important index method. The analysis was focused on the influence of identified factors such as experience level and BIM usage in solving major construction issues. Further, it ranked the significance of internal and external barriers for BIM implementation in the vicinity.

Results of the analysis revealed that BIM usage minimizes encountering major issues in construction industry and facilitates the smooth flow in construction work independently from the work experience. Unawareness of BIM was ranked as the top most barrier in its implementation.

The findings of this study provides an inspiring guide for AEC industry practitioners in Sri Lanka to make the right decision while considering the implementation of BIM technology in their projects.

Keywords: Building Information Modeling, AEC industry, Hypothesis Testing, Mann Whitney u test, Relative Important Index

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LIST OF ABBREVIATIONS

Abbreviation	Description
AEC	Architecture, Engineering and Construction
BIM	Building Information Modeling
CAD	Computer Aided Design
CPM	Critical Path Method
IPD	Integrated Project Delivery
RII	Relative Important Index

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1 INTRODUCTION

1.1 Background

This chapter aims to provide a general understanding on this research study, “The effectiveness of Building Information Modeling in Sri Lanka construction industry”.

It is highly convenient to manage projects if there is an application to reproduce the real building process. This is where “Building Information Modeling (BIM)”comes to the play. Building Information Modeling (BIM) is one of the most gifted developments in the architecture, engineering, and construction (AEC) industries (Eastman, Chuck; Tiecholz, Paul; Sacks, Rafael; Liston, Kathleen , 2011).

There are many definitions of Building Information Modeling. It is simply a platform which provides a three dimensional digital representation of the building system with a database including consistent building data and information. This is far beyond the 2D line work in a CAD drawing and can be developed up to 7D as shown in Figure 1. 3D represents the model and 4D represents the scheduling. 5D is for estimating while 6D and 7D are for sustainability and facility management respectively. All the elements in a BIM model are intelligent and digital prototype of the physical building elements such as walls, columns, windows, doors, stairs etc. This model simulates the building and its behaviour in a virtual environment, way before the beginning of the actual construction.

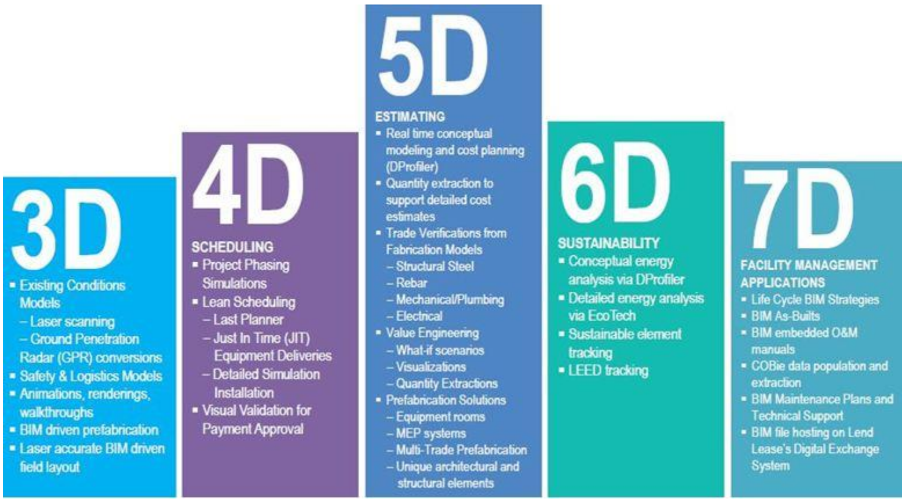

Figure 1: BIM Dimensions

BIM is a revolutionary technology and process that has quickly transformed the way buildings are conceived, designed, constructed and operated (Hardin, 2009). Building Information Model integrates the diverse stakeholders for different purposes during the each phase of the building life cycle. It can be advanced such that clients, building owners and operators to get more access to the BIM model through their mobile devices even without installing a BIM application. It is a tool to design and document a project, but is also used as a mode to enhance communication among all the project stakeholders. (Krygiel, E. and B. Nies , 2008).

Though this emerging technology is not much popular in Sri Lanka, it is likely to become an industrial standard to handle complex projects throughout the world in future. BIM application guided the projects to improve profitability, manage timing and enhance customer-client relationships in order to achieve a faster project delivery. Moreover, reduction of risk, time and material waste, enhancing sustainability and better life cycle performance of the building are added advantages.

BIM encourages the integration of the roles of all stakeholders on a project. This integration has brought greater efficiency and collaboration among the team members of the project. (Salman Azhar, Malik Khalfan, Tayyab Maqsood). For instance, BIM model represents the building completely as the concept in the architect's mind and since all the data is embedded in centralized virtual building model, any architectural or structural change instantly upgrade the model and update the individuals with the relevant modifications. This integrated model approach, not only offers significant productivity increase but also serves as the basis for better-coordination throughout the building process namely planning, design, construction as well as post construction as shown in the Figure 2.

Nevertheless, the benefits are much greater, it should be figure out the effectiveness of adopting BIM in the construction industry of Sri Lanka, as a developing country. On the other hand, whether adopting BIM is truly essential to satisfy the stakeholders' requirements. These defies attract more and more researchers towards the area of BIM in the context of Sri Lankan construction industry.

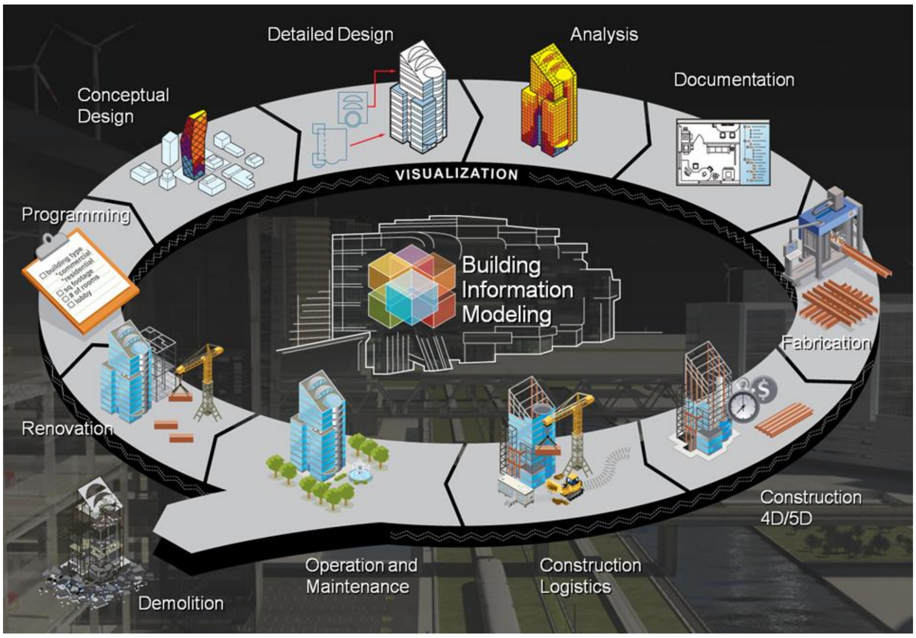

Figure 2: BIM and Building Life Cycle

This research will carry out a comprehensive study on the effectiveness of Building Information Modeling in Sri Lanka Construction Industry. Since the top management who are on the horns of dilemma in view of adopting BIM in their projects, the findings of this study will provide an inspiring guide for AEC industry practitioners in considering implementing BIM technology in Sri Lankan construction industry.

1.2 Problem Statement

Building Information Modeling has promptly grown in worldwide with its demarcating benefits to the construction industry. However, BIM adoption rate in developing countries like Sri Lanka is very much near to the ground. The research focuses on the Sri Lankan building construction and Building Information Modeling which is a very contemporary topic in the industry.

This study intends to provide an insight on the effectiveness of Building Information Modeling in Sri Lanka Construction Industry. The awareness level of the industry, potentials of BIM to solve major construction issues, barriers and stability of the industry to implement BIM and recommendations in implementing it appropriately are the areas subjected to the discussion.

More specifically, the following research questions are anticipated to be addressed in this research.

1. What is the awareness level and adoption of BIM in Sri Lankan construction industry?

2. What are the common issues in the construction industry and the potential of BIM to solve those issues?
3. What are the requisites and barriers to adopt BIM and the competency level of Sri Lankan Construction Industry towards adopting BIM?
4. What are the recommendations to implement BIM properly in Sri Lankan construction industry?

1.3 Objectives

Key objectives of this research can be pointed out as mentioned below.

1. To identify the BIM awareness and adoption level of Sri Lankan Construction Industry.
2. To recognize the potential of BIM to solve common construction issues.
3. To investigate the requisites and barriers to adopt BIM and competency level of Sri Lankan Construction Industry towards adopting BIM.
4. To conclude recommendations for proper BIM implementation

1.4 Research Methodology

The research methodology contains the steps in the flow chart presented in Figure 3. The research area was proposed having a general idea on Building Information Modeling and it was further defined following a desktop study. A preliminary literature review was carried out to upgrade the latest knowledge related to the subject area. Subsequently, a comprehensive literature review was carried out to mine data associated with the study. Meantime, an industry survey was conducted with the purpose of identifying the projects using BIM technology. Moreover, Expert interviews were carried out interviewing BIM users, BIM marketers, project managers, construction managers and other subject related experts, to collect hands on experience of stakeholders of top tier projects.

With the outcome of the literature review and the expert interviews a questionnaire was drafted and a pilot survey was carried out to refine and adjust the questionnaire as appropriate to the study. Modified questionnaire was circulated mostly targeting the engineers involved in top tier construction projects of the country. The gathered information was analysed using a statistical software and relative important index method to derive findings. Finally, the conclusions and recommendations were presented to facilitate the blending of Building Information Modeling with the construction industry.

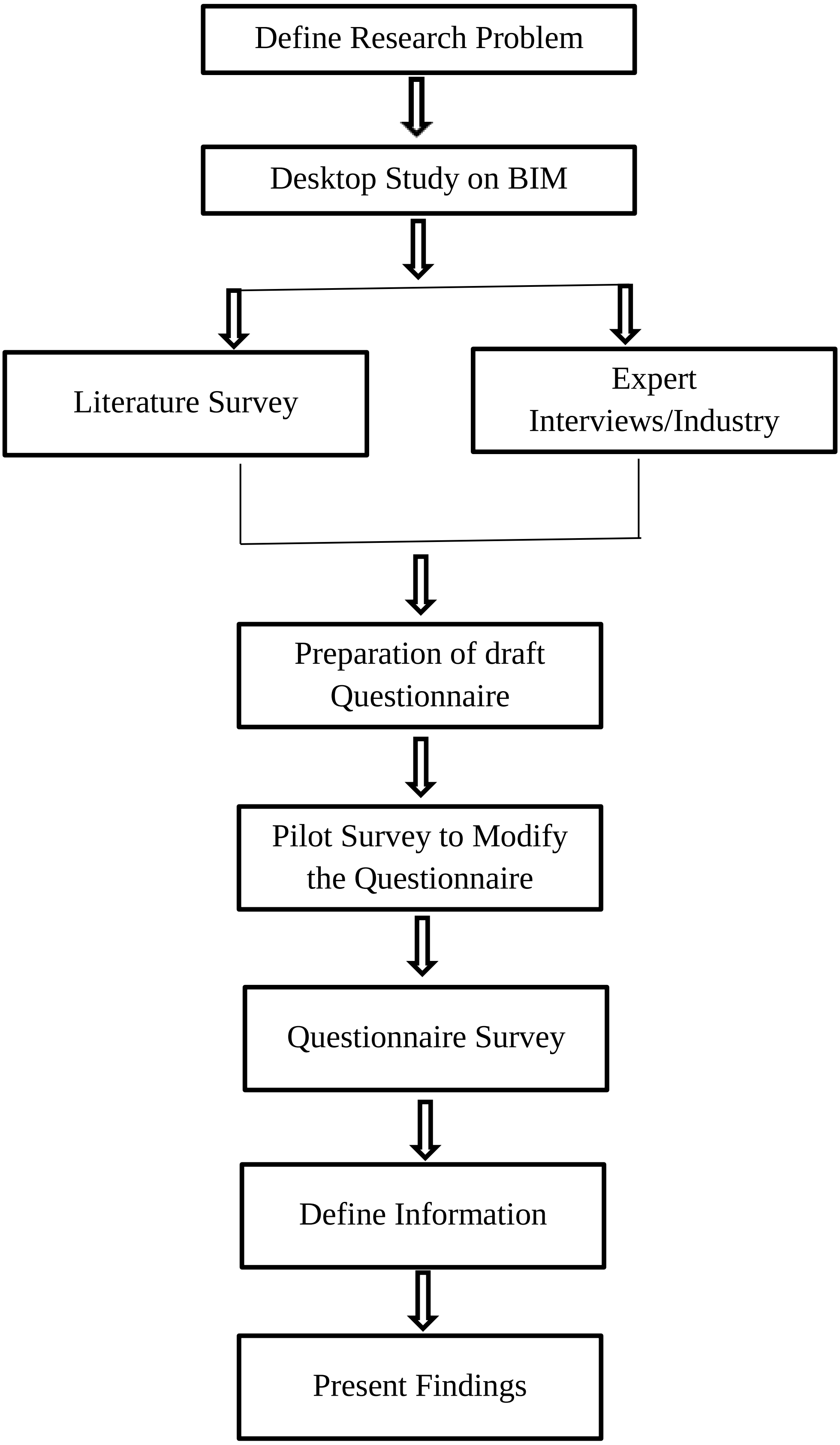

Figure 3: Research Methodology

1.5 Limitations of the Study

More and more researches can be found relating to BIM in construction industry in world wide. Several researches have being carried out with the purpose of identifying the impact of BIM in the construction industry. Since this is a new phenomenon to Sri Lanka, limited number of researches have originated supporting this topic. It is tried to derive required information referring to the related researches carried out throughout the world. The vital area of research is discovering the effectiveness of BIM in the perspective of Sri Lankan construction industry before the implementation of it. Hence, the study mainly focused on Sri Lankan building construction industry where BIM application is considerably implemented at the present. Moreover, the awareness of this application is near to the ground in developing countries like Sri Lanka. Therefore, there was a considerably small community who have practised BIM to distribute the questionnaire survey. These were identified as the limitations in carrying out this study.

1.6 Research Deliverables

1. BIM awareness and adoption level of Sri Lankan Construction Industry
2. The potential of BIM to solve common construction issues
3. The requisites and barriers to adopt BIM and competency level of Sri Lankan Construction Industry towards adopting BIM
4. Recommendations for proper BIM implementation

1.7 Key Findings

Results of the analysis revealed that BIM usage minimizes encountering major issues in construction industry and facilitates the smooth flow in construction work independently from the work experience.

Unawareness of BIM benefits and use was ranked as the top most internal barrier for BIM implementation while the heavy budget requirement, inertia of people for training, computer software and hardware limitation and conventional practices are serving good were next in order.

When external barriers are taken in to account, lack of knowledge and experienced client, limited adoption in local market, concern about lack of company standards and legal/contractual concerns were identified as the barriers with the highest impact to the lowest.

1.8 Guide to Thesis

Chapter 01 - Introduction

This chapter provides a general understanding on this research study, “The effectiveness of building information modeling in Sri Lanka construction industry”. It contains the sections nakely background of the research area, problem statement, objectives, deliverables, limitations to the study and guide to the thesis.

Chapter 02 – Literature Survey

Chapter 2 illustrates the prevailing literature related to Building Information Modeling which provides a clear understanding on the subject area. A comprehensive study was carried out focusing the fields of BIM definition, development, benefits and further barriers and recommendations in BIM implementation to screen vital facts to streamline the proposed study.

Chapter 03 – Research Methodology

Chapter 3 demonstrates the research methodology followed to carry out this study. It further provides detailed description on the techniques used to collect and analyse data accurately and appropriately to derive conclusions.

Chapter 04 – Data Collection and Analysis

This chapter presents the data collection and analysis carried out in this research. Respondent background, analysis of the impact of identified factors on major issues in construction industry by hypothesis testing, analysis of the impact of barriers in BIM implementation using relative important index method and the summary of analysed data were presented in this chapter.

Chapter 05 – Conclusions and Recommendations

This is the concluding chapter which provided the gist of the whole research carried out. It consists of several sections presenting the main findings of the study, conclusions and recommendations to implement BIM. Finally it pointed out provisions to carry out further research on Building Information Modeling and Sri Lankan Construction Industry.

2 LITERATURE REVIEW

2.1 General

This chapter illustrates the prevailing literature related to Building Information Modeling which provides a clear understanding on the subject area. A comprehensive study was carried out focusing the fields of BIM definition, development, benefits and further barriers and recommendations in BIM implementation to screen vital facts to streamline the proposed study.

Literature review was the component which prevailed from the very beginning to the end of the study. A broad literature review was conducted as the primary research method for this study through electronic searches of journal databases and accessing scholarly literature via web engines, Google Scholar and Science Direct to figure out the development of BIM, features and potentials of BIM, major issues in construction industry, barriers and recommendations in BIM implementation etc. BIM vendors' and Company web sites, annual reports and other published materials were extensive range of sources for information on the subject area. Over 50 numbers of research papers were broadly reviewed to collect information on this study.

Further, desktop study was launched to identify suitable method to analyse the collected data and statistic subject area was studied comprehensively using websites and you tube videos and tutorials to become familiar with SPSS software, Man Whitney U test as well as relative important index.

2.2 Building Information Modeling (BIM)

Several definitions can be found out for Building Information Modeling by going through the literature.

"Building Information Modeling is digital representation of physical and functional characteristics of a building creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition." (Construction Project Information Committee, 2011)

"A BIM or Building information model uses digital technology of last generation to model a computable representation of all the functional and physical characteristics of the facilities and concern information during its life cycle and is intended to be a source of information for the service owner/operator to use and maintain that service during its life cycle." (National Institute of Sciences , 2007)

“BIM is defined as the use of ICT technologies to streamline the building lifecycle processes to provide a safer and more productive environment for its occupants, to assert the least possible environmental impact from its existence, and to be more operationally efficient for its owners throughout the building lifecycle.” (Arayici, Y and Aouad, G, 2010)
According to (Autodesk, 2002), BIM have following three basic characteristics.

- Create and operate in digital databases for collaboration.
- To manage the change through these databases in order to make a change in any part of the database is coordinated with all other parts.
- Capture and preserve the data for reuse by adding industry-specific applications.

Exactal illustrates that all of the physical and functional characteristics of the building model are held in the central database in BIM. These characteristics parametrically adapt to the new design as the model develops. Therefore, these models are rich in information and those information can be extracted and used for a variety of analyses to assist in design, construction and operational optimization.

2.3 Development of Building Information Modeling (BIM)

There is an interesting story behind the evolution of Building Information Modeling. According to Eastman et al., the concept of BIM has originated since the 1970s. The term 'building model' which is used in the sense of BIM as used today was initially found in papers in the mid-1980s. Simon Ruffle published it in a paper in 1985 and Robert Aish in later 1986. (S., 1986 March 7) (Aish, 7-9 July 1986) Then it was mentioned referring to the software used at London's Heathrow Airport by GMW Computers Ltd, developer of RUCAPS software. (Eastman, Chuck; Tiecholz, Paul; Sacks, Rafael; Liston, Kathleen, 2008)

In 1992, the term 'Building Information Model' first appeared in a paper by G.A. van Nederveen and F. P. Tolman. (Van Nederveen, G.A.; Tolman, F.P., 1992)

However, the terms 'Building Information Model' and 'Building Information Modeling' (BIM) was not popular until a decade later. According to Laiserin, Autodesk released a white paper entitled "Building Information Modeling in 2002. Then the other software vendors also declared their involvement in the field of BIM. (Laiserin J. , Comparing pommes and naranjas, 2002). In 2003, Jerry Laiserin made popularize and standardize the term as a common name for the digital representation of the building process with the contributions from Autodesk, Bentley Systems and Graphisoft and other industry spectators.

The same concept of platform for sharing and making available of information in digital format had been earlier offered under differing terminology by Graphisoft as "Virtual Building", Bentley Systems as "Integrated Project Models", and by Autodesk or Vectorworks as "Building Information Modeling". The pioneering role of applications such as RUCAPS, Sonata and Reflex has been recognized by Laiserin. (Laiserin J. , Laiserin's comment to letter from John Mullan, 2003)

As per Laiserin, Graphisoft had been researching such solutions for a longer than other vendors and regarded ArchiCAD application by them as one of the most mature BIM solutions on the market (Laiserin J. , Graphisoft on BIM, 2003). It was considered as the first ever implementation of BIM upon its launch in 1987. (Lincoln H. Forbes, Syed M. Ahmed, 2010) (Cinti Luciani, S. Garagnani, R. Mingucci, 2012). ArchiCAD was the first CAD product on a personal computer facilitate to create both 2D and 3D geometry and also it was the first commercial BIM product for personal computers. (Lincoln H. Forbes, Syed M. Ahmed, 2010) (Quirk, 2015) (Dobelis, 2013).

