DIFFICULTIES OF APPLYING BUILDING INFORMATION MODELING (BIM) IN PRE-CONSTRUCTION STAGE OF CURRENT BUILDING CONSTRUCTION PRACTICE OF SRI LANKA

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DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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I dedicate this piece of research to my beloved family

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Abstract

BIM is identified as a recently introduced technology which delivers various advantages to the construction industry. Despite of the available advantages of BIM adoption, many developing countries still find this valuable technology impractical. As a result, this research is primarily focused on identifying the difficulties of adopting Building Information Modelling (BIM) in current building design and construction practice of Sri Lanka. The study was focused on pre-construction stage because it has been highlighted that the introduction of this technology in the early stage of a construction project assists in achieving a successful completion of a project. With the intention of providing a basis for conducting the study, an in-depth literature review was conducted to identify the enabling processes of BIM in preconstruction phase of construction projects in global context. The research aim was approached through a qualitative research strategy conducted in terms of a case study where the data was collected using document review and semi-structured interviews. The collected qualitative data was analysed with content analysis method to identify the construction practice of BIM enabling activities in pre-construction stage of a Sri Lankan construction project. The research findings further exposed the differences in practice of BIM enabling activities between local context and global context in pre-construction stage. Based on the discovery made on differences in construction practices the difficulties of achieving the global best practices in local context were discovered. Accordingly, the difficulties of applying BIM technology in preconstruction stage of a Sri Lankan construction project were identified. The discovery of difficulties provides a basis for identifying the expected challenges from adopting BIM in Sri Lankan context. Moreover, further research directions can be suggested towards the areas such as concerning other developing countries and focusing on difficulties of BIM implementation in construction stage.

Key words: Pre-construction stage, BIM (Building Information Modeling), Sri Lankan construction projects, BIM enabling processes

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LIST OF ABBREVIATIONS

Abbreviation	Description
AEC	Architecture, Engineering & Construction
BEP	BIM Execution Plan
BIM	Building Information Modeling
BOD	Basis of Design
BOQ	Bills of Quantities
CBA	Cost Benefit Analysis
CDE	Common Data Environment
EIR	Employer's Information Requirements
MEP	Mechanical Electrical and Plumbing
QS	Quantity Surveyor
RIBA	Royal Institute of British Architects

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CHAPTER 01

INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 Background study

Construction industry has a unique nature compared to other industries where the end product is developed and manufactured according to a standard (Younis, Wood, & Malak, 2008). Further, as per Clough, G.A. Sears and Sears (2000), complicated and time-consuming projects are undertaken in this extremely complex industry. As revealed by Poli and Shenhar (2003), these projects open pathways to many rewards for a corporation and therefore, it is important to achieve a successful project (Winch, 2010). As per Globerson and Zwlkael (2002), the capability to complete the project as per the desired specifications, within the specified budget and time schedule in a manner to satisfy the customer and stakeholders is recognized as project success. Further, while exploring the influences on project success, Munns and Bjeirmi (1996) elaborated that proper implementation of techniques for planning and controlling of time, cost and quality which comes under project management can be recognized as significant. Thus, it is obvious that achieving project success is a considerable aspect in the construction industry.

When a construction project is considered, the main stages in its life cycle can be identified as planning, designing, construction, operation, maintenance and decommissioning; and the construction phase can be further subcategorized into pre-construction, actual construction, and post construction stages (Meadati, 2009). According to Gidado (2004), focusing on properly planning and managing of the pre-construction stage can lead to achieve project success despite the detriments arising from the complexity of the construction industry. Additionally, adequate attention provided in the pre-construction stage can lead to minimizing the issues due to slippage in schedules and cost over-runs of a construction project (Al-Reshaid, Kartam, Tewari & Al-Bader, 2005). Therefore, it becomes obvious that focusing on pre-construction stage is favorable to accomplish a successful construction project.

As discovered by Chan, Ho and Tam (2001), project success can be affected by various factors such as devotion of team members of the project; contractor's proficiencies; assessments on risks and liabilities; capabilities of the client; and desires and restrictions of the customer. Further, Building Information Modelling (BIM) is identified as a solution for various inefficiencies in the construction industry (Zuppa, Issa, & Suermann, 2009). Additionally, discovery by Zuppa et al. (2009) revealed that BIM has a potential to influence the success of a project as it is recognized as the robust apparent progressive impact on the quality, time and cost of construction projects. Hence, BIM is known to be a significant technology which can assist in achieving a successful project.

As identified by Azhar (2011), Building Information Modelling (BIM) is one of the modern technological improvements in the construction industry which delivers a digitally created exact virtual model of a building that can be used for planning, designing, construction, and operation. Further, there is a great probability for BIM to integrate into construction projects life cycle becoming an industry standard for construction projects (Nagalingam, Jayasena, & Ranadewa, 2013). As disclosed by Vysotskiy, Makarov, Zolotova and Tuchkevich (2015), if BIM is properly adopted, it results in acceleration of total design process; acceleration of individual tasks; reduction of errors; increase of correction speed; quick and correct data collaboration management. Further, in their research, Khoshnava, Ahankoob, Preece and Rostami (2016) have identified that BIM provides a collective basis for the whole project team allowing convenient data exchange in terms of designs and construction and this collaborative nature of BIM facilitates the optimum benefit of the technology. Moreover, as discovered by Azhar, Hein and Sketo (2008), creation and usage of a virtual model which imitates the planning, designing, construction and operation stages of a project can be expected by BIM implementation. As per the findings of Eadie, Browne, Odeyinka, McKeown and McNiff (2013), even though BIM can be used in all stages within a project lifecycle, it is comparatively used mainly in the initial stages than in the latter stages.