Conventional building design basically depend on two-dimensional technical drawings including plans, elevations and sections. Building Information Modeling extends this beyond 3D, augmenting the three primary spatial dimensions such as width, height and depth with time as the fourth dimension (4D) and cost as the fifth (5D). (4D BIM or Simulation-Based Modeling, 29 May 2012) (ASHRAE Introduction to BIM, 29 May 2012)

Lately, sixth dimension (6D) representing building environmental and sustainability analysis, has introduced while the seventh dimension (7D) was referring for life-cycle facility management aspect. (3D-7D, The Theory of Evolution BIM, 5 October 2018) (BIM 3D, 4D, 5D, 6D, 7D, 5 October 2018)

Figure 4 indicates the software can be used for BIM applications as per the internet.

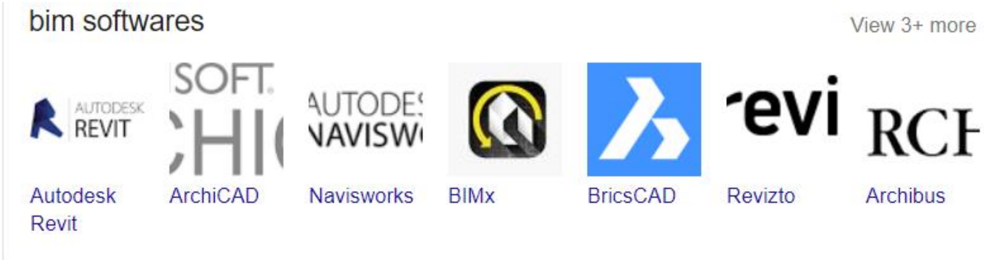

Figure 4: BIM software

2.4 Benefits of Building Information Modeling (BIM)

Most of the stakeholders have a little know how on advantages of Building Information Modeling which can aid facilitating the work. Construction Industry should have a clear point of view about the benefits of BIM in construction industry especially for construction managers. Their judgment approach or orientation may be different but as whole they are agree that BIM has remarkable effects on construction management. Therefore, it is vital finding out the characteristics of this IT solution and having a proper understanding what it can offer. Identified such advantages can be found in prevailing literature.

According to Campbell, a preliminary list of BIM uses may include,

- Design Visualisation
- Design assistance and constructability review
- Site Planning and Site utilisation
- Scheduling and Sequencing (4D)
- Cost Estimating (5D)
- Integration of Subcontractors and supplier models
- Systems coordination
- Layout and fieldwork
- Prefabrication
- Operations and Maintenance (including as-built records)

(Campbell, 2007)

The research carried out by Fatima et al. have highlighted below advantages in detail. Most of the referred literature proved them again.

- **3D Visualization**

Building Information modeling (BIM) is an excellent visualization tool. BIM is making nice architectural visualizations for both Interior and exterior of the building to be build, defining different materials. 3D rendered images and 3D walkthrough videos can be generated with a BIM model by using its tools to provide a three dimensional virtual representation of the building. It can help during both design and bidding process as it can provide a better understanding what they have to construct and how it will look like after completion.

In addition to Fatima et al., BIM models not only contain architectural data but the full depth of the building information including data related to the different engineering disciplines such as the load-bearing structures, all the ducts, pipes, electrical wiring details of the different building systems and even sustainability information as well with which all the characteristics of a building can easily be simulated well in advance.

Structural engineers use BIM model to do structural analysis, wind load simulation and to select materials. They can work with country-specific design codes within the same model. It is easy to create reinforced concrete design and steel design modules based on international steel codes and reinforced concrete codes. Depending on load duration and type, different defined loads can be created, such as dead, live, wind, or seismic. Various types of loads (such as nodal, linear, or planar) can be applied to a structure to the defined load cases. Definitions of load combinations from many national standards, both manual and automatic, are also included within the software.

- **Coordination**

Coordination is a key factor in construction management. It is important for every project, especially when dealing with congested and urban environments as well as when handling challenging sites. All the work and communication with the stake holders such as subcontractors, supervisors, materials suppliers, fabricators and equipment suppliers categorized under coordination. Further, it involves juggling the scheduling, managing the budget, sorting through constructability issues, and managing relationship. The construction manager holds the responsibility of the job role of each worker and the work distribution of the project among workers. Hence, prior coordination efforts of construction avoid design errors and provide better understating of work to be done in advance.

Further, it is an added advantage of having provisions for modifications. All the Architectural, Structural and MEP data is stored in a single BIM model. Therefore, if one party does any alteration to the building design, it will automatically replicate in each views

such as floor plans, sections and elevation. This helps in creating the documentation faster and provides high quality assurance by automatic coordination to the different views.
Clash detection is a highly welcomed feature of BIM in terms of construction management. The BIM and allied technology has been advanced to detect all these 2D, 3D and 4D clashes in project execution. (Vico, Coordination and clash detection, 2012)

- **Prefabrication**

Nowadays, there is a trend of offsite fabrication in the industry due to reduced labor cost, construction time and better quality control. This needs considerable planning and accurate design information. Offsite fabrication facilitates assembling different component or items, fabrications in controlled environment and with greater precision and if any alteration is required then more option are available than site. For examples, a duct work specialist can install branches and leave openings for diffusers/ hoods referring to the BIM model. Carpenter can fabricate furniture such as cupboards fitting to the spaces from extracting required dimensions from the model. Plumbers can also grab pipe size, length and location from BIM to continue their work.

- **Construction Planning and Monitoring**

Construction planning is basically scheduling and sequencing a project in a virtual model to carry out on time. This can be achieved using a 4D BIM model created using one of common scheduling methods, Critical path method (CPM) or line of balance. Time is introduced as the 4th dimension and the work progress to be updated in the model. When considering the critical path method, each and every activity in construction sequence is linked with another activity. Time, money, machinery and man power requirement to be assigned to the work break down structure.

- **Cost Estimation**

Cost estimation consists of two steps namely quantity take off and pricing. Quantity take off from construction drawings in 2D is very much time and staff consuming and often contains calculation errors. One of the significant features of BIM model is offering easy extraction of lengths, areas and volumes which supports to calculate the quantities and then import those to a cost database. For instance, relevant building elements are highlighted in the 3D visual model when a cost item in the schedule is selected in BIM. (Exactal, 2012) (Nomitech, 2011) While most of BIM cost estimating tools can only read BIM models, there are some estimating tools which can write back to BIM models updating its cost properties. (Beck, 2011). Though this is called the fifth dimension of BIM, there is no evidence of real integration of cost estimating into BIM or popular usage of it to cost estimation yet. Having many parameters to decide the total cost rather than sum up individual cost elements may be the possible reason for it. (H.S. Jayasena, C. Weddikkara, 2012)

- **Record Model**

At the end of every project, owner has to deal with a huge amount of documentation with end of project information. In most of the cases owner are not specialized to understand and handle all the construction related information from 2D drawings. So it is better if they have a 3D model of their project. By using BIM tools, after all alteration and as build variations, a record model of BIM can be obtained and handed over to the owner by the construction managers at the end of the project. The recorded model contains all the information of as build and shop drawings from the subcontractors. On the other hand each object properties of the model may also include links for operation and maintenance, submittals and warranty claims and information.

Further, BIM model can be used to scheduling, documentation, material take off, cost estimation, project planning and many more. This will reduce errors, save time and reduce cost. Exact quantity take-offs mean that materials are not over-ordered. Precise programme scheduling enables just-in-time delivery of materials and equipment, reducing potential for damage. Use of the BIM model for automated fabrication of equipment and components enables more efficient materials handling and waste recovery.

- **Project Cost**

BIM application drastically reduces the project cost in several ways. High amount of work with less resources and people, less interruptions and miscommunication and less variations are few of those. The collaboration in the project team is increased by BIM as all the data of the project is handled by the main BIM server or one common data base computer, which results in less errors and changes at the end of the day. (A. Fatima, M. Saleem, S. Alamgir, 2015)

2.5 Building Information Modeling (BIM) and Construction Industry

There are numerous researches on adoption of Building Information Modeling in construction industry throughout the world.

BIM should be regarded as the entire process of exchanging, re-using and controlling project information being generated during the lifecycle of a building project and not just a simple information model. (Ham, N, K Min, Y Lee and J. Kim. , 2008)

BIM applications spans over the project life cycle involving project programming, design, preconstruction, construction, and post-construction (operations and maintenance) phases. (Salman Azhar, Malik Khalfan, Tayyab Maqsood)

In project programming phase, BIM saves time of the project team and provide more value addition through analysing the space and understanding the complexity of space standards and land regulations, which saves time and provide the team with opportunity of doing more value-added activities (CICRP, 2009). There is a trend now on integrating BIM with GIS (Geographical Information Systems) to ease site selection, feasibility and marketing studies. (Berlo, L.V. and Laat, R.D., 2011)

Aid in determining if potential sites meet the required criteria according to project requirements, technical and financial factors, decrease costs of utility demand and demolition and minimize risk of hazardous materials are some of the benefits of 'GIS-BIM' based site analysis. (CICRP, 2009)

According to Azhar et al., BIM applications are advantageous in schematic design, detailed design and construction detailing which are different stages in design of a project as shown in Table 1.

Table 1: BIM applications in project design phase

Schematic design	Detailed design	Construction Detailing
▪ Options Analysis (to compare multiple design options) ▪ Photo Montage (to integrate photo realistic images of	▪ 3D exterior and interior models ▪ Walk-though and fly-through animation ▪ Building performance analyses (e.g. energy modeling)	▪ 4D phasing and scheduling ▪ Building systems analysis (e.g. clash detections) ▪ Shop or fabrication drawings

project with its existing conditions)	▪ Structural analysis and design	

Through a case study analysis, Azhar has proved that Building Information Modeling involves in estimating, site coordination and constructability analysis at the preconstruction phase. Further, BIM assists in project progress monitoring using 4D phasing plans, for trade coordination meetings, integrating RFIs, change orders and punch list information in the BIM models at the construction phase. Updating the BIM model timely and accurately is vital throughout the construction period, so that it reflects the most up-to-date information which later on can be used by the facility managers for building operations and maintenance. Providing information of the building, its spaces, systems and components is the fundamental benefit of a BIM model in post construction stage. These information can be accessed easily and quickly pressing on an element of the model. The overall advantage of this is handing over these data into facility management operations which makes it very simple for a maintenance worker to access the required information vital to different systems in the building. (Philips, S. and Azhar, S., 2011)

Maintenance work order management, emergency service request management, space planning and management, inventory management and inspections, move management and real estate portfolio management are some other benefits as per Azhar's study.

In addition to the BIM involvement in project life cycle, the literature demonstrates the benefits of BIM for project stakeholders. Below tables Table 2 and Table 3 clearly indicate how BIM benefited the stakeholders and BIM applications for them respectively.

Table 2: BIM benefits for Stakeholders

Project Stakeholder	Major Benefits identified
Project Owners	• Early design assessment to ensure project requirements are met • Operations simulation to evaluate building performance and maintainability

	• Low financial risk because of reliable cost estimates and reduced number of change orders • Better marketing of project by making effective use of 3D renderings and walk-though animations • Complete information about building and its systems in a single file (Eastman, Chuck; Tiecholz, Paul; Sacks, Rafael; Liston, Kathleen , 2011) (Reddy, 2011)
Project Designers	• Better design by rigorously analysing digital models and visual simulations and receiving more valuable input from project owners • Early incorporation of sustainability features in building design to predicts its environmental performance • Better code compliance via visual and analytical checks • Early forensic analysis to graphically assess potential failures, leaks, evacuation plans and so forth • Quick production of shop or fabrication drawings (Kymmell, 2008)
Project Constructors	• Quantity take off and cost estimation • Early identification of design errors through clash detections • Construction planning and constructability analysis • Onsite verification, guidance and tracking of construction activities • Offsite prefabrication and modularization • Site safety planning • Value engineering and implementation of lean construction concepts • Better communication with project owner, designer, subcontractors and workers on site Above applications lead the project result in

	○ High profitability ○ Better customer service ○ Cost and schedule compression ○ Better production quality ○ More informed decision making ○ Better safety planning and management (Hardin, 2009)
Facility Managers	• The same critical information is present in a single electronic file • The facility managers do not have to sift through the piles of information to gather data. (Jordani, 2010) (Reddy, 2011)

Table 3 is a summary of the usage of BIM applications to each project stakeholder as per the study carried out by Azhar et al.

Table 3: Summary of the Usage of BIM Applications to each Project Stakeholder

BIM Application	Owners	Designers	Constructors	Facility Managers
Visualization	×	×	×	×
Options analysis	×	×	×	
Sustainability analysis	×	×		
Quantity Survey		×	×	
Cost Estimation	×	×	×	
Site Logistics	×		×	
Phasing and 4D Scheduling		×	×	
Constructability analysis		×	×	
Building performance analysis	×	×	×	×
Building management	×			×

Creating a virtual model before the project execution effectively contributes in checking practical constructability, clarifying ambiguities in the process, designing the structure with less resource wastage, optimizing energy and introducing passive features. (Bynum, P., R. R. Issa, et al., 2012)

Building information modeling (BIM) is the latest generation of object-oriented CAD systems in which all of the intelligent building objects that combine to make up a building design can coexist in a single 'project database' or 'virtual building' that captures everything known about the building. Theoretically, a building information model deliver a single, logical, consistent source for all information associated with the building (Howell, I. and B. Batcheler, 2005)

BIM has made changes the way project stakeholders experience the project throughout its life cycle. BIM model in 3D generate all the required construction detail drawings as an interactive representation of it. Working in a model-based framework ensures that a change you do for a one view will propagate to all other views as appropriate. For instance, moving or deleting an element in plan view updates the revision automatically in section and elevations. Further, once you delete a door from the model, the software simultaneously removes it from all views and updates the door schedule. (Krygiel, E. and B. Nies , 2008)

As envisaged by the development of BIM in the industry, it will totally be a substitute for CAD systems. Adopting BIM as a standard in the market, it will continue to flourish. Users can access to BIM platform through smartphone and tablet kind of advanced electronic devices for proper communication and instant decisions. Growth of cloud technology more facilitates the users to access the virtual model from anywhere. These technological developments integrated and allow project stakeholders in efficient operations of their buildings. (Salman Azhar, Malik Khalfan, Tayyab Maqsood)

According to the research carried out by Fatima et. al, problems in planning and scheduling, site coordination, procurement management, cost estimating and cost control, excessive redoing of work, productivity, construction time and facility management were identified which hamper the smooth run of a project. Further, the factors highly contribute to create the said problems were identified in detail in this research as shown in Table 4.

2.6 Barriers in Building Information Modeling (BIM) Implementation

Many studies reveal that rate of BIM adoption in the real time industry is not satisfactory. “Yet BIM adoption has been much slower than anticipated.” (Azhar, S., Hein, M., and Sketo, B., 2008)

Ten years ago, the prominent BIM application developer Autodesk (2003) predicted that BIM would provide high quality, reliable, integrated, and fully coordinated information in an uninterrupted and instant manner relevant to project design, schedule and cost. BIM supports with important data for three main phases in building life cycle. For example, design, schedule, and budget information in the design phase, quality, schedule, and cost information in the construction phase and performance, utilization, and financial information in the management phase can be highlighted. BIM application clever in providing an overall image of the project for the stakeholders with latest updates and quick access to conclude critical decisions with its integrated digital environment. A decade later, BIM has proved that all these possible, but how effective they are, is yet to be realized.

(H.S. Jayasena, C. Weddikkara, 2012)

It should be highlighted that BIM cannot be considered as an evolution of 3D CAD modeling. Further, it is a new breed of modeling. Therefore, it impossible to compare BIM with 3D CAD and conclude that it is better than 3D CAD in terms of all aspects. Still there is a dilemma whether BIM allows same level of flexibility of traditional CAD for designers, which is yet to be found. (Lockley, 2011)

Both technical and managerial can be identified as barriers in BIM implementation. The technical reasons can be broadly classified into three categories. (Bernstein, P. G., Pittman, J. H., 2005)

- The need for well-defined transactional construction process models to eliminate data interoperability issues
- The requirement that digital design data be computable
- The need for well-developed practical strategies for the purposeful exchange and integration of meaningful information among the building information model components.

Proper awareness of all aspects of BIM is a key factor in effective BIM implementation. Latest studies in United Kingdom evidence that the awareness on BIM of most of the people is not as it should be. Though the situation is as such, the minority using BIM in a proper manner with appropriate knowledge enjoy its advantages and intense to spend for more benefits. (Malleson, 2012)

Studies carried out by Fatima et al. reveal that BIM knowledge of managerial level such as project managers and construction managers of construction industry is at a medium level. Mostly, the current practices for construction management is identified as a barrier to implement this.

Moreover, barriers in BIM implementation can be categorized at company level and external level. In company level people, process, technology and money were tested as hurdles and claimed percentages were 24%, 30%, 25% and 20% respectively. Hence, main internal constraints recognized are the people and conventional practices. (A. Fatima, M. Saleem, S. Alamgir, 2015)

Limited adoption in market, partners' low knowledge, legal issues and low company standards were pointed out as external constrains and 34%, 32%, 15% and 19% were the respective results. Therefore, "Limited adoption in local construction market" vastly affects as an external constraint in BIM adoption and implementation. (A. Fatima, M. Saleem, S. Alamgir, 2015)

Besides many benefits of BIM for project stakeholders there are several risks and barriers to implement BIM. The reason for this is BIM is not a solution for every project and every firm. Identified BIM related risks can be categorized broadly in to two sectors as follows.

1) Technology-related risks

   The primary BIM related technological risk is lack of BIM standards. There can be inconsistencies when multi users access and modify BIM model as they use their own protocols and practices. This affects the integration and management of the BIM model and it needs to be subjected to regular model audits. (Weygant, 2011)

2) Process-related risks

   The BIM process related risks are mainly legal, contractual and organizational risks. The ownership of data will be a problematic situation practically in most of the projects. It should be protected through copyright laws and due to inserting proprietary information of team members to the model, the entire ownership of it cannot be transferred to the owner though he pays totally for the project. The answer is not simple, but unique for each project depending on the stakeholder's requirements. It is required to avoid inhibitions or disincentives that discourage participants from fully realizing the model's potential (Thompson, 2001). To avert disagreement over copyright issues, the best solution is to set forth in the contract documents ownership rights and responsibilities. (Rosenburg, 2007).

A survey conducted in United Kingdom with over thirty construction firms, revealed the following barriers to BIM implementation. (Ku, K., Taiebat, M., 2011)

- Learning curve and lack of skilled personnel
- High cost to implementation
- Reluctance of other stakeholders (e.g. architect, engineer, contractor)
- Lack of collaborative work processes and modeling standards
- Interoperability
- Lack of legal/contractual agreements

2.7 Recommendations for Implementation of Building Information Modeling (BIM)

Building Information Modeling (BIM) facilitates computerization of different designs, construction project management, quantity surveying and procurement procedure and also minimizes design and construction errors which will lead to an overall efficient business. Therefore, at the study carried out by Jayasena et al. (H.S. Jayasena, C. Weddikkara, 2012) recommend “BIM is a technology that Sri Lankan construction industry should go for”. They further pointed out that challenges can be overcome through commitment. It is critical to develop a proper BIM knowledge base in the industry and oversee the barriers and overcome them to encourage integrating BIM strategies such as IPD.

Collective design and construction requires substantial deviations from prevailing methods and habits. Strong effort to be made by the relevant personnel to adopt BIM successfully in Sri Lanka. It may not be difficult as suggested by the current understanding. For example, there has been positive past experiences in implementation, for instance positive changes in cultures and attitudes with the change of procurement strategies. (Gunathilake, S., Jayasena, H. S. , 2008)

BIM has a high potential in bringing economic benefits. Average BIM ROI for projects under study was high. Meanwhile, careful attention to be drawn on legal pitfalls, which include data ownership and associated proprietary issues and risk sharing at the implementation stage. (Salman Azhar, Ph.D., A.M.Asce, 2011)

According to (Sidawi, 2012), human resources, cost, time, scope, and quality management; procurement and risk management, and infrastructure and communication are the major managerial issues especially in remote constructions. The projects under study has proved that BIM adoption serves as a useful remedy to above key issues. This solution has increased the productivity, efficiency, quality and reduced cost, lead times and duplications through collective effort of project stakeholders. (Sidawi, 2012)

Many of the key challenges can be addressed via the adoption of BIM strategically for remote construction projects while it proposes an action research approach for BIM adoption to be successful, considering technology, process and people factors. In the case study example, BIM implementation was initiated by the architectural company. However, if BIM implementation is initiated by the main contracting company, the key benefits of BIM implementation in resolving the key challenges of the remote construction projects can be taking forward to benefit other aspects of construction activities such as health and safety, labour training, communication on site, construction planning and monitoring. (Egbu C., Sidawi B., 2012)

There is an optimistic trend towards increasing awareness of BIM as per the research carried out by Hussain et al. since there was over 88% of respondents have little or general knowledge on BIM. Though, around 65% have no working experience on BIM due to adoption barriers, considerable amount of people have various exposure to BIM technology. According to the overall frequency analysis of the collected data ‘For better visualization and being an interactive tool’, followed by ‘To increase the capacity of design reviews’, were the main reasons to take interest in the BIM applications. ‘Constructability analysis’ followed by ‘Model based estimation and construction sequencing’ were the major anticipated tasks for which BIM is being considered to be adopted. Mostly BIM usage supposed to avoid the risk of discrepancies between orthographic views like plan, section, and elevation and further to generate new sections, elevations and 3D views at once. (Kifayat Hussain, Rafiq Choudhry, 2013)

The research carried out by (Ku, K., Taiebat, M., 2011) indicated that the advances in BIM technology, adoption of IPD and similar project delivery systems, requirement of BIM model by project owners, and introduction of fresh graduates with BIM knowledge in the project teams will erase the obstructions in BIM adoption, pointed out in their research, in due course.

2.8 Summary of Literature Review

In this chapter, a comprehensive study was carried out focusing the fields of BIM definition, development, benefits and further barriers and recommendations in BIM implementation to screen vital facts to streamline the proposed study. Building Information Modeling is digital representation of physical and functional characteristics of a building creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition. This concept originated from 1970 and gradually evolved to a major tool in construction industry with its incredible benefits such as 3D visualization, coordination, and cost estimation and so on. Though, this technology has developed from 3D (3D Models), 4D (Scheduling), 5D (Estimating), 6D (Sustainability) up to seventh dimension 7D (Facility Management), most of the projects are not privileged up to that maximum level in developing countries like Sri Lanka. As per the literature, major issues identified in construction industry can be divided mainly in to design and site coordination, planning and scheduling, cost reduction and cost control and managing the construction time. Moreover, internal and external barriers were identified with its significance level to implement BIM. In addition to that the significance of factors, BIM awareness level and work experience to carry out this study were investigated.

3 RESEARCH METHODOLOGY

3.1 General

This chapter demonstrates the research methodology followed to carry out this study. It further provides detailed description on the techniques used to collect and analyse data accurately and appropriately to derive conclusions.

3.2 Research Methodology

The research methodology contains the steps in the flow chart presented in **Error! Reference source not found.**. The research area was proposed having a general idea on Building Information Modeling and it was further defined following a desktop study. A preliminary literature review was carried out to upgrade the latest knowledge related to the subject area. Subsequently, a comprehensive literature review was carried out to mine data associated with the study. Meantime, an industry survey was conducted with the purpose of identifying the projects using BIM technology. Moreover, Expert interviews were carried out interviewing BIM users, BIM marketers, project managers, construction managers and other subject related experts, to collect hands on experience of stakeholders of top tier projects.

With the outcome of the literature review and the expert interviews a questionnaire was drafted and a pilot survey was carried out to refine and adjust the questionnaire as appropriate to the study. Modified questionnaire was circulated mostly targeting the engineers involved in top tier construction projects of the country. The gathered information was analysed using a statistical software and relative important index method to derive findings. Finally, the conclusions and recommendations were presented to facilitate the blending of Building Information Modeling with the construction industry.

3.3 Method of Data Collection

Several methods were used to gather information related to the research study such as literature survey and Industry survey/ expert interviews at the preliminary stage and subsequently a questionnaire survey. The questionnaire survey was the main approach of data collection in carrying out this research.

3.3.1 Literature Review

Literature review was the component which prevailed from the very beginning to the end of the study. A broad literature review was conducted as the primary research method for this study through electronic searches of journal databases and accessing scholarly literature via web engines, Google Scholar and Science Direct to figure out the development of BIM, features and potentials of BIM, major issues in construction industry, barriers and recommendations in BIM implementation etc. BIM vendors' and Company web sites, annual reports and other published materials were extensive range of sources for information on the subject area. Over 50 numbers of research papers were broadly reviewed to collect information on this study.

Further, desktop study was launched to identify suitable method to analyse the collected data and statistic subject area was studied comprehensively using websites and you tube videos and tutorials to become familiar with SPSS software, Man Whitney U test as well as relative important index.

Refer Chapter 2 for detailed description.

3.3.2 Expert Interviews/ Industry Survey

An industry survey was conducted with the purpose of identifying the projects using BIM technology. Expert interviews were carried out interviewing BIM users, BIM marketers, project managers, construction managers and other subject related experts, to collect hands on experience of stakeholders of top tier projects. This was the methodology used to identify the BIM usage and competency level of Sri Lankan construction industry. Experts expressed their views on BIM as a facilitator to many major issues in construction industry. They further highlighted that the high initial cost, less client requests on BIM, unawareness of BIM and its benefits, software limitation, inertia to change from current practices and limited adoption in Sri Lankan industry as the barriers to implement BIM in projects. These findings were incorporated in preparation the structure of the questionnaire.

3.3.3 Questionnaire Survey

3.3.3.1 Questionnaire Format

Based on the outcomes of literature survey and industry survey with experts, the questionnaire was developed using a web based questionnaire survey site (google docs). The content of the questionnaire can be mainly divided in to four segments as follows.

- General information
- Project information
- Issues in construction industry
- Barriers for BIM implementation

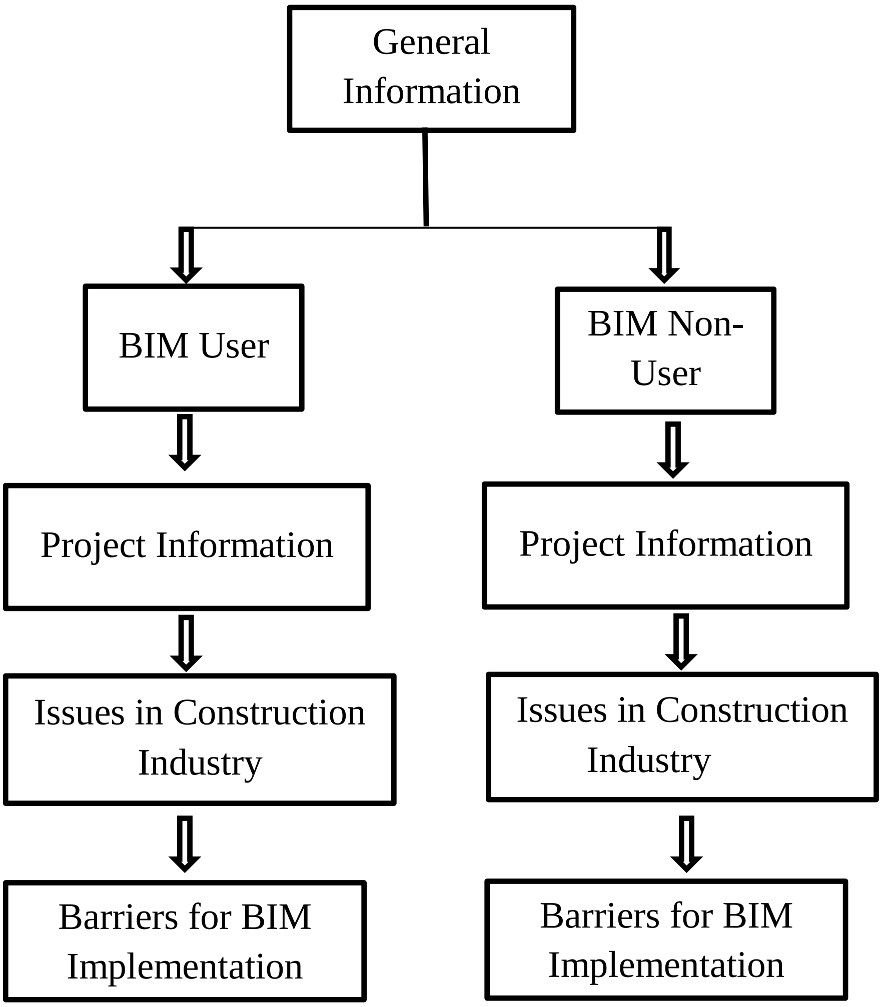

Figure 5: Structure of the Questionnaire

In general section, the experience, academic qualification and awareness level of the respondent were gathered. With the awareness level on BIM, the respondents were categorized as BIM users and BIM non users. Accordingly, the data on project information, issues in construction industry and barriers for BIM implementation were collected. Figure 5 illustrates the structure of the questionnaire and it is attached as Appendix A.

Project information part contains questions related to project type, client, estimated value and the project operation stage and also the software platforms used in those projects.

Issues in construction industry have categorized under four sub topics called design and site coordination, planning and scheduling, cost reduction and cost control and managing the construction time in to a detailed level as presented in Table 4. A four point likert scale (Strongly Disagree, Disagree, Agree and Strongly Agree) was used to express respondents' views on those issues with BIM usage and without BIM usage.

Table 4: Issues in construction industry

	Sub Topics Level	Detailed Level
Major Issues in Construction Industry	Design and Site Coordination	▪ Less effectiveness in sharing required information ▪ Delays in response to request for information (RFI) ▪ Difficulty in understanding of drawings & visualization ▪ Failures in clash detection
	Planning and Scheduling	▪ Insufficient information about project risks ▪ Limited or conflicted information of project ▪ Confusion in construction sequence ▪ Difficulty in handling of revised designs ▪ Limited planning tools & resources
	Cost Reduction and Cost Control	▪ Improper planning of manpower ▪ Improper logistic planning ▪ Procurement management problems ▪ Poor coordination among different departments ▪ Hard to handle sudden changes ▪ Failures in clash detection ▪ Interruptions of stakeholders
	Managing the Construction Time	▪ Delays in the procurement process ▪ Delays in producing shop drawings ▪ Improper resource allocation ▪ Delays in client approvals ▪ Delays in handling suppliers

Barriers for BIM implementation were identified as internal barriers and external barriers as shown in Table 5 and a four point likert scale (None, Low, Medium, High) was introduced to find their impact on BIM implementation.

Table 5: Barriers for BIM implementation

Barriers in BIM Implementation	Internal Barriers	▪ Current practices are serving good ▪ Unawareness of BIM benefits & use ▪ Computer software & hardware limitation ▪ Heavy budget requirement ▪ Inertia of people for training
	External Barriers	▪ Limited adoption in local market ▪ Lack of knowledge & experienced partner/ clients ▪ Legal/Contractual concerns ▪ Concern about lack of company standards

3.3.3.2 Pilot Survey

The pilot survey was conducted with the objective of verifying the reliability of the questionnaire. The questionnaire was distributed among ten respondents including four BIM users and inquired the ability of understanding the questions, clarifications on understanding the instructions and also gathered comments from their own point of view. These outcomes were incorporated before finalizing the questionnaire for circulation.

3.3.4 Data Collection using the Questionnaire Survey

The questionnaire survey was the prime data collection method of this research. The aim was to collect the responses on handing major construction issues with BIM and without it. Not only that the barriers for BIM implementation to be ranked with the responses from the questionnaire. The questionnaire was circulated among professionals in the construction industry especially targeting the stakeholders of recent top tier projects in Sri Lanka. It was distributed through web based questionnaire survey site and 122 responses were received.

3.4 Method of Data Analysis

The collected data was analysed using an appropriate data handling method to derive information on Building Information Modeling potential to overcome common construction issues and to identify the actual barriers to implement BIM and make recommendations for proper implementation.

For easy interpretation, the factors used for the analysis were classified as Table 6 below.

Table 6: Factors used for the Analysis

Type of the Factor	Description	Reference
θ	Major construction issues ▪ Design and site coordination ▪ Planning and scheduling ▪ Cost reduction and cost control ▪ Managing the construction time	Table 4
β	Barriers in BIM implementation ▪ Internal Barriers ▪ External Barriers	Table 5
γ	Usage of Building Information Modeling ▪ BIM Non User ▪ BIM User	-
δ	Experience Level ▪ Juniors (Below 10 years of Experience) ▪ Seniors (Above 10 years of Experience)	-
γ & δ	BIM Usage and Experience Level ▪ Junior BIM Non User ▪ Junior BIM User ▪ Senior BIM Non User ▪ Senior BIM User	-

In this study, generally the impact of factor type γ and δ, on factor type θ and β separately were analysed. In depth analysis was conducted investigating the impact of factor type γ and δ both together, on factor type θ only.

Considering the sample behaviour and aim of the study, analysis methods were selected as shown in Table 7 and accordingly, hypothesis testing and relative important index method were followed for the study. Further, software package called SPSS was used to facilitate the statistical analysis and Ms. Excel was used to carry out calculation work.

Table 7: Methods of Analysis

Analysis	Purpose	Analysis Method	Software Used
Impact of γ or δ on θ	Checking whether there is a statistically significant difference between BIM users and BIM non users, regarding encountering major issues (Design and site coordination, Planning and scheduling, Cost reduction and cost control, Managing the construction time) in construction industry Checking whether there is a statistically significant difference between Juniors and Seniors, regarding encountering major issues (Design and site coordination, Planning and scheduling, Cost reduction and cost control, Managing the construction time) in construction industry	Hypothesis Testing	SPSS
Impact of γ and δ both on θ	Checking whether there is a statistically significant difference between Senior BIM users and Senior BIM non users, regarding encountering major issues (Design and site coordination, Planning and scheduling, Cost reduction and cost control, Managing the construction time) in construction industry Checking whether there is a statistically significant difference between Junior BIM users and Junior BIM non users, regarding encountering major issues (Design and site coordination, Planning and scheduling, Cost reduction and cost control, Managing the construction time) in construction industry	Hypothesis Testing	SPSS

Impact of γ or δ on β	Rank the significance of internal and external barriers considering the impact of usage of Building Information Modeling and experience level	Relative Important Index Method	Ms. Excel

3.4.1 Hypothesis Testing

To analyse the relationship between factor type θ and factor type γ or δ or both, hypothesis testing was carried out targeting the following sectors.

- The Impact of BIM Usage on Major Issues in Construction Industry
- The Impact of Experience Level on Major Issues in Construction Industry
- The Impact of BIM Usage to Seniors on Major Issues in Construction Industry
- The Impact of BIM Usage to Juniors on Major Issues in Construction Industry

The data sets considered for the analysis are independent and ordinal variables. Since the distribution was not normally distributed, Mann Whitney U test was selected as the most appropriate test to carry out the analysis. It is the nonparametric equivalent of the two sample t-test and is used to test the null hypothesis. The null hypothesis is that the two samples come from the same population (both have the same median) or alternatively, whether observations in one sample tend to be larger than observations in the other (one have higher median than the other). The result of performing a Mann Whitney U Test is a U Statistic. For larger samples, the formula shown in

Equation 1 is used to obtain this value. In this study, SPSS software is used to run the test on behalf of the formula. The test was carried out at the 95% level of confidence (α = 0.05).

Equation 1: Formula for Mann Whitney U Test

$$U_1 = R_1 - \frac{n_1(n_1+1)}{2}$$

or

$$U_2 = R_2 - \frac{n_2(n_2+1)}{2}$$

R - Sum of ranks in the sample
n - Number of items in the sample

The assumptions of this test can be listed as follows.

- The dependent variable should be measured on an ordinal scale or a continuous scale.
- The independent variable should be two independent, categorical groups.
- Observations should be independent. There should be no relationship between the two groups or within each group.
- Observations are not normally distributed. However, they should follow the same shape (i.e. both are bell-shaped and skewed left).

The data gathered from the questionnaire survey was entered to SPSS platform following the specified methodology. The required variables were created as necessary for the analysis and the data set was entered accurately.

The factors under four sub topics in issues in construction industry were individually analysed to find out whether there were any statistically significant difference between selected categories. Further, this analysis was summarized up to sub topic level and finally checked the impact of BIM usage and experience level in encountering major issues in construction industry.

To summarize the likert scale data under a sup topic, a super-variable was created estimating the median of each individual factor and interpret the impact on that sub topic. The same procedure was followed to summarize the four sub topics design and site coordination, planning and scheduling, cost reduction and cost control and managing the construction time to interpret the total impact from BIM usage or experience level.

3.4.2 Relative Important Index Method

To rank the influence of factor type B on BIM implementation verses factor type C, Relative Important Index (RII) method was followed. This method is used to determine the relative importance among internal and external barriers to implement BIM generally and also with the point of view of BIM user and non-user as well as senior and junior stakeholders.

The responses were rated according to following rating system as shown in Table 8 to convert the responses into an analytical figure.

Table 8: Scale used for Data Measurement

Item	None	Low	High	Very high
Scale	1 points	2 points	3 points	4 points

Scores assigned to each question by the respondents were entered to an excel sheet and RII of each barrier was calculated using the following equation in *Equation 2*.

Equation 2: Relative Important Index (RII)

$$RII = \frac{\sum W}{A * N} \quad (0 < RII \leq 1)$$

Where:

W- Weight given to each factor by the respondents and ranges from 1 to 4 , (where "1" is "None" and "4" is "Very High");

A – Highest weight (i.e. 4 in this case);

N – Total number of respondents.

Using the calculated RII values the rank of each barrier was determined as 1 to 4 where 1 is the highest impact barrier and the 4 is the barrier with little impact in BIM implementation.

3.5 Summary of Research Methodology

This chapter demonstrates the research methodology followed to carry out this study. It further provides detailed description on the techniques used to collect and analyse data accurately and appropriately to derive conclusions. Questionnaire survey, literature review, expert interviews and industry surveys were the methods followed to collect data. Since the main approach to collect data was the questionnaire survey, the questionnaire was verified by a pilot survey. The target group was the stakeholders of top tier construction projects in the country. According to the sample behaviour and aim of the study, analysis methods were selected. Hypothesis testing was used to find out the impact of BIM usage and experience level individually as well as collectively on major issues in construction industry. The distribution was observed to be not normally distributed and Mann Whitney U test which is a nonparametric test was selected to test the null hypothesis. Relative important index method was applied to rank the significance of internal and external barriers due to the impact of usage of Building Information Modeling and experience level.

4 DATA COLLECTION AND ANALYSIS

4.1 General

This chapter presents the data collection and analysis carried out in this research. Respondent background, analysis of the impact of identified factors on major issues in construction industry by hypothesis testing, analysis of the impact of barriers in BIM implementation using relative important index method and the summary of analysed data were presented in this chapter.

4.2 Respondent Background

122 number of responses were received for the questionnaire survey from mainly from engineers and architects, including project managers and construction managers. Most of them are involved in top tier projects mentioned in Sri Lankan construction industry.

4.2.1 Experience Level

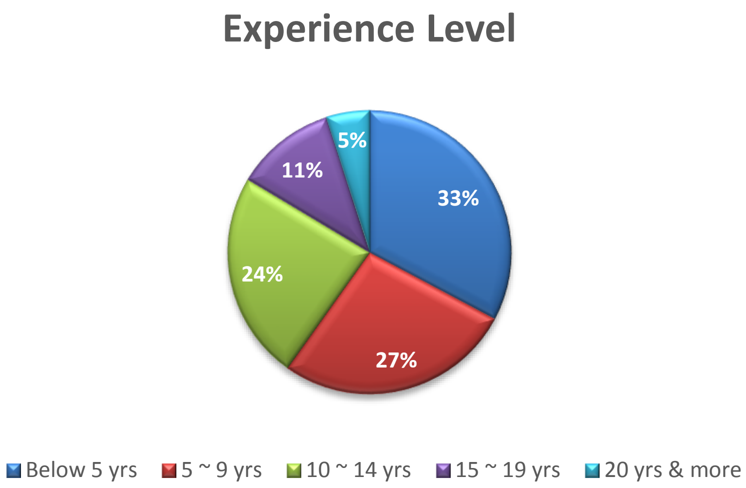

Figure 6: Experience Level

As shown in respondent profile, Figure 6, 33% are possessing less than 5 year experience in construction industry, 27% are between 5 to 9 year experience, 24% are between 10 to 14 year experience, 11% are between 15 to 19 year experience and 5% are above 20 year experience.