As identified by Khosrowshahi and Arayici (2012), the understanding of the advantages of BIM depends upon precise enactment of BIM at an organizational level and its incorporation at the commercial level. As per the empirical findings by Kassem, Succar and Dawood (2013), and A. K. D. Wong, Wong and Nadeem (2009), a significant usage rate of BIM can be identified in countries such as UK, USA, Australia, Norway, Finland, Denmark and Singapore which are categorized as developed countries. Further, in their research, Wong, Wong and Nadeem (2010) have found that a considerable level of support is provided equally by the public and private sectors of these countries to implement BIM in construction projects and the main undertakings include defining the roles of major BIM team players, and introducing an appropriate policy for BIM execution. However, as revealed by Bui, Merschbrock and Munkvold (2016), even though BIM is progressively being adhered in developed countries, there is a considerable low rate of implementations in the developing country context due to issues such as shortage of IT-literate personnel and unavailability of national level programmes supporting BIM implementation. Thus, it could be determined that developed countries when compared to the developing countries have more sustenance from the construction sector for implementing BIM technology in construction projects.

As identified by Arayici et al. (2011), Bernstein and Pittman (2004) and Eastman, Teicholz, Sacks, and Liston (2008), implementing BIM effectively necessitates substantial modifications to the construction practice at virtually each level within the building process which include using new software applications, reinventing the workflow, training employees and assigning duties, and altering the way of modelling the construction. Further, Peansupap, and Walker (2005) have discovered that changing current construction practice in developing countries to adopt BIM technology cannot be effortlessly done due to various practical reasons. Therefore, it demonstrates that implementing BIM technology in developing countries should be carried out while they are following their current construction practice. Therefore, it is apparent that the barriers which prevent obtaining the valuable outcome of implementing BIM in a construction project need to be undeniably addressed.

Consequently, it becomes important to identify the difficulties which influence application of BIM technology in current practice of construction in developing countries such as Sri Lanka.

1.2 Research problem

Developing countries which follow a different building construction practice compared to the developed countries confront difficulties in accepting BIM technology due to numerous practical concerns. Thus, it becomes important to study the adoptability of BIM technology to the existing building construction practice of developing countries, mainly in pre-construction stage of a construction project where a considerable BIM adoptability is visible as well as which can impose a significant impact towards a project success. Therefore, this research expects to fill that research gap by studying the difficulties of applying BIM technology in pre-construction stage of current building construction practice of Sri Lanka.

1.3 Aim and objectives of the study

Aim

The aim of the research was to identify the difficulties of applying Building Information Modeling in pre-contract stage of current building construction practice in Sri Lanka

Objectives

In order to reach the above aim methodically, following objectives were set.

1. Identify the enabling processes of BIM implementation in pre-construction stage in building construction projects
2. Identify the associated processes in pre-construction stage of existing construction practice in Sri Lanka
3. Determine the differences between corresponding processes identified above
4. Identify the difficulties to bridge those differences during pre-construction stage in building construction projects in Sri Lanka

1.4 Methodology of the research

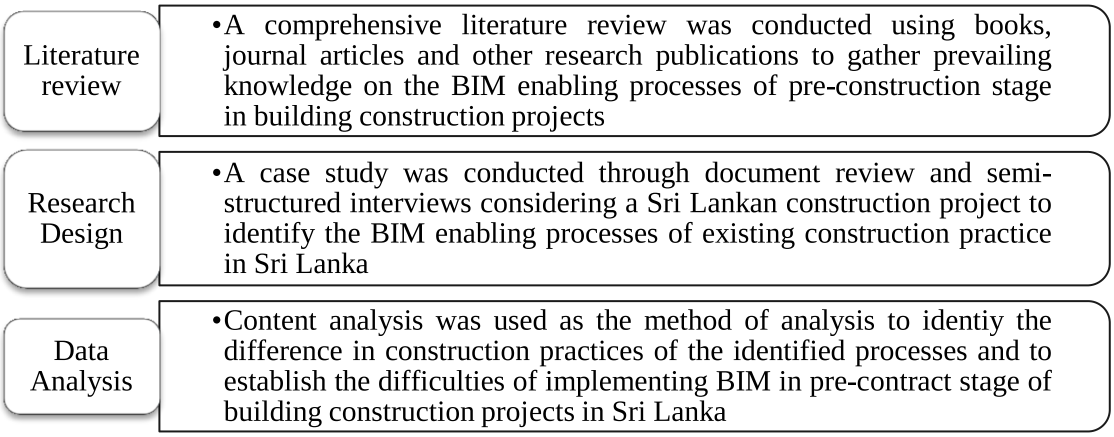

Figure 1.1: Research methodology

1.5 Scope and limitations

This research scope was limited to pre-construction stage of building construction projects in Sri Lanka under private sector. Further, the study refers to BIM level 2 as the BIM technology to avoid misinterpretation of BIM features which depend on the adopted standard level. In addition, the findings were limited to the difficulties that arise if and only when BIM is to be implemented. Other existing difficulties were not counted under BIM implementation difficulties.

1.6 Chapter breakdown

For clarity and ease of following the study, chapters in this thesis are arranged as shown in Table 1.1.

Table 1.1: Chapter breakdown

Chapter	Description
Chapter 1: Introduction	This chapter introduces the research area in a broader view including research problem, aim, objectives, methodology, scope and limitations.
Chapter 2: Literature Review	This chapter elaborates the theoretical aspects related to research problem through extensive literature review in order to recognize and establish the importance of the research problem.
Chapter 3: Research Methodology	The research approach and research process used in the research study is presented in this chapter.
Chapter 4: Research Findings	This chapter presents the research findings from case study data analysis.
Chapter 5: Conclusions and Recommendations	As the final chapter, this concludes the research findings in respect to the research concerns and explanations on practical implications as well as the limitations and further study directions under this area of study.