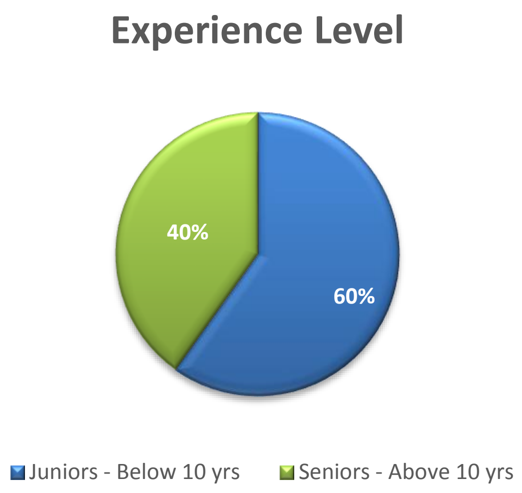

Figure 7: Seniors and Juniors

For the convenience of the study, the respondents were divided in to two groups as juniors (below 10 year experience) 60% and seniors (above 10 year experience) 40% as shown in Figure 7.

4.2.2 BIM Awareness

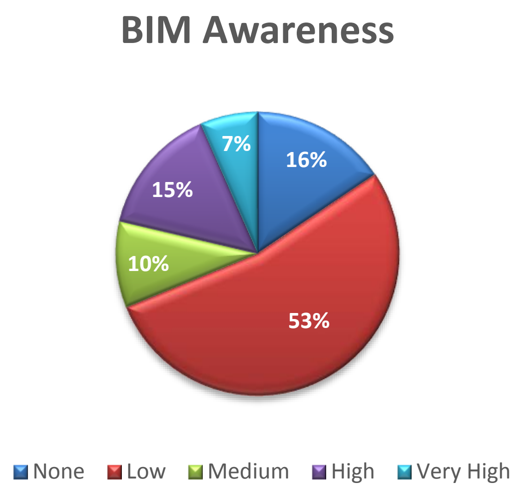

Figure 8: BIM awareness

Respondents' awareness level on Building Information Modelling was tested via the questionnaire as shown in Figure 8, 16% of them has responded as None (I do not know about BIM), 53% as Low (I have a little knowledge on BIM), 10% of them as Medium (I have plans to implement BIM in a project) and 15% and 7% as High (I have involved in a project using BIM) and Very High (I have involved in few projects using BIM) respectively.

For the convenience of the study, the respondents were divided in to two groups as BIM non users (None and Low) 69% and BIM users (Medium, High and Very High) 31% as shown in Figure 9. This 31% has involved in one or more BIM projects and experienced it. Though, about 69% of respondents claim that they have nix or low level of awareness on BIM, 53% of them even have heard about this.

It reflects the present BIM adoption level in construction industry of Sri Lanka. Those respondent have very high knowledge of BIM probably have working experience on international project with international consultant and designers.

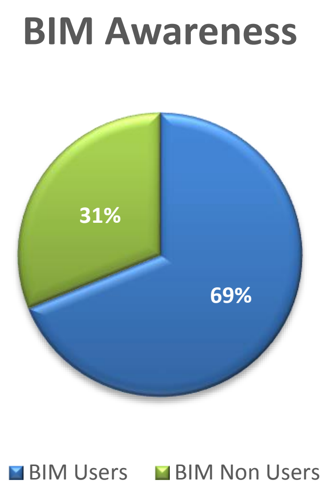

Figure 9: BIM users and BIM Non Users

4.2.3 Experience Level and BIM Awareness

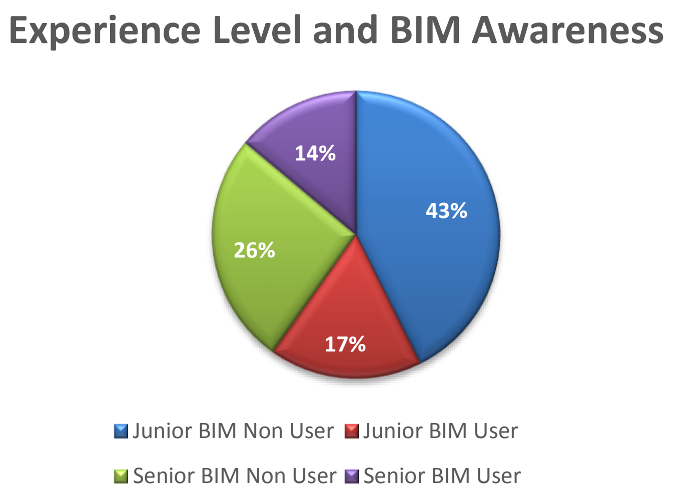

Figure 10: Experience Level and BIM Awareness

To facilitate the analysis, BIM users and BIM non users were further categorized considering the experience level. There are 43% of junior BIM non users, 17% of junior BIM users, 26% of senior BIM non users and 14% of senior BIM users as illustrated in Figure 10.

4.2.4 Academic Qualification

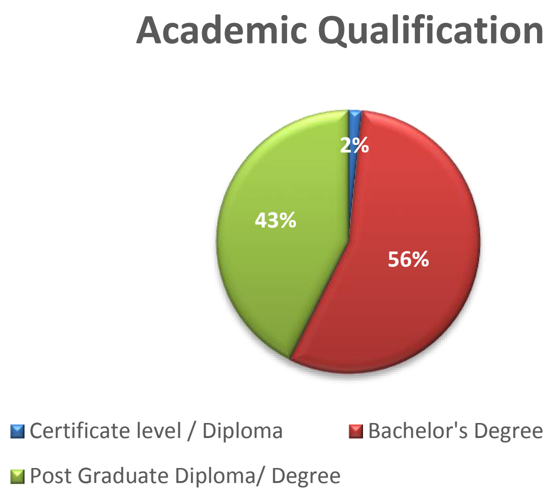

Figure 11: Academic Qualification

On the basis of their academic qualifications, all respondents are divided in to three categories as shown in Figure 11. 56% of respondents have qualified with Bachelor's degree and 43% of them possessed a Post Graduate Diploma or a Degree. All the respondents have at least qualified with Certificate level or Diploma.

4.2.5 Type of the Project

When deeply analyse the responses, it is noted that 89% of the respondents are involved in building projects as shown in Figure 12 and responded the questionnaire with that experience. Therefore, the study can be drove towards the building industry in Sri Lanka straightforwardly.

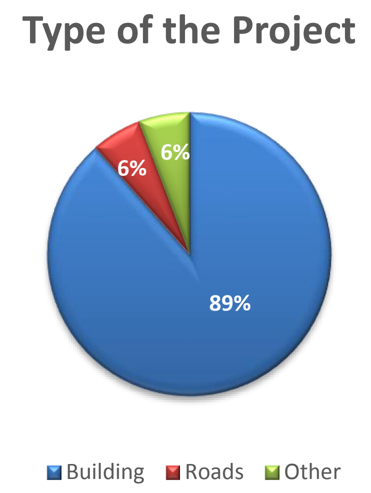

Figure 12: Type of the Project

4.2.6 Role of the Project

Generally, the respondent's role in the project is illustrated in Figure 13. Majority of the respondents, 57% are playing their role in the project as the consultant and 32% and 11% are involved the projects as the contractor and the client respectively.

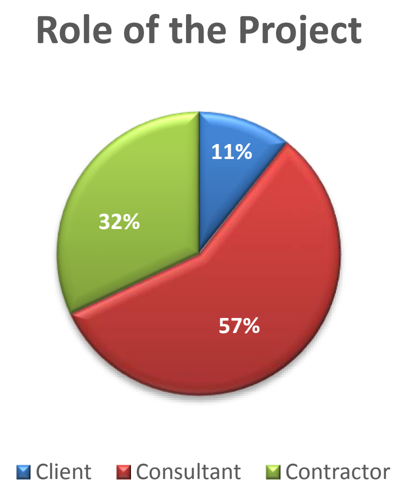

Figure 13: Role of the Project

4.2.7 Client of the Project

Considering all the responses, the client type of the projects consider for the study can be categorized as government, private and foreign with percentages of 48%, 24% and 28% as illustrated in Figure 14. Nearly half of the respondents are from the projects implemented by the government.

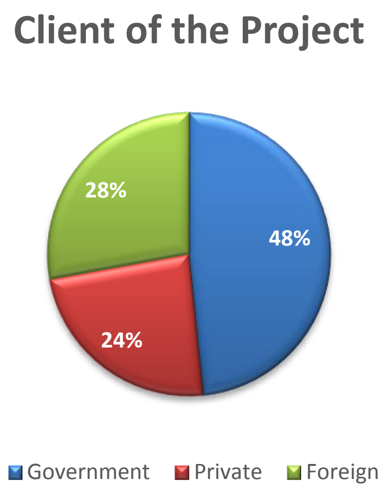

Figure 14: Client of the Project

This can be further categorized as the projects using BIM and the projects not using BIM to obtain an idea on the clients who currently prefer BIM in their projects. It shows that most of the projects operated with BIM technology are implemented by foreign and private firms where there percentages are 47% and 37% respectively. The Figure 15 further confirms this.

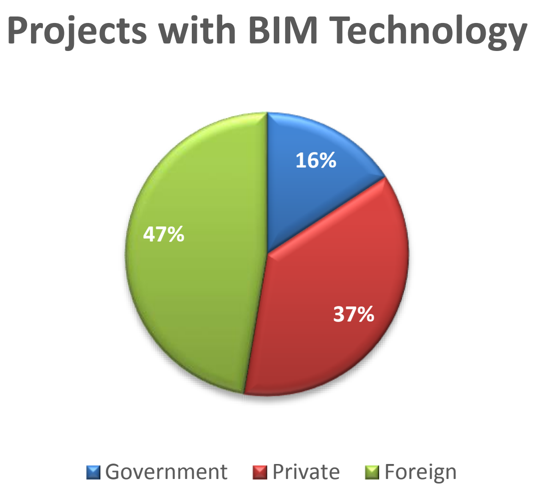

Figure 15: Projects with BIM Technology

It is highlighted that, though the highest number of respondents are from government projects, the projects with BIM technology are highly facilitated by foreign and private organizations more than government firms.

4.2.8 Value of the Project

The value of the projects involved by the respondents are expands in a broad area from less than 5 Billion projects to more than 20 Billion projects as shown in Figure 16.

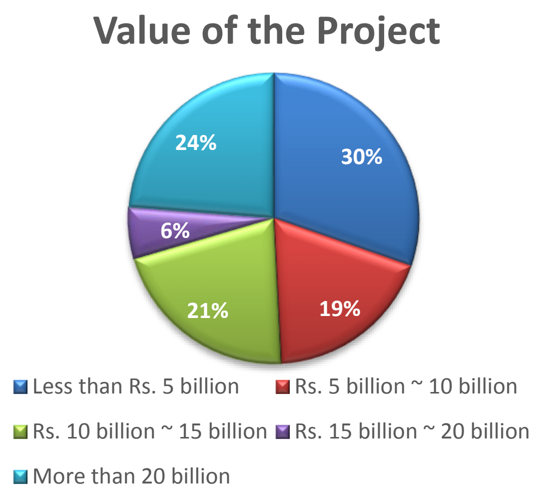

Figure 16: Value of the Project

The analysis was carried out targeting BIM implemented projects and generally there is an equal distribution in all considered project value ranges. This result is illustrated in Figure 17 and gives an idea that there is no significant impact of project value on BIM implementation. The result of the interviews also confirmed this factor concluding that project with any cost, low, medium or high can have benefits from using BIM in those.

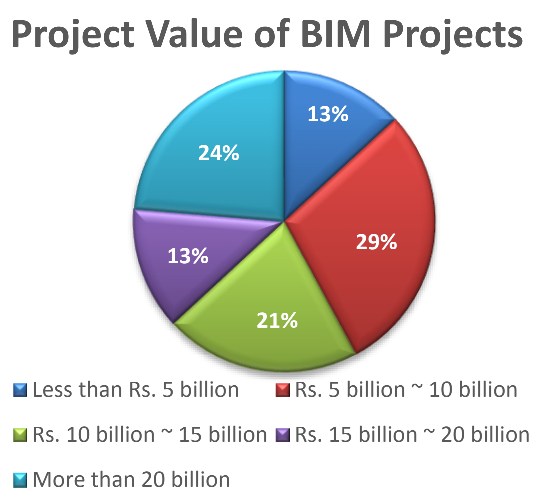

Figure 17: Project Value of BIM Projects

4.3 Analysis of the Impact of Identified Factors on Major Issues in Construction Industry by Hypothesis Testing

4.3.1 Nature of the Collected Data

The factor types considered for the study θ, γ and δ are independent and ordinal variables. The normality of the distribution was checked using SPSS software.

4.3.2 The Impact of BIM Usage on Major Issues in Construction Industry

4.3.2.1 Difficulty in Design and Site Coordination

A) Less effectiveness in sharing required information

Table 9: Less effectiveness in sharing required information

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Less effectiveness in sharing required information	BIM Non user	84	74.54	6261.00
	BIM User	38	32.68	1242.00
	Total	122		

Test Statistics[a]

	Less effectiveness in sharing required information
Mann-Whitney U	501.000
Wilcoxon W	1242.000
Z	-6.446
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding less effectiveness in sharing required information

H_1: Less effectiveness in sharing required information of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than α = 0.05, we reject H_o at 95% level of confidence.

Therefore, we conclude that less effectiveness in sharing required information of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

B) Delays in response to request for information (RFI)

Table 10: Delays in response to RFI

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Delays in response to RFI	BIM Non user	84	76.49	6425.00
	BIM User	38	28.37	1078.00
	Total	122		

Test Statistics[a]

	Delays in response to RFI
Mann-Whitney U	337.000
Wilcoxon W	1078.000
Z	-7.670
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding delays in response to request for information (RFI)

H_1: Delays in response to request for information (RFI) of BIM non users are statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.

Therefore, we conclude that delays in response to request for information (RFI) of BIM non users are statistically significantly higher than the same of BIM users at a 95% level of confidence.

C) Difficulty in understanding of drawings and visualization

Table 11: Difficulty in understanding of drawings & visualization

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Difficulty in understanding of drawings & visualization	BIM Non user	84	74.72	6276.50
	BIM User	38	32.28	1226.50
	Total	122		

Test Statistics[a]

	Difficulty in understanding of drawings & visualization
Mann-Whitney U	485.500
Wilcoxon W	1226.500
Z	-6.456
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding difficulty in understanding of drawings and visualization

H_1: Difficulty in understanding of drawings and visualization of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in understanding of drawings and visualization of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

D) Failures in clash detection

Table 12: Failures in clash detection

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Failures in clash detection	BIM Non user	84	74.96	6297.00
	BIM User	38	31.74	1206.00
	Total	122		

Test Statistics[a]

	Failures in clash detection
Mann-Whitney U	465.000
Wilcoxon W	1206.000
Z	-6.580
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding failures in clash detection

H_1: Failures in clash detection of BIM non users are statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that failures in clash detection of BIM non users are statistically significantly higher than the same of BIM users at a 95% level of confidence.

Summary of Difficulty in Design and Site Coordination

Table 13: Design and Site Coordination

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
DesignAndSiteCoordination	BIM Non user	84	75.92	6377.50
	BIM User	38	29.62	1125.50
	Total	122		

Test Statistics[a]

	DesignAndSite Coordination
Mann-Whitney U	384.500
Wilcoxon W	1125.500
Z	-6.914
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding difficulty in design and site coordination

H_1: Difficulty in design and site coordination of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in design and site coordination of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

4.3.2.2 Difficulty in Planning and Scheduling

A) Insufficient information about project risks

Table 14: Insufficient information about project risks

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Insufficient information about project risks	BIM Non user	84	73.17	6146.50
	BIM User	38	35.70	1356.50
	Total	122		

Test Statistics[a]

	Insufficient information about project risks
Mann-Whitney U	615.500
Wilcoxon W	1356.500
Z	-5.893
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding insufficient information about project risks

H_1: Insufficient information about project risks of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that insufficient information about project risks of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

B) Limited or conflicted information of project

Table 15: Limited or conflicted information of project

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Limited or conflicted information of project	BIM Non user	84	70.52	5923.50
	BIM User	38	41.57	1579.50
	Total	122		

Test Statistics[a]

	Limited or conflicted information of project
Mann-Whitney U	838.500
Wilcoxon W	1579.500
Z	-4.525
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding limited or conflicted information of project

H_1: Limited or conflicted information of project of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that limited or conflicted information of project of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

C) Confusion in construction sequence

Table 16: Confusion in construction sequence

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Confusion in construction sequence	BIM Non user	84	73.76	6196.00
	BIM User	38	34.39	1307.00
	Total	122		

Test Statistics[a]

	Confusion in construction sequence
Mann-Whitney U	566.000
Wilcoxon W	1307.000
Z	-6.044
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding confusion in construction sequence

H_1: Confusion in construction sequence of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that confusion in construction sequence of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

D) Difficulty in handling of revised designs

Table 17: Difficulty in handling of revised designs

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Difficulty in handling of revised designs	BIM Non user	84	73.78	6197.50
	BIM User	38	34.36	1305.50
	Total	122		

Test Statistics[a]

	Difficulty in handling of revised designs
Mann-Whitney U	564.500
Wilcoxon W	1305.500
Z	-6.064
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding difficulty in handling of revised designs

H_1: Difficulty in handling of revised designs of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in handling of revised designs of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

E) Limited planning tools and resources

Table 18: Limited planning tools and resources

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Limited planning tools & resources	BIM Non user	84	70.45	5917.50
	BIM User	38	41.72	1585.50
	Total	122		

Test Statistics[a]

	Limited planning tools & resources
Mann-Whitney U	844.500
Wilcoxon W	1585.500
Z	-4.558
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding limited planning tools and resources

H_1: Limited planning tools and resources of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that limited planning tools and resources of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

Summary of Difficulty in Planning and Scheduling

Table 19: Planning and Scheduling

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
PlanningAndScheduling	BIM Non user	84	72.51	6091.00
	BIM User	38	37.16	1412.00
	Total	122		

Test Statistics[a]

	PlanningAndScheduling
Mann-Whitney U	671.000
Wilcoxon W	1412.000
Z	-5.760
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding difficulty in planning and scheduling

H_1: Difficulty in planning and scheduling of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in planning and scheduling of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

4.3.2.3 Difficulty in Cost Reduction and Cost Control

A) Improper planning of manpower

Table 20: Improper planning of manpower

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Improper planning of manpower	BIM Non user	84	70.08	5887.00
	BIM User	38	42.53	1616.00
	Total	122		

Test Statistics[a]

	Improper planning of manpower
Mann-Whitney U	875.000
Wilcoxon W	1616.000
Z	-4.347
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding improper planning of manpower

H_1: Improper planning of manpower of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that improper planning of manpower of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

B) Improper logistic planning

Table 21: Improper logistic planning

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Improper logistic planning	BIM Non user	84	69.00	5796.00
	BIM User	38	44.92	1707.00
	Total	122		

Test Statistics[a]

	Improper logistic planning
Mann-Whitney U	966.000
Wilcoxon W	1707.000
Z	-3.911
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding improper logistic planning

H_1: Improper logistic planning of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that improper logistic planning of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

C) Procurement management problems

Table 22: Procurement management problems

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Procurement management problems	BIM Non user	84	74.07	6222.00
	BIM User	38	33.71	1281.00
	Total	122		

Test Statistics[a]

	Procurement management problems
Mann-Whitney U	540.000
Wilcoxon W	1281.000
Z	-6.208
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding procurement management problems

H_1: Procurement management problems of BIM non users are statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that procurement management problems of BIM non users are statistically significantly higher than the same of BIM users at a 95% level of confidence.

D) Poor coordination among different department

Table 23: Poor coordination among different department

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Poor coordination among different department	BIM Non user	84	73.32	6159.00
	BIM User	38	35.37	1344.00
	Total	122		

Test Statistics[a]

	Poor coordination among different department
Mann-Whitney U	603.000
Wilcoxon W	1344.000
Z	-5.774
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding poor coordination among different departments

H_1: Poor coordination among different departments of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.