CHAPTER 02

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

While chapter one has focused on briefly introducing the research study area, the literature review chapter is aimed at recognizing the research by conducting a comprehensive study of the prevailing literature. Further, the literature review reveals the current knowledge level of the field of study with the purpose of familiarizing the research problem to the reader. Opening of the chapter explains the nature of the projects in construction industry which the study is focused on. Then the project processes as identified by different authors were revealed to familiarize the variance in construction practice. Further, the importance of focusing on pre-construction stage was identified while establishing an interpretation for the same to proceed with the study. With the intention of covering the first objective of the research, enabling processes of BIM implementation in pre-construction stage in building construction projects were identified using existing literature. Further, to provide a base for achieving the second objective of the study, literature were reviewed to discover the existing practice adopted in identified enabling processes of BIM implementation in pre-construction stage in building construction projects of Sri Lanka. The literature has been synthesized as much as possible to formulate a solid base for the research problem.

2.2 Industry of construction and its projects

As identified by Hao, Shen, Neelamkavil and Thomas (2008), construction industries of many countries are fragmented. However, it is identified as an industry which provides an immense contribution to a country’s national, social and economic growth significantly in developing countries of the world (Ofori, 2015; Lopes, Oliveira & Abreu, 2011; and Hillebrandt, 2000). As stated by Ofori (2015), it is vital to work towards the improvement of construction industry by finding its significant requirements. In their research Saqib, Farooqui, and Lodi (2008) emphasized that success of construction projects becomes a significant factor when it comes to the constancy of a construction industry.

According to Clough et al. (2000), projects in construction industry are complicated and time consuming endeavours. Similarly, A. P. C. Chan, Scott and Chan (2004) identified that recent building projects are comparatively more complex and challenging. According to Kagioglou, Cooper, and Sexton (2000), project complexity can result in uncoordinated and highly variable construction project processes. A project in the industry of construction is implemented based on the planned and unplanned events and interactions arise through a process (Sanvido, Grobler, Parfitt, Guvenis & Coyle, 1992). Therefore, observing construction projects makes it important to examine the applicable construction processes which are elaborated in the next section.

2.3 Construction project process

The process in a construction project mainly involves planning and budgeting stage by the owner; designing stage for creating plans and drawings; the stage where contractor is selected and; physically construction execution phase where the project is completed and handed over to the owner (Klinger & Susong, 2006). As identified by Bennet (2007), construction project process involves pre-project decisions by the owner; planning and design of the project; selection of the contractor, mobilization for field operations; construction and; close. Further, these phases can be illustrated as in figure 2.1.

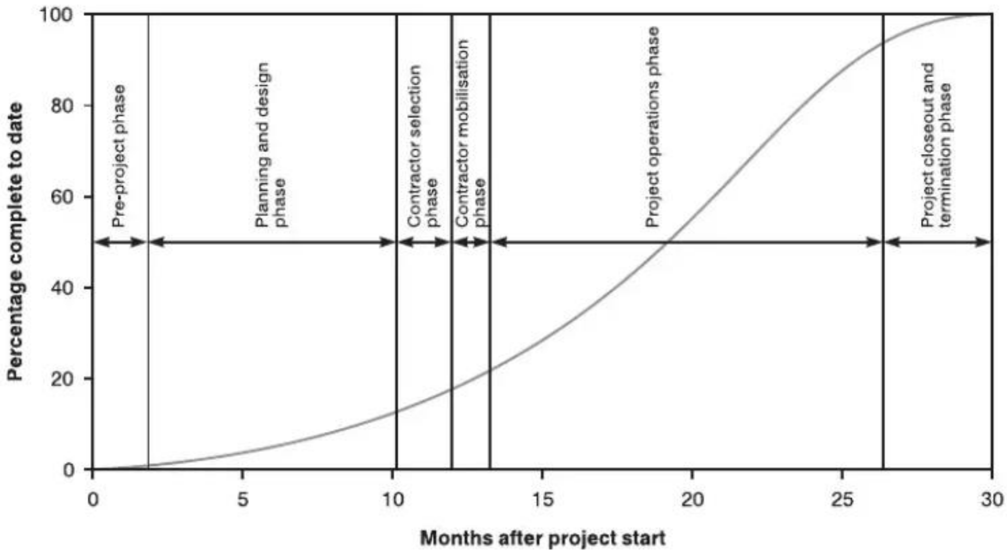

Figure 2.1: Stages of construction project
Source*:* Bennet (2007)

As identified by Westland (2007), construction projects include initiation, planning, execution, performance and monitoring, and closure as the main phases. Further, building process can be divided as concept, briefing, planning, production, and management of the finished building which facilitates control, dissection of obligations and management of cost (Ryd, 2004). According to Hughes (2003), the process of a construction project is well described in the RIBA (Royal Institute of British Architects) plan of works. As per the findings of Royal Institute of British Architects (RIBA, 2007), main stages of a construction project include preparation phase, designing, pre-construction activities, work execution and usage where the sequence can be changed based on the selected procurement system. In addition, RIBA (2013) identified the stages of a construction project as strategic definition; preparation and brief; concept design; developed design; technical design; construction; handover and close out; and in use. As revealed by Cooper et al. (2012), RIBA plan of work which was primarily introduced in 1964 can be acknowledged as a standard process of project implementation. However, according to Ryd (2004), even though building process can be divided in to different phases, overlapping of work activities can be expected.

Considering the life cycle of a construction project, Winch (2001) disclosed that a progressive decrease of project uncertainties through time can be observed within a project process as demonstrated in figure 2.2.