Therefore, we conclude that poor coordination among different departments of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

E) Hard to handle sudden changes

Table 24: Hard to handle sudden changes

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Hard to handle sudden changes	BIM Non user	84	76.08	6390.50
	BIM User	38	29.28	1112.50
	Total	122		

Test Statistics[a]

	Hard to handle sudden changes
Mann-Whitney U	371.500
Wilcoxon W	1112.500
Z	-7.204
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding hard to handle sudden changes

H_1: Hard to handle sudden changes of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that hard to handle sudden changes of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

F) Failures in clash detection

Table 25: Failures in clash detection

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Failures in clash detection	BIM Non user	84	75.74	6362.50
	BIM User	38	30.01	1140.50
	Total	122		

Test Statistics[a]

	Failures in clash detection
Mann-Whitney U	399.500
Wilcoxon W	1140.500
Z	-7.082
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding failures in clash detection

H_1: Failures in clash detection of BIM non users are statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that failures in clash detection of BIM non users are statistically significantly higher than the same of BIM users at a 95% level of confidence.

G) Interruptions of stakeholders

Table 26: Interuptions of stakeholders

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Interuptions of stakeholders	BIM Non user	84	69.07	5801.50
	BIM User	38	44.78	1701.50
	Total	122		

Test Statistics[a]

	Interuptions of stakeholders
Mann-Whitney U	960.500
Wilcoxon W	1701.500
Z	-3.788
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding interruptions of stakeholders

H_1: Interruptions of stakeholders of BIM non users are statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that interruptions of stakeholders of BIM non users are statistically significantly higher than the same of BIM users at a 95% level of confidence.

Summary of Difficulty in Cost Reduction and Cost Control

Table 27: Cost Reduction and Cost Control

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
CostReductionAndCostControl	BIM Non user	84	73.73	6193.00
	BIM User	38	34.47	1310.00
	Total	122		

Test Statistics[a]

	CostReductionAndCostControl
Mann-Whitney U	569.000
Wilcoxon W	1310.000
Z	-6.795
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding difficulty in cost reduction and cost control

H_1: Difficulty in cost reduction and cost control of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in cost reduction and cost control of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

4.3.2.4 Difficulty in Managing the Construction Time

A) Delays in the procurement process

Table 28: Delays in the procurement

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Delays in the procurement	BIM Non user	84	72.01	6049.00
	BIM User	38	38.26	1454.00
	Total	122		

Test Statistics[a]

	Delays in the procurement
Mann-Whitney U	713.000
Wilcoxon W	1454.000
Z	-5.546
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding delays in procurement

H_1: Delays in procurement of BIM non users are statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in procurement of BIM non users are statistically significantly higher than the same of BIM users at a 95% level of confidence.

B) Delays in producing shop drawings

Table 29: Delays in producing shopdrawing

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Delays in producing shopdrawing	BIM Non user	84	71.25	5985.00
	BIM User	38	39.95	1518.00
	Total	122		

Test Statistics[a]

	Delays in producing shopdrawing
Mann-Whitney U	777.000
Wilcoxon W	1518.000
Z	-4.889
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding delays in producing shop drawings

H_1: Delays in producing shop drawings of BIM non users are statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in producing shop drawings of BIM non users are statistically significantly higher than the same of BIM users at a 95% level of confidence.

C) Improper resource allocation

Table 30: Improper resource allocation

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Improper resource allocation	BIM Non user	84	74.15	6228.50
	BIM User	38	33.54	1274.50
	Total	122		

Test Statistics[a]

	Improper resource allocation
Mann-Whitney U	533.500
Wilcoxon W	1274.500
Z	-6.363
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding improper resource allocation

H_1: Improper resource allocation of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that improper resource allocation of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

D) Delays in client approvals

Table 31: Delays in client approvals

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Delays in client approvals	BIM Non user	84	72.60	6098.50
	BIM User	38	36.96	1404.50
	Total	122		

Test Statistics[a]

	Delays in client approvals
Mann-Whitney U	663.500
Wilcoxon W	1404.500
Z	-5.493
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding delays in client approvals

H_1: Delays in client approvals of BIM non users are statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in client approvals of BIM non users are statistically significantly higher than the same of BIM users at a 95% level of confidence.

E) Delays in handling suppliers

Table 32: Delays in handling suppliers

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
Delays in handling suppliers	BIM Non user	84	73.80	6199.50
	BIM User	38	34.30	1303.50
	Total	122		

Test Statistics[a]

	Delays in handling suppliers
Mann-Whitney U	562.500
Wilcoxon W	1303.500
Z	-6.368
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding delays in handling suppliers

H_1: Delays in handling suppliers of BIM non users are statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in handling suppliers of BIM non users are statistically significantly higher than the same of BIM users at a 95% level of confidence.

Summary of Difficulty in Managing the Construction Time

Table 33: Managing Construction Time

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
ManagingConstructionTime	BIM Non user	84	73.19	6148.00
	BIM User	38	35.66	1355.00
	Total	122		

Test Statistics[a]

	ManagingConstructionTime
Mann-Whitney U	614.000
Wilcoxon W	1355.000
Z	-6.304
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding difficulty in managing the construction time

H_1: Difficulty in managing the construction time of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in managing the construction time of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

<u>Overall Summary - The Impact of BIM Usage on Major Issues in Construction Industry</u>

Table 34: Major Construction Issues

Ranks

	UsersAndNonUsers	N	Mean Rank	Sum of Ranks
MajorConstructionIssues	BIM Non user	84	75.49	6341.00
	BIM User	38	30.58	1162.00
	Total	122		

Test Statistics[a]

	MajorConstructionIssues
Mann-Whitney U	421.000
Wilcoxon W	1162.000
Z	-7.085
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: UsersAndNonUsers

H_o: There is no statistically significant difference between BIM users and BIM non users, regarding encountering major issues in construction industry

H_1: Encountering major issues in construction industry of BIM non users is statistically significantly higher than the same of BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that encountering major issues in construction industry of BIM non users is statistically significantly higher than the same of BIM users at a 95% level of confidence.

4.3.3 The Impact of Experience Level on Major Issues in Construction Industry

4.3.3.1 Difficulty in Design and Site Coordination

A) Less effectiveness in sharing required information

Table 35: Less effectiveness in sharing required information

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Less effectiveness in sharing required information	Juniors (Below 10 Years)	73	58.05	4238.00
	Seniors (Above 10 Years)	49	66.63	3265.00
	Total	122		

Test Statistics[a]

	Less effectiveness in sharing required information
Mann-Whitney U	1537.000
Wilcoxon W	4238.000
Z	-1.399
Asymp. Sig. (2-tailed)	.162

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding less effectiveness in sharing required information

H_1: Less effectiveness in sharing required information of Seniors is statistically significantly higher than the same of Juniors

Since the Mann-Whitney U test U-Statistic = 0.162 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding less effectiveness in sharing required information at a 95% level of confidence.

B) Delays in response to request for information (RFI)

Table 36: Delays in response to RFI

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Delays in response to RFI	Juniors (Below 10 Years)	73	60.27	4400.00
	Seniors (Above 10 Years)	49	63.33	3103.00
	Total	122		

Test Statistics[a]

	Delays in response to RFI
Mann-Whitney U	1699.000
Wilcoxon W	4400.000
Z	-.515
Asymp. Sig. (2-tailed)	.607

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding delays in response to request for information (RFI)

H_1: Delays in response to request for information (RFI) of Seniors is statistically significantly higher than the same of Juniors

Since the Mann-Whitney U test U-Statistic = 0.607 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding delays in response to request for information (RFI) at a 95% level of confidence.

C) Difficulty in understanding of drawings and visualization

Table 37: Difficulty in understanding of drawings & visualization

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Difficulty in understanding of drawings & visualization	Juniors (Below 10 Years)	73	60.30	4402.00
	Seniors (Above 10 Years)	49	63.29	3101.00
	Total	122		

Test Statistics[a]

	Difficulty in understanding of drawings & visualization
Mann-Whitney U	1701.000
Wilcoxon W	4402.000
Z	-.481
Asymp. Sig. (2-tailed)	.631

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding difficulty in understanding of drawings and visualization

H_1: Difficulty in understanding of drawings and visualization of Seniors is statistically significantly higher than the same of Juniors

Since the Mann-Whitney U test U-Statistic = 0.631 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding difficulty in understanding of drawings and visualization of Seniors at a 95% level of confidence.

D) Failures in clash detection

Table 38: Failures in clash detection

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Failures in clash detection	Juniors (Below 10 Years)	73	58.66	4282.00
	Seniors (Above 10 Years)	49	65.73	3221.00
	Total	122		

Test Statistics[a]

	Failures in clash detection
Mann-Whitney U	1581.000
Wilcoxon W	4282.000
Z	-1.140
Asymp. Sig. (2-tailed)	.254

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding failures in clash detection

H_1: Failures in clash detection of Seniors are statistically significantly higher than the same of Juniors

Since the Mann-Whitney U test U-Statistic = 0.254 is greater than α = 0.05, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding failures in clash detection at a 95% level of confidence.

Summary of Difficulty in Design and Site Coordination

Table 39: Design and Site Coordination

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
DesignAndSiteCoordination	Juniors (Below 10 Years)	73	57.66	4209.50
	Seniors (Above 10 Years)	49	67.21	3293.50
	Total	122		

Test Statistics[a]

	DesignAndSite Coordination
Mann-Whitney U	1508.500
Wilcoxon W	4209.500
Z	-1.509
Asymp. Sig. (2-tailed)	.131

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding difficulty in design and site coordination

H_1: Difficulty in design and site coordination of Seniors is statistically significantly higher than the same of Juniors

Since the Mann-Whitney U test U-Statistic = 0.131 is greater than α = 0.05, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding difficulty in design and site coordination at a 95% level of confidence.

4.3.3.2 Difficulty in Planning and Scheduling

A) Insufficient information about project risks

Table 40: Insufficient information about project risks

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Insufficient information about project risks	Juniors (Below 10 Years)	73	63.19	4613.00
	Seniors (Above 10 Years)	49	58.98	2890.00
	Total	122		

Test Statistics[a]

	Insufficient information about project risks
Mann-Whitney U	1665.000
Wilcoxon W	2890.000
Z	-.701
Asymp. Sig. (2-tailed)	.483

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding insufficient information about project risks

H_1: Insufficient information about project risks of Juniors is statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.483 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding insufficient information about project risks at a 95% level of confidence.

B) Limited or conflicted information of project

Table 41: Limited or conflicted information of project

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Limited or conflicted information of project	Juniors (Below 10 Years)	73	63.20	4613.50
	Seniors (Above 10 Years)	49	58.97	2889.50
	Total	122		

Test Statistics[a]

	Limited or conflicted information of project
Mann-Whitney U	1664.500
Wilcoxon W	2889.500
Z	-.700
Asymp. Sig. (2-tailed)	.484

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding limited or conflicted information of project

H_1: Limited or conflicted information of project of Juniors is statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.484 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding limited or conflicted information of project at a 95% level of confidence.

C) Confusion in construction sequence

Table 42: Confusion in construction sequence

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Confusion in construction sequence	Juniors (Below 10 Years)	73	65.34	4770.00
	Seniors (Above 10 Years)	49	55.78	2733.00
	Total	122		

Test Statistics[a]

	Confusion in construction sequence
Mann-Whitney U	1508.000
Wilcoxon W	2733.000
Z	-1.555
Asymp. Sig. (2-tailed)	.120

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding confusion in construction sequence

H_1: Confusion in construction sequence of Juniors is statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.120 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding confusion in construction sequence at a 95% level of confidence.

D) Difficulty in handling of revised designs

Table 43: Difficulty in handling of revised designs

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Difficulty in handling of revised designs	Juniors (Below 10 Years)	73	61.53	4491.50
	Seniors (Above 10 Years)	49	61.46	3011.50
	Total	122		

Test Statistics[a]

	Difficulty in handling of revised designs
Mann-Whitney U	1786.500
Wilcoxon W	3011.500
Z	-.011
Asymp. Sig. (2-tailed)	.991

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding difficulty in handling of revised designs

H_1: Difficulty in handling of revised designs of Juniors is statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.991 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding difficulty in handling of revised designs at a 95% level of confidence.

E) Limited planning tools and resources

Table 44: Limited planning tools & resources

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Limited planning tools & resources	Juniors (Below 10 Years)	73	62.94	4594.50
	Seniors (Above 10 Years)	49	59.36	2908.50
	Total	122		

Test Statistics[a]

	Limited planning tools & resources
Mann-Whitney U	1683.500
Wilcoxon W	2908.500
Z	-.602
Asymp. Sig. (2-tailed)	.547

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding limited planning tools and resources

H_1: Limited planning tools and resources of Juniors is statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.547 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding limited planning tools and resources at a 95% level of confidence.

Summary of Difficulty in Planning and Scheduling

Table 45: Planning and Scheduling

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
PlanningAndScheduling	Juniors (Below 10 Years)	73	62.77	4582.00
	Seniors (Above 10 Years)	49	59.61	2921.00
	Total	122		

Test Statistics[a]

	PlanningAndScheduling
Mann-Whitney U	1696.000
Wilcoxon W	2921.000
Z	-.544
Asymp. Sig. (2-tailed)	.586

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding difficulty in planning and scheduling

H_1: Difficulty in planning and scheduling of Juniors are statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.586 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding difficulty in planning and scheduling at a 95% level of confidence.

4.3.3.3 Difficulty in Cost Reduction and Cost Control

A) Improper planning of manpower

Table 46: Improper planning of manpower

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Improper planning of manpower	Juniors (Below 10 Years)	73	68.35	4989.50
	Seniors (Above 10 Years)	49	51.30	2513.50
	Total	122		

Test Statistics[a]

	Improper planning of manpower
Mann-Whitney U	1288.500
Wilcoxon W	2513.500
Z	-2.848
Asymp. Sig. (2-tailed)	.004

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding improper planning of manpower

H_1: Improper planning of manpower of Juniors is statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.004 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that improper planning of manpower of Juniors is statistically significantly higher than the same of Seniors at a 95% level of confidence.

B) Improper logistic planning

Table 47: Improper logistic planning

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Improper logistic planning	Juniors (Below 10 Years)	73	67.89	4956.00
	Seniors (Above 10 Years)	49	51.98	2547.00
	Total	122		

Test Statistics[a]

	Improper logistic planning
Mann-Whitney U	1322.000
Wilcoxon W	2547.000
Z	-2.735
Asymp. Sig. (2-tailed)	.006

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding improper logistic planning

H_1: Improper logistic planning of Juniors is statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.006 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that improper logistic planning of Juniors is statistically significantly higher than the same of Seniors at a 95% level of confidence.

C) Procurement management problems

Table 48: Procurement management problems

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Procurement management problems	Juniors (Below 10 Years)	73	63.01	4599.50
	Seniors (Above 10 Years)	49	59.26	2903.50
	Total	122		

Test Statistics[a]

	Procurement management problems
Mann-Whitney U	1678.500
Wilcoxon W	2903.500
Z	-.611
Asymp. Sig. (2-tailed)	.541

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding procurement management problems

H_1: Procurement management problems of Juniors are statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.541 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding procurement management problem at a 95% level of confidence.

D) Poor coordination among different department

Table 49: Poor coordination among different department

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Poor coordination among different department	Juniors (Below 10 Years)	73	67.39	4919.50
	Seniors (Above 10 Years)	49	52.72	2583.50
	Total	122		

Test Statistics[a]

	Poor coordination among different department
Mann-Whitney U	1358.500
Wilcoxon W	2583.500
Z	-2.362
Asymp. Sig. (2-tailed)	.018

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding poor coordination among different departments

H_1: Poor coordination among different departments of Juniors is statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.018 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.

Therefore, we conclude that poor coordination among different departments of Juniors is statistically significantly higher than the same of Seniors at a 95% level of confidence.

E) Hard to handle sudden changes

Table 50: Hard to handle sudden changes

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Hard to handle sudden changes	Juniors (Below 10 Years)	73	61.73	4506.00
	Seniors (Above 10 Years)	49	61.16	2997.00
	Total	122		

Test Statistics[a]

	Hard to handle sudden changes
Mann-Whitney U	1772.000
Wilcoxon W	2997.000
Z	-.092
Asymp. Sig. (2-tailed)	.927

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding hard to handle sudden changes

H_1: Hard to handle sudden changes of Juniors is statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.927 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding hard to handle sudden changes at a 95% level of confidence.

F) Failures in clash detection

Table 51: Failures in clash detection

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Failures in clash detection	Juniors (Below 10 Years)	73	58.38	4261.50
	Seniors (Above 10 Years)	49	66.15	3241.50
	Total	122		

Test Statistics[a]

	Failures in clash detection
Mann-Whitney U	1560.500
Wilcoxon W	4261.500
Z	-1.275
Asymp. Sig. (2-tailed)	.202

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding failures in clash detection

H_1: Failures in clash detection of Seniors are statistically significantly higher than the same of Juniors

Since the Mann-Whitney U test U-Statistic = 0.202 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding failures in clash detection at a 95% level of confidence.

G) Interruptions of stakeholders

Table 52: Interuptions of stakeholders

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Interuptions of stakeholders	Juniors (Below 10 Years)	73	68.88	5028.00
	Seniors (Above 10 Years)	49	50.51	2475.00
	Total	122		

Test Statistics[a]

	Interuptions of stakeholders
Mann-Whitney U	1250.000
Wilcoxon W	2475.000
Z	-3.032
Asymp. Sig. (2-tailed)	.002

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding interruptions of stakeholders

H_1: Interruptions of stakeholders of Juniors are statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.002 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that interruptions of stakeholders of Juniors are statistically significantly higher than the same of Seniors at a 95% level of confidence.

Summary of Difficulty in Cost Reduction and Cost Control

Table 53: Cost Reduction and Cost Control

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
CostReductionAndCostControl	Juniors (Below 10 Years)	73	63.86	4662.00
	Seniors (Above 10 Years)	49	57.98	2841.00
	Total	122		

Test Statistics[a]

	CostReductionAndCostControl
Mann-Whitney U	1616.000
Wilcoxon W	2841.000
Z	-1.078
Asymp. Sig. (2-tailed)	.281

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding difficulty in cost reduction and cost control

H_1: Difficulty in cost reduction and cost control of Juniors are statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.281 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding difficulty in cost reduction and cost control at a 95% level of confidence.

4.3.3.4 Difficulty in Managing the Construction Time

A) Delays in the procurement process

Table 54: Delays in the procurement

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Delays in the procurement	Juniors (Below 10 Years)	73	62.36	4552.00
	Seniors (Above 10 Years)	49	60.22	2951.00
	Total	122		

Test Statistics[a]

	Delays in the procurement
Mann-Whitney U	1726.000
Wilcoxon W	2951.000
Z	-.371
Asymp. Sig. (2-tailed)	.711

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding delays in procurement

H_1: Delays in procurement of Juniors are statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.711 is greater than α = 0.05, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding delays in procurement at a 95% level of confidence.

B) Delays in producing shop drawings

Table 55: Delays in producing shop drawing

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Delays in producing shop drawing	Juniors (Below 10 Years)	73	64.72	4724.50
	Seniors (Above 10 Years)	49	56.70	2778.50
	Total	122		

Test Statistics[a]

	Delays in producing shopdrawing
Mann-Whitney U	1553.500
Wilcoxon W	2778.500
Z	-1.325
Asymp. Sig. (2-tailed)	.185

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding delays in producing shop drawings

H_1: Delays in producing shop drawings of Juniors are statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.185 is greater than α = 0.05, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding delays in producing shop drawings at a 95% level of confidence.

C) Improper resource allocation

Table 56: Improper resource allocation

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Improper resource allocation	Juniors (Below 10 Years)	73	66.79	4875.50
	Seniors (Above 10 Years)	49	53.62	2627.50
	Total	122		

Test Statistics[a]

	Improper resource allocation
Mann-Whitney U	1402.500
Wilcoxon W	2627.500
Z	-2.184
Asymp. Sig. (2-tailed)	.029

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding improper resource allocation

H_1: Improper resource allocation of Juniors is statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.029 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that improper resource allocation of Juniors is statistically significantly higher than the same of Seniors at a 95% level of confidence.

D) Delays in client approvals

Table 57: Delays in client approvals

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Delays in client approvals	Juniors (Below 10 Years)	73	65.68	4794.50
	Seniors (Above 10 Years)	49	55.28	2708.50
	Total	122		

Test Statistics[a]

	Delays in client approvals
Mann-Whitney U	1483.500
Wilcoxon W	2708.500
Z	-1.697
Asymp. Sig. (2-tailed)	.090

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding delays in client approvals

H_1: Delays in client approvals of Juniors are statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.090 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding delays in client approvals at a 95% level of confidence.

E) Delays in handling suppliers

Table 58: Delays in handling suppliers

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
Delays in handling suppliers	Juniors (Below 10 Years)	73	62.95	4595.50
	Seniors (Above 10 Years)	49	59.34	2907.50
	Total	122		

Test Statistics[a]

	Delays in handling suppliers
Mann-Whitney U	1682.500
Wilcoxon W	2907.500
Z	-.617
Asymp. Sig. (2-tailed)	.537

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding delays in handling suppliers

H_1: Delays in handling suppliers of Juniors are statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.537 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding delays in handling suppliers at a 95% level of confidence.

Summary of Difficulty in Managing the Construction Time

Table 59: Managing Construction Time

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
ManagingConstructionTime	Juniors (Below 10 Years)	73	63.31	4621.50
	Seniors (Above 10 Years)	49	58.81	2881.50
	Total	122		

Test Statistics[a]

	ManagingConstructionTime
Mann-Whitney U	1656.500
Wilcoxon W	2881.500
Z	-.800
Asymp. Sig. (2-tailed)	.423

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding difficulty in managing the construction time

H_1: Difficulty in managing the construction time of Juniors is statistically significantly higher than the same of Seniors

Since the Mann-Whitney U test U-Statistic = 0.423 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding difficulty in managing the construction time at a 95% level of confidence.

Overall Summary - The Impact of Experience Level on Major Issues in Construction Industry

Table 60: Major Construction Issues

Ranks

	ExperienceLevel	N	Mean Rank	Sum of Ranks
MajorConstructionIssues	Juniors (Below 10 Years)	73	60.47	4414.00
	Seniors (Above 10 Years)	49	63.04	3089.00
	Total	122		

Test Statistics[a]

	MajorConstructionIssues
Mann-Whitney U	1713.000
Wilcoxon W	4414.000
Z	-.430
Asymp. Sig. (2-tailed)	.667

a. Grouping Variable: ExperienceLevel

H_o: There is no statistically significant difference between Seniors and Juniors, regarding encountering major issues in construction industry

H_1: Encountering major issues in construction industry of Seniors is statistically significantly higher than the same of Juniors

Since the Mann-Whitney U test U-Statistic = 0.667 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Seniors and Juniors, regarding encountering major issues in construction industry at a 95% level of confidence.

4.3.4 The Impact of BIM Usage to Seniors on Major Issues in Construction Industry

4.3.4.1 Difficulty in Design and Site Coordination

A) Less effectiveness in sharing required information

Table 61: Less effectiveness in sharing required information

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Less effectiveness in sharing required information	Senior BIM Non User	32	32.64	1044.50
	Senior BIM User	17	10.62	180.50
	Total	49		

Test Statistics[a]

	Less effectiveness in sharing required information
Mann-Whitney U	27.500
Wilcoxon W	180.500
Z	-5.353
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding less effectiveness in sharing required information

H_1: Less effectiveness in sharing required information of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that less effectiveness in sharing required information of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

B) Delays in response to request for information (RFI)

Table 62: Delays in response to RFI

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Delays in response to RFI	Senior BIM Non User	32	32.06	1026.00
	Senior BIM User	17	11.71	199.00
	Total	49		

Test Statistics[a]

	Delays in response to RFI
Mann-Whitney U	46.000
Wilcoxon W	199.000
Z	-5.005
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding delays in response to request for information (RFI)

H_1: Delays in response to request for information (RFI) of Senior BIM non users are statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in response to request for information (RFI) of Senior BIM non users are statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

C) Difficulty in understanding of drawings and visualization

Table 63: Difficulty in understanding of drawings & visualization

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Difficulty in understanding of drawings & visualization	Senior BIM Non User	32	31.97	1023.00
	Senior BIM User	17	11.88	202.00
	Total	49		

Test Statistics[a]

	Difficulty in understanding of drawings & visualization
Mann-Whitney U	49.000
Wilcoxon W	202.000
Z	-4.891
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding difficulty in understanding of drawings and visualization

H_1: Difficulty in understanding of drawings and visualization of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in understanding of drawings and visualization of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

D) Failures in clash detection

Table 64: Failures in clash detection

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Failures in clash detection	Senior BIM Non User	32	32.69	1046.00
	Senior BIM User	17	10.53	179.00
	Total	49		

Test Statistics[a]

	Failures in clash detection
Mann-Whitney U	26.000
Wilcoxon W	179.000
Z	-5.349
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding failures in clash detection

H_1: Failures in clash detection of Senior BIM non users are statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that failures in clash detection of Senior BIM non users are statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

Summary of Difficulty in Design and Site Coordination

Table 65: Design and Site Coordination

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
DesignAndSiteCoordination	Senior BIM Non User	32	32.97	1055.00
	Senior BIM User	17	10.00	170.00
	Total	49		

Test Statistics[a]

	DesignAndSite Coordination
Mann-Whitney U	17.000
Wilcoxon W	170.000
Z	-5.441
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding difficulty in design and site coordination

H_1: Difficulty in design and site coordination of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in design and site coordination of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

4.3.4.2 Difficulty in Planning and Scheduling

A) Insufficient information about project risks

Table 66: Insufficient information about project risks

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Insufficient information about project risks	Senior BIM Non User	32	31.19	998.00
	Senior BIM User	17	13.35	227.00
	Total	49		

Test Statistics[a]

	Insufficient information about project risks
Mann-Whitney U	74.000
Wilcoxon W	227.000
Z	-4.360
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding insufficient information about project risks

H_1: Insufficient information about project risks of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that insufficient information about project risks of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

B) Limited or conflicted information of project

Table 67: Limited or conflicted information of project

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Limited or conflicted information of project	Senior BIM Non User	32	31.55	1009.50
	Senior BIM User	17	12.68	215.50
	Total	49		

Test Statistics[a]

	Limited or conflicted information of project
Mann-Whitney U	62.500
Wilcoxon W	215.500
Z	-4.581
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding limited or conflicted information of project

H_1: Limited or conflicted information of project of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that limited or conflicted information of project of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

C) Confusion in construction sequence

Table 68: Confusion in construction sequence

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Confusion in construction sequence	Senior BIM Non User	32	30.55	977.50
	Senior BIM User	17	14.56	247.50
	Total	49		

Test Statistics[a]

	Confusion in construction sequence
Mann-Whitney U	94.500
Wilcoxon W	247.500
Z	-3.922
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding confusion in construction sequence

H_1: Confusion in construction sequence of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that confusion in construction sequence of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

D) Difficulty in handling of revised designs

Table 69: Difficulty in handling of revised designs

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Difficulty in handling of revised designs	Senior BIM Non User	32	32.47	1039.00
	Senior BIM User	17	10.94	186.00
	Total	49		

Test Statistics[a]

	Difficulty in handling of revised designs
Mann-Whitney U	33.000
Wilcoxon W	186.000
Z	-5.353
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding difficulty in handling of revised designs

H_1: Difficulty in handling of revised designs of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in handling of revised designs of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

E) Limited planning tools and resources

Table 70: Limited planning tools and resources

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Limited planning tools & resources	Senior BIM Non User	32	32.00	1024.00
	Senior BIM User	17	11.82	201.00
	Total	49		

Test Statistics[a]

	Limited planning tools & resources
Mann-Whitney U	48.000
Wilcoxon W	201.000
Z	-4.980
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding limited planning tools and resources

H_1: Limited planning tools and resources of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that limited planning tools and resources of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

Summary of Difficulty in Planning and Scheduling

Table 71: Planning and Scheduling

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
PlanningAndScheduling	Senior BIM Non User	32	31.78	1017.00
	Senior BIM User	17	12.24	208.00
	Total	49		

Test Statistics[a]

	PlanningAndScheduling
Mann-Whitney U	55.000
Wilcoxon W	208.000
Z	-4.867
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding difficulty in planning and scheduling

H_1: Difficulty in planning and scheduling of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in planning and scheduling of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

4.3.4.3 Difficulty in Cost Reduction and Cost Control

A) Improper planning of manpower

Table 72: Improper planning of manpower

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Improper planning of manpower	Senior BIM Non User	32	31.41	1005.00
	Senior BIM User	17	12.94	220.00
	Total	49		

Test Statistics[a]

	Improper planning of manpower
Mann-Whitney U	67.000
Wilcoxon W	220.000
Z	-4.539
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding improper planning of manpower

H_1: Improper planning of manpower of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that improper planning of manpower of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

B) Improper logistic planning

Table 73: Improper logistic planning

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Improper logistic planning	Senior BIM Non User	32	30.53	977.00
	Senior BIM User	17	14.59	248.00
	Total	49		

Test Statistics[a]

	Improper logistic planning
Mann-Whitney U	95.000
Wilcoxon W	248.000
Z	-4.027
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding improper logistic planning

H_1: Improper logistic planning of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude improper logistic planning of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

C) Procurement management problems

Table 74: Procurement management problems

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Procurement management problems	Senior BIM Non User	32	32.64	1044.50
	Senior BIM User	17	10.62	180.50
	Total	49		

Test Statistics[a]

	Procurement management problems
Mann-Whitney U	27.500
Wilcoxon W	180.500
Z	-5.331
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding procurement management problems

H_1: Procurement management problems of Senior BIM non users are statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that procurement management problems of Senior BIM non users are statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

D) Poor coordination among different department

Table 75: Poor coordination among different department

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Poor coordination among different department	Senior BIM Non User	32	32.02	1024.50
	Senior BIM User	17	11.79	200.50
	Total	49		

Test Statistics[a]

	Poor coordination among different department
Mann-Whitney U	47.500
Wilcoxon W	200.500
Z	-5.004
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding poor coordination among different departments

H_1: Poor coordination among different departments of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that poor coordination among different departments of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

E) Hard to handle sudden changes

Table 76: Hard to handle sudden changes

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Hard to handle sudden changes	Senior BIM Non User	32	32.97	1055.00
	Senior BIM User	17	10.00	170.00
	Total	49		

Test Statistics[a]

	Hard to handle sudden changes
Mann-Whitney U	17.000
Wilcoxon W	170.000
Z	-5.564
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding hard to handle sudden changes

H_1: Hard to handle sudden changes of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that hard to handle sudden changes of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

F) Failures in clash detection

Table 77: Failures in clash detection

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Failures in clash detection	Senior BIM Non User	32	32.66	1045.00
	Senior BIM User	17	10.59	180.00
	Total	49		

Test Statistics[a]

	Failures in clash detection
Mann-Whitney U	27.000
Wilcoxon W	180.000
Z	-5.406
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding failures in clash detection

H_1: Failures in clash detection of Senior BIM non users are statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that failures in clash detection of Senior BIM non users are statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

G) Interruptions of stakeholders

Table 78: Interuptions of stakeholders

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Interuptions of stakeholders	Senior BIM Non User	32	30.30	969.50
	Senior BIM User	17	15.03	255.50
	Total	49		

Test Statistics[a]

	Interuptions of stakeholders
Mann-Whitney U	102.500
Wilcoxon W	255.500
Z	-3.762
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding interruptions of stakeholders

H_1: Interruptions of stakeholders of Senior BIM non users are statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that interruptions of stakeholders of Senior BIM non users are statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

<u>Summary of Difficulty in Cost Reduction and Cost Control</u>

Table 79: Cost Reduction and Cost Control

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
CostReductionAndCostControl	Senior BIM Non User	32	32.41	1037.00
	Senior BIM User	17	11.06	188.00
	Total	49		

Test Statistics[a]

	CostReductionAndCostControl
Mann-Whitney U	35.000
Wilcoxon W	188.000
Z	-5.492
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding difficulty in cost reduction and cost control

H_1: Difficulty in cost reduction and cost control of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in cost reduction and cost control of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

4.3.4.4 Difficulty in Managing the Construction Time

A) Delays in the procurement process

Table 80: Delays in the procurement

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Delays in the procurement	Senior BIM Non User	32	31.31	1002.00
	Senior BIM User	17	13.12	223.00
	Total	49		

Test Statistics[a]

	Delays in the procurement
Mann-Whitney U	70.000
Wilcoxon W	223.000
Z	-4.556
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding delays in procurement

H_1: Delays in procurement of Senior BIM non users are statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in procurement of Senior BIM non users are statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

B) Delays in producing shop drawings

Table 81: Delays in producing shopdrawing

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Delays in producing shopdrawing	Senior BIM Non User	32	30.77	984.50
	Senior BIM User	17	14.15	240.50
	Total	49		

Test Statistics[a]

	Delays in producing shopdrawing
Mann-Whitney U	87.500
Wilcoxon W	240.500
Z	-4.040
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding delays in producing shop drawings

H_1: Delays in producing shop drawings of Senior BIM non users are statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Senior BIM users and Senior BIM non users, delays in producing shop drawings at a 95% level of confidence.

C) Improper resource allocation

Table 82: Improper resource allocation

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Improper resource allocation	Senior BIM Non User	32	30.97	991.00
	Senior BIM User	17	13.76	234.00
	Total	49		

Test Statistics[a]

	Improper resource allocation
Mann-Whitney U	81.000
Wilcoxon W	234.000
Z	-4.296
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding improper resource allocation

H_1: Improper resource allocation of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.

Therefore, we conclude that improper resource allocation of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

D) Delays in client approvals

Table 83: Delays in client approvals

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Delays in client approvals	Senior BIM Non User	32	30.08	962.50
	Senior BIM User	17	15.44	262.50
	Total	49		

Test Statistics[a]

	Delays in client approvals
Mann-Whitney U	109.500
Wilcoxon W	262.500
Z	-3.601
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding delays in client approvals

H_1: Delays in client approvals of Senior BIM non users are statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in client approvals of Senior BIM non users are statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

E) Delays in handling suppliers

Table 84: Delays in handling suppliers

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Delays in handling suppliers	Senior BIM Non User	32	31.69	1014.00
	Senior BIM User	17	12.41	211.00
	Total	49		

Test Statistics[a]

	Delays in handling suppliers
Mann-Whitney U	58.000
Wilcoxon W	211.000
Z	-4.802
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding delays in handling suppliers

H_1: Delays in handling suppliers of Senior BIM non users are statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in handling suppliers of Senior BIM non users are statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

Summary of Difficulty in Managing the Construction Time

Table 85: Managing Construction Time

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
ManagingConstructionTime	Senior BIM Non User	32	30.66	981.00
	Senior BIM User	17	14.35	244.00
	Total	49		

Test Statistics[a]

	ManagingConstructionTime
Mann-Whitney U	91.000
Wilcoxon W	244.000
Z	-4.241
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding difficulty in managing the construction time

H_1: Difficulty in managing the construction time of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in managing the construction time of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

Overall Summary - The Impact of BIM Usage to Seniors on Major Issues in Construction Industry

Table 86: MajorConstructionIssues

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
MajorConstructionIssues	Senior BIM Non User	32	32.38	1036.00
	Senior BIM User	17	11.12	189.00
	Total	49		

Test Statistics[a]

	MajorConstructionIssues
Mann-Whitney U	36.000
Wilcoxon W	189.000
Z	-5.223
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Senior BIM users and Senior BIM non users, regarding encountering major issues in construction industry

H_1: Encountering major issues in construction industry of Senior BIM non users is statistically significantly higher than the same of Senior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.

Therefore, we conclude that encountering major issues in construction industry of Senior BIM non users is statistically significantly higher than the same of Senior BIM users at a 95% level of confidence.

4.3.5 The Impact of BIM Usage to Juniors on Major Issues in Construction Industry

4.3.5.1 Difficulty in Design and Site Coordination

A) Less effectiveness in sharing required information

Table 87: Less effectiveness in sharing required information

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Less effectiveness in sharing required information	Junior BIM Non User	52	42.34	2201.50
	Junior BIM User	21	23.79	499.50
	Total	73		

Test Statistics[a]

	Less effectiveness in sharing required information
Mann-Whitney U	268.500
Wilcoxon W	499.500
Z	-3.695
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding less effectiveness in sharing required information

H_1: Less effectiveness in sharing required information of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that less effectiveness in sharing required information of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

B) Delays in response to request for information (RFI)

Table 88: Delays in response to RFI

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Delays in response to RFI	Junior BIM Non User	52	44.94	2337.00
	Junior BIM User	21	17.33	364.00
	Total	73		

Test Statistics[a]

	Delays in response to RFI
Mann-Whitney U	133.000
Wilcoxon W	364.000
Z	-5.843
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding delays in response to request for information (RFI)

H_1: Delays in response to request for information (RFI) of Junior BIM non users are statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in response to request for information (RFI) of Junior BIM non users are statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

C) Difficulty in understanding of drawings and visualization

Table 89: Difficulty in understanding of drawings & visualization

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Difficulty in understanding of drawings & visualization	Junior BIM Non User	52	43.24	2248.50
	Junior BIM User	21	21.55	452.50
	Total	73		

Test Statistics[a]

	Difficulty in understanding of drawings & visualization
Mann-Whitney U	221.500
Wilcoxon W	452.500
Z	-4.222
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding difficulty in understanding of drawings and visualization

H_1: Difficulty in understanding of drawings and visualization of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in understanding of drawings and visualization of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

D) Failures in clash detection

Table 90: Failures in clash detection

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Failures in clash detection	Junior BIM Non User	52	42.52	2211.00
	Junior BIM User	21	23.33	490.00
	Total	73		

Test Statistics[a]

	Failures in clash detection
Mann-Whitney U	259.000
Wilcoxon W	490.000
Z	-3.819
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding failures in clash detection

H_1: Failures in clash detection of Junior BIM non users are statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that failures in clash detection of Junior BIM non users are statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

<u>Summary of Difficulty in Design and Site Coordination</u>

Table 91: Design and Site Coordination

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
DesignAndSiteCoordination	Junior BIM Non User	52	43.04	2238.00
	Junior BIM User	21	22.05	463.00
	Total	73		

Test Statistics[a]

	DesignAndSite Coordination
Mann-Whitney U	232.000
Wilcoxon W	463.000
Z	-4.059
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding difficulty in design and site coordination

H_1: Difficulty in design and site coordination of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in design and site coordination of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

4.3.5.2 Difficulty in Planning and Scheduling

A) Insufficient information about project risks

Table 92: Insufficient information about project risks

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Insufficient information about project risks	Junior BIM Non User	52	42.25	2197.00
	Junior BIM User	21	24.00	504.00
	Total	73		

Test Statistics[a]

	Insufficient information about project risks
Mann-Whitney U	273.000
Wilcoxon W	504.000
Z	-3.762
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding insufficient information about project risks

H_1: Insufficient information about project risks of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that insufficient information about project risks of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

B) Limited or conflicted information of project

Table 93: Limited or conflicted information of project

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Limited or conflicted information of project	Junior BIM Non User	52	38.81	2018.00
	Junior BIM User	21	32.52	683.00
	Total	73		

Test Statistics[a]

	Limited or conflicted information of project
Mann-Whitney U	452.000
Wilcoxon W	683.000
Z	-1.303
Asymp. Sig. (2-tailed)	.193

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding limited or conflicted information of project

H_1: Limited or conflicted information of project of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.193 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding limited or conflicted information of project at a 95% level of confidence.

C) Confusion in construction sequence

Table 94: Confusion in construction sequence

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Confusion in construction sequence	Junior BIM Non User	52	43.66	2270.50
	Junior BIM User	21	20.50	430.50
	Total	73		

Test Statistics[a]

	Confusion in construction sequence
Mann-Whitney U	199.500
Wilcoxon W	430.500
Z	-4.538
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding confusion in construction sequence

H_1: Confusion in construction sequence of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that confusion in construction sequence of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

D) Difficulty in handling of revised designs

Table 95: Difficulty in handling of revised designs

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Difficulty in handling of revised designs	Junior BIM Non User	52	42.03	2185.50
	Junior BIM User	21	24.55	515.50
	Total	73		

Test Statistics[a]

	Difficulty in handling of revised designs
Mann-Whitney U	284.500
Wilcoxon W	515.500
Z	-3.382
Asymp. Sig. (2-tailed)	.001

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding difficulty in handling of revised designs

H_1: Difficulty in handling of revised designs of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.001 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in handling of revised designs of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

E) Limited planning tools and resources

Table 96: Limited planning tools and resources

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Limited planning tools & resources	Junior BIM Non User	52	38.65	2010.00
	Junior BIM User	21	32.90	691.00
	Total	73		

Test Statistics[a]

	Limited planning tools & resources
Mann-Whitney U	460.000
Wilcoxon W	691.000
Z	-1.191
Asymp. Sig. (2-tailed)	.234

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding limited planning tools and resources

H_1: Limited planning tools and resources of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.234 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding limited planning tools and resources at a 95% level of confidence.