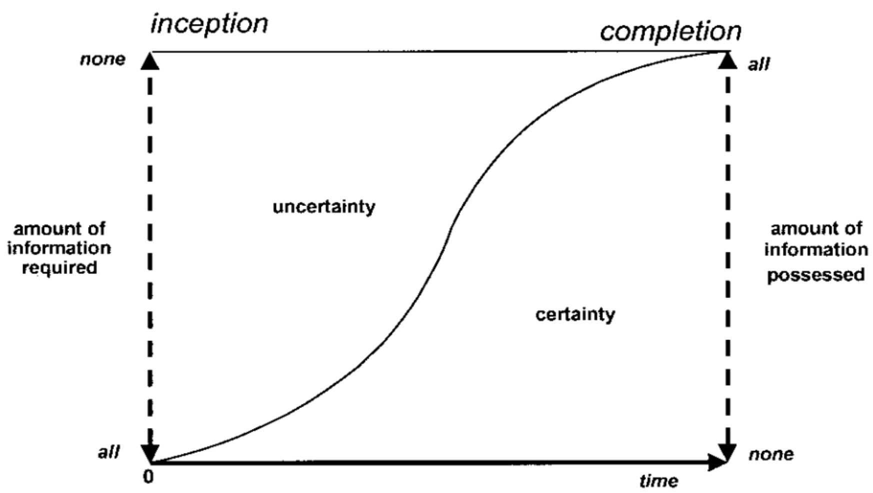

Figure 2.2: Decrease of uncertainty through time in project process
Source: Winch (2001)

As exemplified through figure 2.2, it becomes obvious that initial phase of a construction project, before commencement of construction, requires a significant level of attention in terms of minimizing uncertainties when compared to the other stages. Further, as disclosed by Al-Reshaid et al. (2005), the concentration on pre-construction phase guarantees the effective implementation during construction phase driving the project to success. Therefore, it becomes obvious that concentrating on pre-construction stage under the study can provide an outcome which is comparatively more effective to the construction industry.

2.3.1 Pre-construction stage of a construction project

Initial stage of a construction project is focused on bridging the client with the project where a complex and pre-defined object of interest is achieved by implementing actions through a production process (Ryd, 2004). As identified by Klinger and Susong (2006), construction stage of a construction project can be identified in three different sections as pre-construction stage, construction stage and post-construction stage. According to Kagioglou et al. (2000), pre-construction phase of a construction project involves defining client's needs through an appropriate design solution which is developed based on a rational arrangement, with the purpose of delivering permitted production information. As revealed by Thabet (2000), preconstruction stage includes conceptual planning phase, design development phase and procurement phase which expands through conceptual estimate; planning; programme; development of schematic and detailed designs; bidding; award; schedule and budget review. In addition, RIBA (2007) stated that when it comes to a construction project, the 'pre-construction stage' includes production information, tender documentation and tender action. However, in their research, Kassem, Kelly, Dawood, Iqbal and Lockley (2014) graphically illustrated the main stages of a construction project as demonstrated in figure 2.3.

As per the figure 2.3, it is obvious that stages prior to construction also involve project appraisal, design brief, conceptual design, design development and technical design.

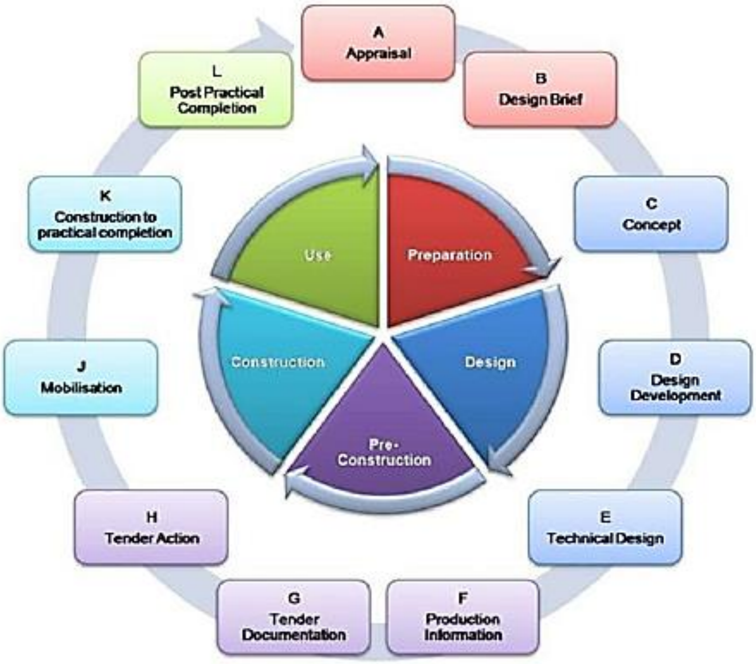

Figure 2.3: Stages of a construction project as per RIBA plan of work 2007
Source: Kassem (2014)

Further, the tasks identified by Klinger and Susong (2006) under the pre-construction stage can be summarized and tabulated as in table 2.1. As per table 2.1, pre-construction stage of a construction project mainly involves planning, designing, engineering and contractor selection which are achieved by implementing a set of tasks.

Table 2.1 Main tasks to be achieved in pre-construction stage of a construction project

Phase	Tasks
Planning phase	Preparation of feasibility or development reports
	Investigation of the site constraints by the planner
	Budgeting and estimations
	Obtaining authority approvals including environmental reviews
Designing phase	Establishing project design criteria which describes project's aim, goals in terms of architecture, applicable codes and distinct necessities
	Selection and appointment of the designer
	Schematic designs
	Design development including draft specification
	Development of final construction drawings and specifications
Engineering phase	Preliminary cost estimating
	Constructability reviews
	Value engineering
Contractor selection	Selection of the contracting method
	Bidding
	Selection of the contractor

Moreover, as revealed by Gilliland (2019), engaging a project manager for ensuring feasibility; forming a strategic plan; generating a design; ensuring entitlements; and assembling the labor and resources required for construction are the main stages of the pre-construction stage of a project.

Based on the literature findings, it becomes obvious that stage prior to the commencement of construction works in a project is defined by researchers using different terminologies. This emphasizes the importance of a harmonized interpretation. Therefore, after careful consideration of the available literature, appraisal, design brief, concept design, design development, technical design, production information, tender documentation and tender action are identified as the main processes involved in the pre-construction stage of a construction project for the purpose of conducting the study.

As revealed by Mcconnell (2018), project appraisal stage of a construction project involves project reviewing; evaluation of project content for approval; identification of problems; generation solutions or alternatives; selection of the most feasible option, feasibility studies; establishment of solution statement; identification of project stakeholders; and establishment of expected project outcomes. Further, according to Kirkpatrick and Weiss (1996), Van Pelt (1993) and Brzozowska (2007), project appraisal stage involves conducting Cost Benefit Analysis (CBA). Moreover, project appraisal is an endeavor used to rationalize the project through analysis where project feasibility and cost-effectiveness is determined (Mcconnell, 2018). In addition, Lopes and Flavell (1998) revealed that Project Appraisal stage is mainly focused on exploring the financial and technical feasibility of a project. Moreover, as per RIBA (2007), appraisal stage of a construction project identifies the needs and objectives of the client and possible boundaries on development while conducting feasibility studies and exploring alternatives to assist the client's decision on proceeding with the project.

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While describing the design briefing stage of a construction project, Ryd (2004) stated that design brief of a project performs as a mode of information delivery from design phase to production phase in a construction project which focuses on the decision-making process and creation of requirements. Further, in his publication, Phillips (2004) identified design brief as a description in writing regarding the project which requires a form of chromatic design. Blyth and Worthington (2002) revealed that briefing is a ingenious process where design is briefed and briefing relies on the design. Further, this phase directs a project to its brief which is equated with the client's contentment on outcome of the building process (Ryd, 2004). Moreover, Blyth and Worthington (2002) identified effective design briefing is relied on effective decision-making processes are the backbone of an effective briefing strategy. In addition, as identified by RIBA (2007), design brief stage ensures the incorporation of initial statement which includes client's key requirements and constraints in to the project design brief while establishing the method of procurement, procedures, organizational structure and required stakeholders for the project.

In his research, Sinclair (2019) revealed that concept design stage is a decisive stage for the principal designer where a concept design is developed in to meet the initial project brief in a manner to obtain the approval from client and other stakeholders. As identified by Rodgers, Green and McGown (2000), sketches are used for expressing ideas during the conceptual design stage. As revealed by RIBA (2007), concept design stage is mainly focused on implementing the design brief and delivering supplementary data derived from outline proposals for structural and services systems of the building; framework specifications and initial cost plan. Further, the concept design assists in linking the client's brief, project plans, the site works and the architect's vision, while supporting the other significant designs which are essential for proceeding construction (Sinclair, 2019). In addition, RIBA (2007) identified this stage as a step to review the project procurement route.

Gilliland (2019) discovered that when it comes to the the design development process of a construction project, it becomes more collaborative and necessitates the interaction of client, architect, engineer and project manager to deliver a design that imitates the client's desires while being intelligently and sustainably sound in structure. As per Sinclair (2019), design development stage includes design information that is coordinated with project strategies or other project information which tests the concept design through the development of specifications and cost information. Similarly, RIBA (2007) recognizes this stage as an assistance to embrace the structural as well as building services systems; restructured outline specifications and cost plan in to the design while completing the project brief and applying permission for comprehensive planning.

As per RIBA (2007), technical design stage includes developing technical designs and specifications which can be used to harmonize building components and elements while providing information for statutory criteria and construction safety. Similarly, Sinclair (2019) identified that the project design is progressed to the next level of detail while incorporating mechanical and electrical services during the technical design phase.

While describing the production information stage of a construction project, Odediran and Windapo (2014) and RIBA (2007) stated that this stage involves providing details for tendering; obtaining statutory permits and preparation of further details for work execution under the building contract.

As revealed by Odediran and Windapo (2014) and RIBA (2007), tender documentation stage requires preparation of tender documents with sufficient details to proceed with tendering. Brook (2016) stated that this stage is focused on a link among clients, professional advisers and contractors through documentation which clearly reveal the duties and rights of each party.

Tender action stage of a construction project is focused on identifying and evaluating the prospective contractors for the project; collecting and evaluating tender documents and recommendations on the most suitable contractors to the client (Odediran & Windapo, 2014, & RIBA, 2007).

After establishing the understanding on construction project's pre-construction stage, to proceed with the study, it becomes important to recognize the activities which can be implemented using BIM technology. In order to obtain the existing knowledge on BIM enabling processes of construction projects in an effective manner, observing the overview of BIM technology in construction industry becomes essential. Therefore, main features of BIM technology are identified in the subsequent section.

2.4 BIM technology in construction industry

Identification of BIM enabling processes in a construction project's pre-construction stage to proceed with the study requires obtaining an overall understanding of the BIM technology. Building Information Modelling can be identified as a tool, process or a product which can build up computer-generated intelligent models related with management tools which facilitate teamwork encouragement, visual aid and constructability (Kymmell, 2007). Further, in their research, Chen and Luo (2014) discovered BIM as a tool that can be used to promote visualizing and coordinating AEC (architecture, engineering and construction). In addition, Zuppa et al. (2009) introduced BIM as a tool under new IT technology which contributes the construction industry by increasing efficiencies through implementing new processes based collaboration between stakeholders. Further, as per Winch (2009) and stated that lack of information availability for decision making which is one of the main difficulties arise when managing construction projects that can be controlled by BIM implementation. When it comes to the BIM implementation standards, 4 different levels can be identified as level 0, level 1, level 2 and level 3 which differs depending on the level of collaboration and integration it provides (Gu & London, 2010; & Sacks., Eastman, Lee, & Teicholz (2018).