Summary of Difficulty in Planning and Scheduling

Table 97: Planning and Scheduling

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
PlanningAndScheduling	Junior BIM Non User	52	41.04	2134.00
	Junior BIM User	21	27.00	567.00
	Total	73		

Test Statistics[a]

	PlanningAndScheduling
Mann-Whitney U	336.000
Wilcoxon W	567.000
Z	-3.055
Asymp. Sig. (2-tailed)	.002

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding difficulty in planning and scheduling

H_1: Difficulty in planning and scheduling of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.002 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in planning and scheduling of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

4.3.5.3 Difficulty in Cost Reduction and Cost Control

A) Improper planning of manpower

Table 98: Improper planning of manpower

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Improper planning of manpower	Junior BIM Non User	52	39.32	2044.50
	Junior BIM User	21	31.26	656.50
	Total	73		

Test Statistics[a]

	Improper planning of manpower
Mann-Whitney U	425.500
Wilcoxon W	656.500
Z	-1.671
Asymp. Sig. (2-tailed)	.095

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding improper planning of manpower

H_1: Improper planning of manpower of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.095 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding improper planning of manpower at a 95% level of confidence.

B) Improper logistic planning

Table 99: Improper logistic planning

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Improper logistic planning	Junior BIM Non User	52	39.00	2028.00
	Junior BIM User	21	32.05	673.00
	Total	73		

Test Statistics[a]

	Improper logistic planning
Mann-Whitney U	442.000
Wilcoxon W	673.000
Z	-1.505
Asymp. Sig. (2-tailed)	.132

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding improper logistic planning

H_1: Improper logistic planning of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.132 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding improper logistic planning at a 95% level of confidence.

C) Procurement management problems

Table 100: Procurement management problems

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Procurement management problems	Junior BIM Non User	52	41.65	2166.00
	Junior BIM User	21	25.48	535.00
	Total	73		

Test Statistics[a]

	Procurement management problems
Mann-Whitney U	304.000
Wilcoxon W	535.000
Z	-3.238
Asymp. Sig. (2-tailed)	.001

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding procurement management problems

H_1: Procurement management problems of Junior BIM non users are statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.001 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that procurement management problems of Junior BIM non users are statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

D) Poor coordination among different department

Table 101: Poor coordination among different department

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Poor coordination among different department	Junior BIM Non User	52	42.08	2188.00
	Junior BIM User	21	24.43	513.00
	Total	73		

Test Statistics[a]

	Poor coordination among different department
Mann-Whitney U	282.000
Wilcoxon W	513.000
Z	-3.394
Asymp. Sig. (2-tailed)	.001

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding poor coordination among different departments

H_1: Poor coordination among different departments of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.001 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that poor coordination among different departments of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

E) Hard to handle sudden changes

Table 102: Hard to handle sudden changes

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Hard to handle sudden changes	Junior BIM Non User	52	43.20	2246.50
	Junior BIM User	21	21.64	454.50
	Total	73		

Test Statistics[a]

	Hard to handle sudden changes
Mann-Whitney U	223.500
Wilcoxon W	454.500
Z	-4.406
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding hard to handle sudden changes

H_1: Hard to handle sudden changes of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that hard to handle sudden changes of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

F) Failures in clash detection

Table 103: Failures in clash detection

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Failures in clash detection	Junior BIM Non User	52	43.35	2254.00
	Junior BIM User	21	21.29	447.00
	Total	73		

Test Statistics[a]

	Failures in clash detection
Mann-Whitney U	216.000
Wilcoxon W	447.000
Z	-4.444
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding failures in clash detection

H_1: Failures in clash detection of Junior BIM non users are statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that failures in clash detection of Junior BIM non users are statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

G) Interruptions of stakeholders

Table 104: Interuptions of stakeholders

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Interuptions of stakeholders	Junior BIM Non User	52	39.21	2039.00
	Junior BIM User	21	31.52	662.00
	Total	73		

Test Statistics[a]

	Interuptions of stakeholders
Mann-Whitney U	431.000
Wilcoxon W	662.000
Z	-1.606
Asymp. Sig. (2-tailed)	.108

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding interruptions of stakeholders

H_1: Interruptions of stakeholders of Junior BIM non users are statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.108 is greater than $\alpha = 0.05$, we do not have enough evidence to reject H_o at 95% level of confidence.
Therefore, we conclude that there is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding interruptions of stakeholders at a 95% level of confidence.

Summary of Difficulty in Cost Reduction and Cost Control

Table 105: Cost Reduction and Cost Control

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
CostReductionAndCostControl	Junior BIM Non User	52	41.63	2164.50
	Junior BIM User	21	25.55	536.50
	Total	73		

Test Statistics[a]

	CostReductionAndCostControl
Mann-Whitney U	305.500
Wilcoxon W	536.500
Z	-3.839
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding difficulty in cost reduction and cost control

H_1: Difficulty in cost reduction and cost control of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in cost reduction and cost control of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

4.3.5.4 Difficulty in Managing the Construction Time

A) Delays in the procurement process

Table 106: Delays in the procurement

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Delays in the procurement	Junior BIM Non User	52	41.09	2136.50
	Junior BIM User	21	26.88	564.50
	Total	73		

Test Statistics[a]

	Delays in the procurement
Mann-Whitney U	333.500
Wilcoxon W	564.500
Z	-3.127
Asymp. Sig. (2-tailed)	.002

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding delays in procurement

H_1: Delays in procurement of Junior BIM non users are statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.002 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in procurement of Junior BIM non users are statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

B) Delays in producing shop drawings

Table 107: Delays in producing shopdrawing

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Delays in producing shopdrawing	Junior BIM Non User	52	40.69	2116.00
	Junior BIM User	21	27.86	585.00
	Total	73		

Test Statistics[a]

	Delays in producing shopdrawing
Mann-Whitney U	354.000
Wilcoxon W	585.000
Z	-2.646
Asymp. Sig. (2-tailed)	.008

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding delays in producing shop drawings

H_1: Delays in producing shop drawings of Junior BIM non users are statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.008 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in producing shop drawings of Junior BIM non users are statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

C) Improper resource allocation

Table 108: Improper resource allocation

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Improper resource allocation	Junior BIM Non User	52	43.66	2270.50
	Junior BIM User	21	20.50	430.50
	Total	73		

Test Statistics[a]

	Improper resource allocation
Mann-Whitney U	199.500
Wilcoxon W	430.500
Z	-4.667
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding improper resource allocation

H_1: Improper resource allocation of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that improper resource allocation of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

D) Delays in client approvals

Table 109: Delays in client approvals

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Delays in client approvals	Junior BIM Non User	52	42.90	2231.00
	Junior BIM User	21	22.38	470.00
	Total	73		

Test Statistics[a]

	Delays in client approvals
Mann-Whitney U	239.000
Wilcoxon W	470.000
Z	-4.025
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding delays in client approvals

H_1: Delays in client approvals of Junior BIM non users are statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in client approvals of Junior BIM non users are statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

E) Delays in handling suppliers

Table 110: Delays in handling suppliers

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
Delays in handling suppliers	Junior BIM Non User	52	42.56	2213.00
	Junior BIM User	21	23.24	488.00
	Total	73		

Test Statistics[a]

	Delays in handling suppliers
Mann-Whitney U	257.000
Wilcoxon W	488.000
Z	-4.091
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding delays in handling suppliers

H_1: Delays in handling suppliers of Junior BIM non users are statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that delays in handling suppliers of Junior BIM non users are statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

Summary of Difficulty in Managing the Construction Time

Table 111: Managing Construction Time

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
ManagingConstructionTime	Junior BIM Non User	52	43.02	2237.00
	Junior BIM User	21	22.10	464.00
	Total	73		

Test Statistics[a]

	ManagingConstructionTime
Mann-Whitney U	233.000
Wilcoxon W	464.000
Z	-4.586
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding difficulty in managing the construction time

H_1: Difficulty in managing the construction time of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that difficulty in managing the construction time of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

<u>Overall Summary - The Impact of BIM Usage to Juniors on Major Issues in Construction Industry</u>

Table 112: Major Construction Issues

Ranks

	ExperienceAndBIMUsage	N	Mean Rank	Sum of Ranks
MajorConstructionIssues	Junior BIM Non User	52	43.52	2263.00
	Junior BIM User	21	20.86	438.00
	Total	73		

Test Statistics[a]

	MajorConstructionIssues
Mann-Whitney U	207.000
Wilcoxon W	438.000
Z	-4.656
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: ExperienceAndBIMUsage

H_o: There is no statistically significant difference between Junior BIM users and Junior BIM non users, regarding encountering major issues in construction industry

H_1: Encountering major issues in construction industry of Junior BIM non users is statistically significantly higher than the same of Junior BIM users

Since the Mann-Whitney U test U-Statistic = 0.000 is lesser than $\alpha = 0.05$, we reject H_o at 95% level of confidence.
Therefore, we conclude that encountering major issues in construction industry of Junior BIM non users is statistically significantly higher than the same of Junior BIM users at a 95% level of confidence.

4.4 Analysis of the Impact of Barriers in BIM Implementation using Relative Important Index Method

Barriers for BIM implementation can be categorized in to two as internal and external barriers. Main internal and external barriers were identified through the literature survey and those were shortlisted to the questionnaire survey. The responses from BIM users and BIM non users reflect their own point of view regarding these barriers.

4.4.1 The Impact of Internal Barriers in BIM Implementation

4.4.1.1 General

Table 113: Impact of Internal Barriers in BIM Implementation

	Current practices are serving good	Unawareness of BIM benefits and use	Computer software & hardware limitation	Heavy budget requirement	Inertia of people for training
	291	431	382	404	397
	0.60	0.88	0.78	0.83	0.81
Rank	**5**	**1**	**4**	**2**	**3**

4.4.1.2 BIM Users' perspective

Table 114: Impact of Internal Barriers in BIM Implementation

	Current practices are serving good	Unawareness of BIM benefits and use	Computer software & hardware limitation	Heavy budget requirement	Inertia of people for training
	79	127	118	126	127
	0.52	0.84	0.78	0.83	0.84
Rank	**5**	**1**	**4**	**3**	**1**

4.4.1.3 BIM Non Users' perspective

Table 115: Impact of Internal Barriers in BIM Implementation

	Current practices are serving good	Unawareness of BIM benefits and use	Computer software & hardware limitation	Heavy budget requirement	Inertia of people for training
	212	304	264	278	270
	0.63	0.90	0.79	0.83	0.80
Rank	**5**	**1**	**4**	**2**	**3**

4.4.2 The Impact of External Barriers in BIM Implementation

4.4.2.1 General

Table 116: Impact of External Barriers in BIM Implementation

	Limited adoption in local market	Lack of knowledge & Experienced client	Legal/Contractual concerns	Concern about lack of company standards
	407	435	315	337
	0.83	0.89	0.65	0.69
Rank	**2**	**1**	**4**	**3**

4.4.2.2 BIM Users' perspective

Table 117: Impact of External Barriers in BIM Implementation

	Limited adoption in local market	Lack of knowledge & Experienced client	Legal/Contractual concerns	Concern about lack of company standards
	128	138	87	99
	0.84	0.91	0.57	0.65
Rank	**2**	**1**	**4**	**3**

4.4.2.3 BIM Non Users' perspective

Table 118: Impact of External Barriers in BIM Implementation

	Limited adoption in local market	Lack of knowledge & Experienced client	Legal/Contractual concerns	Concern about lack of company standards
	279	297	228	238
	0.83	0.88	0.68	0.71
Rank	**2**	**1**	**4**	**3**

4.5 Discussion on the Results of the Analysis

4.5.1 Respondent Background

122 number of responses were received for the questionnaire survey from mainly from engineers and architects, including project managers and construction managers. Most of them are involved in top tier projects mentioned in Sri Lankan construction industry.

The scope of the respondents was broadened from below 5 year experience to above 20 year experience. They were divided in to two groups, 60% possessing below 10 year experience and 40% possessing above 10 year experience. These two groups were named as juniors and seniors respectively for the convenience of the study.

Respondents' awareness level on Building Information Modelling tested via the questionnaire was from none to very high level. For the convenience of the study, the respondents were divided in to two groups as BIM non users (None and Low) 69% and BIM users (Medium, High and Very High) 31%. This 31% has involved in one or more BIM projects and experienced it. Though, about 69% of respondents claim that they have nix or low level of awareness on BIM, 53% of them even have heard about this.

Considering both the BIM usage and experience level, the respondents were further categorized as 43% of junior BIM non users, 17% of junior BIM users, 26% of senior BIM non users and 14% of senior BIM users, to facilitate the study.

All the respondents have at least qualified with Certificate level or Diploma and 56% of them have qualified with Bachelor's degree and 43% possessed a Post Graduate Diploma or a Degree.

Deeply analyzing the responses, it is noted that 89% of the respondents are involved in building project and responded the questionnaire with that experience.

Majority of the respondents, 57% are playing their role in the project as the consultant and 32% and 11% are involved the projects as the contractor and the client respectively.

Considering all the responses, the client type of the projects consider for the study can be categorized as government, private and foreign with percentages of 48%, 24% and 28%. Nearly half of the respondents are from the projects implemented by the government. This can be further categorized as the projects using BIM and the projects not using BIM to obtain an idea on the clients who currently prefer BIM in their projects. It shows that most of the projects operated with BIM technology are implemented by foreign and private firms where there percentages are 47% and 37% respectively.

It is highlighted that, though the highest number of respondents are from government projects, the projects with BIM technology are highly facilitated by foreign and private organizations more than government firms.

The value of the projects involved by the respondents are expands in a broad area from less than 5 Billion projects to more than 20 Billion projects. The analysis was carried out targeting BIM implemented projects and generally there is an equal distribution in all considered project value ranges.

4.5.2 The Impact of Identified Factors on Major Construction Issues

Table 119: The Impact of Identified Factors on Major Construction Issues

Major Construction Issues Encountered	BIM Usage		Experience Level		BIM Usage & Seniors		BIM Usage & Juniors	
	BIM User	BIM Non User	Seniors (Above 10 years)	Juniors (Below 10 years)	Senior BIM User	Senior BIM Non User	Junior BIM User	Junior BIM Non User
Difficulty in Design and Site Coordination	-	✓	-	-	-	✓	-	✓
A) Less effectiveness in sharing required information	-	✓	-	-	-	✓	-	✓
B) Delays in response to request for information (RFI)	-	✓	-	-	-	✓	-	✓
C) Difficulty in understanding of drawings and visualization	-	✓	-	-	-	✓	-	✓

D) Failures in clash detection	-	✓	-	-	-	✓	-	✓
Difficulty in Planning and Scheduling	-	✓	-	-	-	✓	-	✓
A) Insufficient information about project risks	-	✓	-	-	-	✓	-	✓
B) Limited or conflicted information of project	-	✓	-	-	-	✓	-	-
C) Confusion in construction sequence	-	✓	-	-	-	✓	-	✓
D) Difficulty in handling of revised designs	-	✓	-	-	-	✓	-	✓
E) Limited planning tools and resources	-	✓	-	-	-	✓	-	-
Difficulty in Cost Reduction and Cost Control	-	✓	-	-	-	✓	-	✓
A) Improper planning of manpower	-	✓	-	✓	-	✓	-	-
B) Improper logistic planning	-	✓	-	✓	-	✓	-	-
C) Procurement management problems	-	✓	-	-	-	✓	-	✓
D) Poor coordination among different department	-	✓	-	✓	-	✓	-	✓
E) Hard to handle sudden changes	-	✓	-	-	-	✓	-	✓
F) Failures in clash detection	-	✓	-	-	-	✓	-	✓
G) Interruptions of stakeholders	-	✓	-	✓	-	✓	-	-

Difficulty in Managing the Construction Time	-	✓	-	-	-	✓	-	✓
A) Delays in the procurement process	-	✓	-	-	-	✓	-	✓
B) Delays in producing shop drawings	-	✓	-	-	-	✓	-	✓
C) Improper resource allocation	-	✓	-	✓	-	✓	-	✓
D) Delays in client approvals	-	✓	-	-	-	✓	-	✓
E) Delays in handling suppliers	-	✓	-	-	-	✓	-	✓
OVERALL INMPACT ON MAJOR CONSTRUCTION ISSUES ENCOUNTERED	-	✓	-	-	-	✓	-	✓

4.5.3 The Impact of Barriers in BIM Implementation

Generally, it is identified that the unawareness of BIM benefits and use, heavy budget requirement, inertia of people for training, computer software and hardware limitation and current practices are serving good as the order for internal barriers from the highest impact to the lowest. According to BIM users, both unawareness of BIM benefits and use and inertia of people for training have the highest significant level while the heavy budget requirement comes to the next. BIM non users' result of the analysis also follow the same order as identified in general analysis. All parties believe that the highest internal barrier as the unawareness of BIM benefits and use and the least internal barrier as the current practices are serving good.

When external barriers are taken in to account in general, lack of knowledge and experienced client, limited adoption in local market, concern about lack of company standards and legal/contractual concerns were identified as the significance descending order. Both BIM users and BIM non users believe in the same way that lack of knowledge and experienced client have the highest significant level while the legal/contractual concerns comes to the last.

4.6 Summary of Data Collection and Analysis

This chapter presents the data collection and analysis carried out in this research study. Firstly, respondent background was analysed based on experience level, BIM awareness, academic qualification, type of the project, role of the project, client of the project and value of the project etc. Secondly, the nature of the collected data was investigated and the analysis of the impact of identified factors on major issues in construction industry was carried out using hypothesis testing. The identified factors are BIM usage and experience level individually and both together. Moreover, relative important index method was applied to explore the impact of internal barriers and external barriers to implement BIM and were analysed based on common views and the points of view of BIM users and BIM non users. Finally, the summary of analysed data was presented at the end of this chapter as a discussion on the outcome of the analysis.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This research study explored the effectiveness of building information modeling in Sri Lanka construction industry. It was mainly focused on the impact of identified factors such as experience level and BIM awareness in encountering major construction issues in construction industry. Further, the influence of the same factors on the barriers in BIM implementation was also analysed. The conclusions made throughout the study were outlined below.

- Building Information Modeling is generally understood as a platform which provides a three dimensional digital representation of the building system with a database including consistent building data and information. This spreads far beyond the 2D line work in a CAD drawing and can be developed up to 7D. 3D to 7D represent the model, the scheduling, estimating, sustainability and facility management respectively. The BIM model simulates the building and its behaviour throughout the building life cycle, in a virtual environment, way before the beginning of the actual construction.
- Even though more and more researches can be found relating to BIM in construction industry in worldwide, few researches have being carried out with the purpose of identifying the impact of BIM in the construction industry. Since this is a new phenomenon to Sri Lanka, limited number of researches have originated supporting this topic in the context of Sri Lanka. It is tried to derive required information referring to the related researches carried out throughout the world. The vital area of research is discovering the effectiveness of BIM in the perspective of Sri Lankan construction industry before the implementation of it. Hence, the study was mainly focused on Sri Lankan building construction industry where BIM application is considerably implemented at the present. Moreover, the awareness of this application is near to the ground in developing countries like Sri Lanka. Therefore, there was a considerably small community who have practised BIM to distribute the questionnaire survey. These were identified as the limitations in carrying out this study.
- According to literature review chapter, a comprehensive study was carried out focusing the fields of BIM definition, development, benefits and further barriers and recommendations in BIM implementation to screen vital facts to streamline the

proposed study. Building Information Modeling is digital representation of physical and functional characteristics of a building creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition. This concept originated from 1970 and gradually evolved to a major tool in construction industry with its incredible benefits. Most of the projects are not yet privileged up to that maximum level in developing countries like Sri Lanka. As per the literature, major issues identified in construction industry can be divided mainly in to design and site coordination, planning and scheduling, cost reduction and cost control and managing the construction time. Moreover, internal and external barriers were identified with its significance level to implement BIM. In addition to that the significance of factors, BIM awareness level and work experience were investigated.

- The research methodology consists of a questionnaire survey followed by a pilot survey as the main approach to collect data. Additionally, literature review, expert interviews and industry surveys were conducted. According to the sample behaviour and aim of the study, analysis methods were selected. Hypothesis testing was used to find out the impact of BIM usage and experience level individually as well as collectively on major issues in construction industry. The distribution was observed to be not normally distributed and Mann Whitney U test which is a nonparametric test was selected to test the null hypothesis. Relative important index method was applied to rank the significance of internal and external barriers due to the impact of usage of Building Information Modeling and experience level.
- As presented in the fourth chapter, the data collection and analysis were carried out. Firstly, respondent background was analysed based on experience level, BIM awareness, academic qualification, type of the project, role of the project, client of the project and value of the project etc. 122 number of responses were received for the questionnaire survey from mainly from engineers and architects, including project managers and construction managers. Most of them are involved in top tier projects mentioned in Sri Lankan construction industry.
    - The scope of the respondents was broadened from below 5 year experience to above 20 year experience. They were divided in to two groups, 60% possessing below 10 year experience and 40% possessing above 10 year experience. These two groups were named as juniors and seniors respectively for the convenience of the study.

- Respondents' awareness level on Building Information Modelling tested via the questionnaire was from none to very high level. For the convenience of the study, the respondents were divided in to two groups as BIM non users (None and Low) 69% and BIM users (Medium, High and Very High) 31%. This 31% has involved in one or more BIM projects and experienced it. Though, about 69% of respondents claim that they have nix or low level of awareness on BIM, 53% of them even have heard about this. It reflects the present BIM adoption level in construction industry of Sri Lanka. Those respondent have very high knowledge of BIM probably have working experience on international project with international consultant and designers.
- Considering both the BIM usage and experience level, the respondents were further categorized as 43% of junior BIM non users, 17% of junior BIM users, 26% of senior BIM non users and 14% of senior BIM users, to facilitate the study.
- All the respondents have at least qualified with Certificate level or Diploma and 56% of them have qualified with Bachelor's degree and 43% possessed a Post Graduate Diploma or a Degree. This reflects more about the educated background of the respondents.
- Deeply analyzing the responses, it is noted that 89% of the respondents are involved in building project and responded the questionnaire with that experience. Therefore, the study can be drove towards the building industry in Sri Lanka straightforwardly.
- Majority of the respondents, 57% are playing their role in the project as the consultant and 32% and 11% are involved the projects as the contractor and the client respectively.
- Considering all the responses, the client type of the projects consider for the study can be categorized as government, private and foreign with percentages of 48%, 24% and 28%. Nearly half of the respondents are from the projects implemented by the government. This can be further categorized as the projects using BIM and the projects not using BIM to obtain an idea on the clients who currently prefer BIM in their projects. It shows that most of the projects operated with BIM technology are implemented by foreign and private firms where there percentages are 47% and 37% respectively.

    - It is highlighted that, though the highest number of respondents are from government projects, the projects with BIM technology are highly facilitated by foreign and private organizations more than government firms.
    - The value of the projects involved by the respondents are expands in a broad area from less than 5 Billion projects to more than 20 Billion projects. The analysis was carried out targeting BIM implemented projects and generally there is an equal distribution in all considered project value ranges. This result gives an idea that there is no significant impact of project value on BIM implementation. The result of the interviews also confirmed this factor concluding that project with any cost, low, medium or high can have benefits from using BIM in those.
- After analysing of respondents' background, the nature of the collected data was investigated and the analysis of the impact of identified factors on major issues in construction industry was carried out using hypothesis testing as illustrated in chapter 4. The identified factors are BIM usage and experience level individually and both together. Following conclusions were made at this analysis considering a 95% level of confidence.
    - Difficulty in design and site coordination, planning and scheduling, cost reduction and cost control and managing the construction time of BIM non users are statistically significantly higher than the same of BIM users. Hence, encountering major issues in construction industry of BIM non users is statistically significantly higher than the same of BIM users.
    - There is no statistically significant difference between Seniors and Juniors, regarding difficulty in design and site coordination, planning and scheduling, cost reduction and cost control and managing the construction time. Hence, there is no statistically significant difference between Seniors and Juniors, regarding encountering major issues in construction industry. However, theoretically it feels that there should be a difference between them in handling these issues due to the more practice of Seniors instead of the same theoretical knowledge. The reason may be the study considered respondents below 10 year experience as Juniors and above 10 years as Seniors. Nevertheless, the overall conclusion is in that manner, detail analysis showed that improper manpower planning, improper logistic planning and difficulty in coordination among different departments, interruptions of stakeholders and improper resource allocation are significantly

higher for Juniors than Seniors. It can be concluded that practical experience always highly assists the experienced people in handling situations like planning and communication.

- The difficulty in design and site coordination of Senior BIM non users is statistically significantly higher than the same of Senior BIM users. The difficulty in planning and scheduling cost reduction and cost control and managing the construction time also demonstrate the same behavior. Hence, encountering major issues in construction industry of Senior BIM non users is statistically significantly higher than the same of Senior BIM users.
- The difficulty in design and site coordination, planning and scheduling, cost reduction and cost control, managing the construction time of Junior BIM non users are statistically significantly higher than the same of Junior BIM users. Hence, encountering major issues in construction industry of Junior BIM non users is statistically significantly higher than the same of Junior BIM users.

- Analysing the above findings, it was observed that BIM usage avoid encountering major issues in construction industry to a considerable level. The experience level do not show such significant difference in handling these issues. This is further proved by the extended analysis carried out categorizing seniors and juniors with their BIM experience. In both senior category and junior category the result was BIM non users encounter major issues in construction industry than BIM users. Hence, it can be concluded that BIM usage minimizes construction issues and facilitates the smooth flow in construction work independently from the work experience.
- Moreover, relative important index method was applied to explore the impact of internal barriers and external barriers to implement BIM and were analysed based on common views and the points of view of BIM users and BIM non users.
- Generally, it is identified that the unawareness of BIM benefits and use, heavy budget requirement, inertia of people for training, computer software and hardware limitation and current practices are serving good as the order for internal barriers from the highest impact to the lowest. According to BIM users, both unawareness of BIM benefits and use and inertia of people for training have the highest significant level while the heavy budget requirement comes to the next. BIM non users' result of the analysis also follow the same order as identified in general analysis. All parties believe that the highest internal barrier as the unawareness of BIM benefits and use

and the least internal barrier as the current practices are serving good. This further implied that almost all of them are not satisfied with the prevailing systems. Another important point to highlight is that, though BIM non users think that heavy budget is a barrier to implement BIM, BIM users say that it is inertia of people which comes before the heavy budget problem. They indicates that inertia of people has the same significance as unawareness of BIM benefits and use which is a miserable situation.

- When external barriers are taken in to account in general, lack of knowledge and experienced client, limited adoption in local market, concern about lack of company standards and legal/contractual concerns were identified as the significance descending order. Both BIM users and BIM non users believe in the same way that lack of knowledge and experienced client have the highest significant level while the legal/contractual concerns comes to the last. Most of the industrial surveys claimed that the lack of government support is an immense reason to low adoption of BIM in the country. Due to less knowledge sharing among iconic projects in the country, the experiences of BIM in those projects are not revealed. In addition, the demand for commonly use type drawings (AutoCAD) by the clients may discourage Revit users/firms which transforms them again to the conventional methods at the end of the day.

5.2 Recommendations

Determination of recommendations for proper BIM implementation of the country is the last but the most important objective of this research. The following recommendations were made based on the conclusions stated in section 5.1.

- It was highlighted that the awareness of BIM is very much near to the ground in Sri Lanka, throughout the study. Nevertheless Sri Lanka is a developing country, there is a great responsibility for all the higher and lower authorities to familiarize this technology in the local construction industry. The support of the government in this context is highly valued. BIM has become a habit in construction projects take place in developed countries like China, Singapore etc. Technology transfer from such countries should be facilitated and encouraged. Since most of the iconic projects are run in the country has this international exposure, this can be carried out easily. Allowing local companies to make joint ventures with international companies to implement the projects enables the penetration of these technologies to our country. Those respondent have very high knowledge of BIM probably have worked in experience on international project with international consultant and designers. On the other hand, there is no proper methodology to transfer or expose advanced technologies to our Engineers in majority of top tier projects run by international contractors here which should be eliminated even by engaging Government of Sri Lanka.
- It is recommended to apply BIM in to a project in its high perform level with a team consists of professionals, foreign firms and local firms to conduct as a pilot project. The lessons learnt and experience of it will be a great example to adopt BIM in their projects. It will further perform as a guideline to future projects and will be sharpened with other BIM involved projects.
- The universities and other engineering institutions also can contribute enormously to spread this concept to fresh engineers as well as experienced engineers through their undergraduate courses, post graduate courses and researches. Universities have taken steps on this already as per the collected information. Public lectures, seminars and workshops can be arranged to make the construction personnel aware on these latest technologies. Local clients, consultants and contractors can make it complementary for their projects which helps to bring the local construction industry

to a new level. In this manner, the awareness on BIM in the local context can be systematically improved.

- Though most of the respondents using BIM are from building industry, it can be recommended for other type of projects such as road projects which make the handling and coordination of the project easier. Not only a one party, but also every stakeholder are beneficial in a unique way with this technology. Therefore, it can be recommended to the client, consultant and the contractor and all of their coordination finally creates a great output. Majority of the clients of the BIM using projects are private and local firms. Those projects are seem to be successful and well organized than government projects. Hence, the state clients are suggested to implement this technology to feel the difference while adoring its privileges. Through the practise, one can specifically verify whether this technology is appropriate or not.
- The study reveals that even projects with small scale has implemented BIM and there is no significant impact of project value on BIM implementation. The result of the interviews also confirmed this factor concluding that project with any cost, low, medium or high can have benefits from using BIM in those. However, it is recommended to carry out a detailed cost benefit analysis before purchasing BIM software and required computer hardware if it is only to run a small project since the capital budget is considerably high. It is much-admired if the priority is given to implement it in large scale projects and in the mean time for small scale projects.
- The study indicates that BIM usage typically avoids encountering major issues in construction industry arisen due to difficulties in design and site coordination, planning and scheduling, cost reduction and cost control and managing the construction time. In addition, it indicates that the experience level do not show any significant impact on these major construction issues in overall consideration . However, it is highlighted that the practical experience gained with time and with more projects highly supports handling situations like planning and communication.
- There is a significantly higher difficulty in handling major construction issues for BIM non users when both BIM usage and experience level considered together. Therefore, it can be mentioned that BIM aids to avoid difficulty in construction work independently to the experience level. It never underestimates the importance of experience to a work. With the practice and experience, one can enhance any work adding a great value to that. Overall BIM technology can be recommended to a

project to minimize construction issues and facilitate the smooth flow in construction work.

- Generally, unawareness of BIM benefits and use, heavy budget requirement, inertia of people for training, computer software and hardware limitation and current practices are serving good are the order for internal barriers from the highest impact to the lowest. Practically, it is found that inertia of people for training have the equal impact to unawareness of BIM benefits and both of those have higher impact in BIM implementation than heavy budget requirement. This will assist to insist the top management of companies who hesitate to invest BIM considering it as an overpriced option. Further, it is recommended to carry out people changing programme in addition to implement the suggestions mentioned earlier in this section to make aware the industry on BIM technology. Mostly this can be overcome touching the attitude of people individually via specially arranged workshops or programs.
- Another most important thing is the least internal barrier to adopt a new technology to the construction industry was found as the current practices are serving well. This further implied that almost all of them are not satisfied with the prevailing systems. Consequently, it is suggested as a high time to go for a system change and the attention of top management is drawn towards this point.
- Lack of knowledge and experienced client, limited adoption in local market, concern about lack of company standards and legal/contractual concerns were identified as the significance descending order of external barriers to adopt this technology. The Sri Lankan government has to play a major role to support to overcome these external barriers. It is commended encouraging knowledge sharing in the industry with examples and lessons learnt from BIM adopted projects in the country. A framework to be developed to transfer BIM experience of iconic projects carried out by international parties to the local construction industry.
- It is a contemporary requirement to all parties to get together to uplift the effectiveness of the construction industry of Sri Lanka.

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APPENDIXES

Appendix A

Building Information Modelling (BIM) & Sri Lankan Construction Industry

The purpose of this questionnaire is to collect data on above mentioned MSc research study. The findings of the survey will be solely used for an academic exercise where confidentiality will strictly be maintained. Your kind cooperation in completing the questionnaire is highly regarded.

* Required

1. **Name of the Respondent**

2. **1. Name of the Organization** *

3. **2. Experience in the construction industry** *
Mark only one oval.
   - Below 5 yrs
   - 5 ~ 9 yrs
   - 10 ~ 14 yrs
   - 15 ~ 19 yrs
   - 20 yrs & more
   - Other:

4. **3. Academic Qualifications** *
Mark only one oval.
   - Certificate level / Diploma
   - Bachelor's Degree
   - Post Graduate Diploma/ Degree
   - Other:

5. **4. Awareness level on Building Information Modelling (BIM is a platform providing a 3D digital representation of the building with a consistent database integrating diverse stakeholders to manage the project during the each phase of the building life cycle.)** *
Mark only one oval.
   - None - I do not know about BIM *Skip to question 22.*
   - Low - I have a little knowledge on BIM *Skip to question 22.*
   - Medium - I have plans to implement BIM in a project *Skip to question 6.*
   - High - I have involved in a project using BIM *Skip to question 6.*
   - Very High - I have involved in few projects using BIM *Skip to question 6.*

BIM Users

Please provide details relevant to a significant project implemented using BIM.

6. **1. Name of the project**

____

7. **2. Type of the project** *

Mark only one oval.

- ( ) Building
- ( ) Road
- ( ) Water Supply or Irrigation
- ( ) Other: _______________

8. **3. Role of your organization in the project** *

Mark only one oval.

- ( ) Client
- ( ) Consultant
- ( ) Contractor
- ( ) Other: _______________

9. **4. Type of the Client of the project** *

Mark only one oval.

- ( ) Government
- ( ) Private - local
- ( ) Foreign
- ( ) Other: _______________

10. **5. Value of the project** *

Mark only one oval.

- ( ) Less than Rs. 5 billion
- ( ) Rs. 5 billion ~ 10 billion
- ( ) Rs. 10 billion ~ 15 billion
- ( ) Rs. 15 billion ~ 20 billion
- ( ) More than 20 billion

11. **6. Project operating stage** *

Mark only one oval.

- ( ) Design Stage
- ( ) Planning Stage
- ( ) Construction Stage
- ( ) Operation & Maintenance Stage
- ( ) Other: _______________

12. **7. The software platform used for BIM (Revit, Bentley, Autodesk Naviswork etc.)** *

____

13. **8. The functions/ levels (3D~7D) BIM performing in the project?**

____

____

____

____

____

Issues in Construction Industry & BIM

Please indicate your views relevant to a construction project implementing using BIM.

14. **1. Design & site coordination** *

Mark only one oval per row.

	Strongly Disagree	Disagree	Agree	Strongly Agree
Less effectiveness in sharing required information	⬭	⬭	⬭	⬭
Delays in response to request for information (RFI)	⬭	⬭	⬭	⬭
Difficulty in understanding of drawings & visualization	⬭	⬭	⬭	⬭
Failures in clash detection	⬭	⬭	⬭	⬭

15. **2. Planning & scheduling** *

Mark only one oval per row.

	Strongly Disagree	Disagree	Agree	Strongly Agree
Insufficient information about project risks	⬭	⬭	⬭	⬭
Limited or conflicted information of project	⬭	⬭	⬭	⬭
Confusion in construction sequence	⬭	⬭	⬭	⬭
Difficulty in handling of revised designs	⬭	⬭	⬭	⬭
Limited planning tools & resources	⬭	⬭	⬭	⬭

16. **3. Cost reduction & cost control** *

Mark only one oval per row.

	Strongly Disagree	Disagree	Agree	Strongly Agree
Improper planning of manpower	⬭	⬭	⬭	⬭
Improper logistic planning	⬭	⬭	⬭	⬭
Procurement management problems	⬭	⬭	⬭	⬭
Poor coordination among different departments	⬭	⬭	⬭	⬭
Hard to handle sudden changes	⬭	⬭	⬭	⬭
Failures in clash detection	⬭	⬭	⬭	⬭
Interuptions of stakeholders	⬭	⬭	⬭	⬭

17. **4. Managing the construction time** *

Mark only one oval per row.

	Strongly Disagree	Disagree	Agree	Strongly Agree
Delays in the procurement process				
Delays in producing shop drawings				
Improper resource allocation				
Delays in client approvals				
Delays in handling suppliers				

18. **5. Any other positive/negative impacts of BIM on a project?**

Barriers for BIM Implementation

Please rate the impact of following barriers on BIM implementation as per your experience. (No impact - None & High impact - High).

19. **1. Impact of the internal barriers in BIM implementation** *

Mark only one oval per row.

	None	Low	Medium	High
Current practices are serving good				
Unawareness of BIM benefits & use				
Computer software & hardware limitation				
Heavy budget requirement				
Inertia of people for training				

20. **2. Impact of the external barriers in BIM implementation** *

Mark only one oval per row.

	None	Low	Medium	High
Limited adoption in local market				
Lack of knowledge & experienced partner/ clients				
Legal/Contractual concerns				
Concern about lack of company standards				

21. **3. Any other significant barriers affect on BIM implementation**

Stop filling out this form.

Non BIM Users

Please provide details relevant to a significant project you involved or currently working on.

22. **1. Name of the project**

____

23. **2. Type of the project** *

Mark only one oval.

- ( ) Building
- ( ) Road
- ( ) Water Supply or Irrigation
- ( ) Other: ________________

24. **3. Role of your organization in the project** *

Mark only one oval.

- ( ) Client
- ( ) Consultant
- ( ) Contractor
- ( ) Other: ________________

25. **4. Type of the Client of the project** *

Mark only one oval.

- ( ) Government
- ( ) Private - local
- ( ) Foreign
- ( ) Other: ________________

26. **5. Value of the project** *

Mark only one oval.

- ( ) Less than Rs. 5 billion
- ( ) Rs. 5 billion ~ 10 billion
- ( ) Rs. 10 billion ~ 15 billion
- ( ) Rs. 15 billion ~ 20 billion
- ( ) More than 20 billion

27. **6. Project operating stage** *

Mark only one oval.

- ( ) Design Stage
- ( ) Planning Stage
- ( ) Construction Stage
- ( ) Operation & Maintenance Stage
- ( ) Other: ________________

28. **7. Softwares using for design, planning etc in the project**

Issues in Construction Industry

Please indicate your views/experience relevant to a construction projects. Not essential to specify on the project mentioned in the previous section.

29. **1. Design & site coordination** *

Mark only one oval per row.

	Strongly Disagree	Disagree	Agree	Strongly Agree
Less effectiveness in sharing required information				
Delays in response of request for information				
Difficulty in understanding of drawings & visualization				
Failures in clash detection				

30. **2. Planning & scheduling** *

Mark only one oval per row.

	Strongly Disagree	Disagree	Agree	Strongly Agree
Insufficient information about project risks				
Limited or conflicted information of project				
Confusion in construction sequence				
Difficulty in handling of revised designs				
Limited planning tools & resources				

31. **3. Cost reduction & cost control** *

Mark only one oval per row.

	Strongly Disagree	Disagree	Agree	Strongly Agree
Improper planning of manpower				
Improper logistic planning				
Procurement management problems				
Poor coordination among different departments				
Hard to handle sudden changes				
Failures in clash detection				
Interuptions of stakeholders				

32. **4. Managing the construction time** *
Mark only one oval per row.

	Strongly Disagree	Disagree	Agree	Strongly Agree
Delays in the procurement process				
Delays in producing shop drawings				
Improper resource allocation				
Delays in client approvals				
Delays in handling suppliers				

33. **5. Any other similar issues faced in construction industry?**

Barriers for BIM Implementation

Please rate the impact of following barriers on BIM implementation in your point of view. (No impact - None & High impact - High).

34. **1. Impact of the internal barriers in BIM implementation** *
Mark only one oval per row.

	None	Low	Medium	High
Current practices are serving good				
Unawareness of BIM benefits & use				
Computer software & hardware limitation				
Heavy budget requirement				
Inertia of people for training				

35. **2. Impact of the external barriers in BIM implementation** *
Mark only one oval per row.

	None	Low	Medium	High
Limited adoption in local market				
Lack of knowledge & experienced partner/ clients				
Legal/Contractual concerns				
Concern about lack of company standards				

36. **3. Any other significant barriers affect on BIM implementation**