As identified by Gu and London (2010), BIM level 3 provides the highest level of collaboration and integration which has not yet been achieved up to date. When it comes to the BIM implementation levels, BIM level 2 can be used to deliver an integrated platform to collaborate in an effective and efficient working environment within the construction industry which is recognized as the ultimate goal of the practitioners as well as the stakeholders (Ganah & John, 2014). Similarly, Eynon (2016) revealed the importance of achieving level 2 of BIM implementation by referring to the BIM maturity levels as described in ‘Bew-Richard’s maturity ramp’ which is illustrated in figure 2.4.

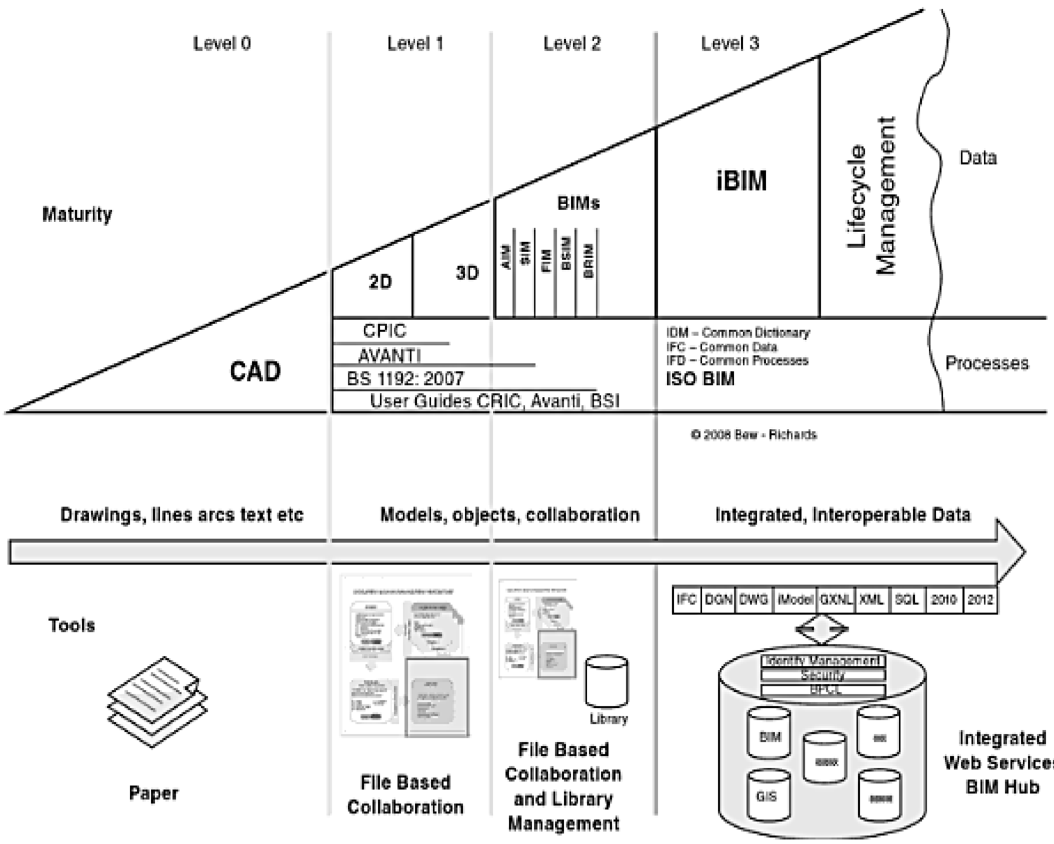

Figure 2.4: Bew-Richards maturity ramp
Source: (Eynon, 2016)

Further, as described by Dakhil, Alshawi and Underwood (2015) and RIBA (2012), features of BIM levels can be elaborated as in table 2.2.

Table 2.2 Features of BIM levels

BIM level	Features
Level 0	This is the simplest form of BIM where no collaboration can be expected. Mainly 2D CAD drafting and paper based output can be observed.
Level 1	Combination of 2D and 3D CAD can be observed. While adopting standards such as BS 1192:2007, common data environment (CDE) is managed for data sharing. However, BIM model is not used collaboratively between team members.
Level 2	This involves using common file formats by all project participants while establishing a unique information exchange process in a particular project for coordination. Further, designer's ensure the logical progress of their models by understanding and utilizing BS 1192:2007
Level 3	This level is not yet defined in full. Early design analysis, quickly derived cost models and health and safety aspects which are analyzed parallel to the design are some of the expected facilities through this level.

Therefore, considering the practical achievability in the current building construction practice and allowing for the expected effectiveness, BIM level 2 is identified as the BIM technology considered within the study to avoid misinterpretation and to establish scope and limitations for the study.

While identifying the importance of implementing BIM technology Alshawi, Goulding, Khosrowshahi, Lou, and Underwood (2008) and Yan and Demian (2008), revealed that despite the benefits BIM can provide, most people are reluctance to adopt BIM in construction projects due to various reasons. As identified by Chien, Wu and Huang (2014) and Bryde, Broquetas and Volm (2013), teamwork, collaboration, and information sharing within the construction industry are the key concerns that generates challenges and risks for BIM implementation. Therefore, it becomes obvious that BIM which provides various benefits requires a substantial motivation to be implemented.

After discovering the fundamental features of BIM technology, it becomes important to identify the process of construction projects which enables BIM implementation in the pre-construction stage which is elaborated in the subsequent section.

2.5 Enabling processes of BIM implementation in pre- construction stage

After identification of the key phases in a construction project's pre-construction stage under section 2.3, the processes required to be applied under each main phase in order to implement BIM technology are established with the intent of proceeding with the study. As revealed by Building and Construction Authority of Singapore (BCAS, 2013), project work flow of a BIM implemented project where the designs are mainly based on model development can differ from the traditional practice.

According to the BCAS (2013), development of a BIM execution plan which includes BIM aim and procedures; roles of project team members, staff engagement and proficiency; process and strategy of BIM implementation; formats of submissions and BIM exchange protocol; data requirement for implementing BIM; collaboration process and mode of managing the shared models; controlling and maintaining the quality; and technology arrangement and software becomes essential to efficiently host BIM into the project lifecycle.

As identified by DBL (2019), BIM implantation in a construction project requires identifying decision making and information deliverables at each stage of the process to ensure the creation and sharing of appropriate information in a suitable format on time. As revealed by Zanni, Soetanto and Ruikar (2014), the RIBA Work plan is focused on addressing the matters that arise concerning coordination and fragmentation due to BIM usage and the conception of collaborative project team. As per RIBA (2012), BIM enabling activities can be summarized as in table 2.3.

Table 2.3 Activities required for BIM implementation as identified by RIBA

Work stage	Activities required to implement BIM
Appraisal	Identification of project life cycle, desires related to facilities management of the building and potential restrictions on development to reflect the importance of identifying of the client's necessities related to BIM including identifying the implementation scope and commissioning BIM surveys and investigation reports.
Design brief	Examining the scope of the project to identify the BIM scope including inputs and outputs
	Identification of project organizational structure and defining roles and responsibilities of the members to define enduring accountabilities and identify the model's ownership early in the project

Table 2.3 Activities required for BIM implementation as identified by RIBA (Cont'd)

Work stage	Activities required to implement BIM
Conceptual design	Agreeing on the project quality plan and change control protocols which becomes essential for generating the BIM execution plan
	Identification of significant elements that can be modeled such as prefabricated building components for creating parametric objects for all main essentials as a basis for implementing BIM execution plan
Design development	Sharing data co-ordination of design and technical aspects and accumulating specification data to develop the design using BIM
	Conducting detailed investigations to develop the design using BIM
	Progression of design components to develop the design using BIM
Technical design	Technical designs and specifications development with adequate details to export for planning application
Production information	Developing project data in-detail for exporting to Building Control Analysis and exchanging data to finalize design co-ordination; and detailed analysis with subcontractors and to initiate performance specified works
	Comprehensive modeling, integration and exploration including embedding specifications to model to allow specialist contractors to commence work
	Referring supplier's information and creating production level parametric objects for all key building elements including to enable commencement of specialist contractors' work
	Adopting a Building Control Analysis
	Review of construction sequence and information provided by contractors and specialists to integrate into project data
Tender documentation	Providing BIM model to the contractor as an aid for tendering

As per the table 2.3, BIM implementation is mainly enabled through appraisal, design brief, concept, design development, technical design, production information and tender documentation stages. According to Shaikh and Darade (2016), project quality plan is a document defining the performance, features, conformance, reliability, durability, service, aesthetic, perceived quality of activities that need to be adhered for achieving the expected project quality. Therefore, it becomes obvious that plan of achieving quality concerns of a project which also assist in BIM implementation opt to be revealed in a project's conceptual stage. Further, Hao et al. (2008) discovered that a change control protocol elaborates the processes of recognizing change, evaluations and proposals, obtaining approvals, method of implementation and review.

Accordingly, it can be observed that early stages of a construction project reveal the method of controlling the project changes which similarly becomes important for BIM implementation.

Further, as identified by British Standards Institution (BSI, 2013), PAS 1192-2 is a standard which offers detailed guidance related to information management of BIM implemented projects. Moreover, BIM format is not used to originate, exchange or manage all information on a project as the intention of a BIM implemented project is to manage information in a consistent and structured manner to enable efficient and accurate information exchange (BSI, 2013).

As explained by British Standards Institution (BSI, 2007) through BS 1192:2007, for BIM implementation in a construction project, commitment and agreement of a standard method and procedure by all the members of the project team at the pre-construction stage becomes essential. Accordingly, the required activities for BIM implementation as identified by BSI (2007) can be tabulated as in table 2.4.

Table 2.4 Activities required for BIM implementation as identified in BS 1192:2007

Work stage	Requirements for implementing BIM
Design brief	Agree on roles and responsibilities to implement standard method and procedure
	Creating and maintaining project specific names and codes following provided standards for efficient access of information
	Adopting a CDE (Common Data Environment) approach to allow information sharing
	Agree on a suitable information hierarchy which assists the concepts of the CDE and the document origin
	Agree on data exchange processes
Conceptual design	Establishing the project origin and orientation while ensuring the relation to project grid and site perspective
	Create 2D or 3D models adhering to a common project origin and positioning referring to a conventional Cartesian axis and common measurement unit
	Adopt a quality policy to ensure the maintenance of models over their life times
Design development	Develop 2D or 3D models adhering to a common project origin and positioning referring to a conventional Cartesian axis and common measurement unit
	Maintaining a quality policy to ensure the maintenance of models over their life times

According to the table 2.4, adopting BIM in a construction project requires on thoroughly focusing on roles and responsibilities; project specific codes; CDE; information hierarchy; data exchange processes; using a conventional Cartesian axis and common measurement unit for creating simulations; and quality policy. Further, as elaborated in Bim dictionary (2019), agreement on data exchange process in a BIM implemented project involves agreeing on the formats and specifications of data that required to be exchanged in terms of models or documents.

According to DBL (2019), BIM adoption in projects requires establishing spatial coordination and information exchange processes during the conceptual design stage assuring proper functioning of information management solutions, information management processes and engagement of participants with applicable talents and proficiencies. Further, resolution of any interoperability, preparation or other matters should be done before design inauguration (DBL, 2019).

As revealed by BSI (2013), BIM implementation requires the project process to adopt activities as elaborated in table 2.5.

Table 2.5 Activities required for BIM implementation as identified under PAS 1192-2

Work stage	Requirements for implementing BIM
Design brief	Establishing data sharing using single CDE to manage the formation, exchange and publish project information
	Clearly defining the employer's information requirements (EIR) and key desires through contracts to establish BIM execution plan
	Assigning roles, responsibilities and authorities to define the team member's proposed approach, proficiency, capability and skills to meet the EIR
	Adopting standards, methods and procedures
Conceptual design	Defining information in models
Tender Action	Evaluation of the proposed methodology, competence and capability of each supplier and their supply chain to deliver the required information before awarding the contract

While describing the general practice in BIM implementation, Barnes and Davies (2015) revealed the CDE as a platform where data, documents, graphical models and non-graphical assets can be collected, managed and shared among the project team members.

Further, as per BSI (2013), in order to successfully implement BIM in a construction project, the CDE should be in a position to provide accessibility which fulfills the pre-established rules by the team members; traceability to identify the modifications made to the shared model; ability to support files with different software formats; easy exchange of information; conservation and updating over time; assurance on confidentiality and security. Furthermore, as revealed by Ashworth, Tucker and Druhmann (2017), the EIR is a document which describes the requirement of the client with regard to the project information models at each stage of the project.

As recognized by Sinclair (2019), design development stage of a BIM implemented project requires having a federated model comprising all of the 3D building information modelling models of the design team which is reviewed by the lead designer before being uploaded to the common data environment. According to Boton and Forgues (2018), for a construction project to adopt BIM in an effective manner, three-dimensional models need to be maintained as the main database and course of information exchange during the life cycle. Further, efficient BIM execution requires to be provided an intensive collaborative work environment for the team members which can result in significant reduction in delayed decision-making (Boton & Forgues, 2018). As revealed by BCAS (2013), the requirements to be implemented while adopting BIM in a construction project can be tabulated as in table 2.6.

Table 2.6 Activities required for BIM adoption as identified by BCAS

Work stage	Requirements for implementing BIM
Design brief	Agree on needs, objectives, process and outcomes of the project to agree and sign the BIM Execution Plan
	Conducting a site analysis and apply an outline planning permission if necessary to create a site model
Conceptual design	Using models to create architectural, structural, MEP design implementation to obtain a coordinated design model
	Development of cost estimations based on the architectural cost models to deliver preliminary cost estimate
Design Development	Maintain and update architectural models, structural models and MEP models in preparation for regulatory submission
	Development of cost estimates for MEP services based on the MEP model
	Carry out design coordination among the Architectural models, Structural models and MEP models
	Referring the design models, produce detailed cost approximation and BOQs using a standard method of measurement

As revealed by the research group of Penn State University (PSU, 2019), site analysis is prepared for evaluating the sites within a given area to select the optimum site location for the project. As explained by the US General Services Administration (2019), the BIM Execution Plan (BEP) which can be identified as a foundational framework ensuring effective adherence of design technologies in a BIM implemented project is used to deliver a management plan for the project data and allocate responsibilities and accountabilities for modeling and data integration at project initiation stage.

Accordingly, based on the literature findings, the BIM enabling processes in construction project's initial stages can be summarized under each main work stage as in table 2.7.

Table 2.7 BIM enabling processes in pre-construction phase

Work stage		BIM enabling activities
Project appraisal	1	Identification of project life cycle, desires related to facilities management of the building and potential restrictions on development to reflect the importance of identifying of the client's necessities related to BIM including identifying the implementation scope and commissioning BIM surveys and investigation reports.
Design brief	2	Identifying the scope of the project and come to an agreement on needs, intentions, procedure and products of the project plan to identify the BIM inputs, outputs and scope and to agree and sign the BIM Execution plan
	3	Identification of project organizational structure and defining roles, responsibilities and authorities of the members to define long-term responsibilities including implementing standard methods and procedures; identify the ownership of model early in the project; and to demonstrate the team member's proposed approach, proficiency, capability and skill to achieve the EIR
	4	Creating and maintaining project specific names and codes following provided standards for efficient access of information
	5	Adopting a CDE approach and agree on an appropriate information hierarchy to allow creation, sharing and publishing of project related information within the project team
	6	Agree on data exchange processes
	7	Properly defining the EIR and key decision points using formal contracts to establish BIM execution plan
	8	Conducting a site analysis to create a site model

Table 2.7 BIM enabling processes in pre-construction phase (Cont'd)

Work stage		BIM enabling activities
Conceptual design	9	Formal agreement by the team members on the project quality plan and change control protocols which is required to establish the BIM execution plan
	10	Identification of key elements to create concept level 3D models for all major elements for providing basis for implementing BIM execution plan
	11	Establishing the project origin and orientation ensuring the consistency of project grid and site context
	12	Create all models adhering to a common project orientation which comprises a conventional Cartesian axis and same measurement unit
	13	Adopt a quality policy to ensure the maintenance of models over their life times
	14	Defining information in models
	15	Using models to create architectural design
	16	Development of cost estimations based on the architectural cost models to deliver preliminary cost estimate
Design development	17	Sharing project data for coordinating the architectural and structural designs; conducting technical analysis; and improving specification details to develop the design
	18	Using computer-generated simulations to create architectural, structural, MEP design implementation to obtain a coordinated design model
	19	Conducting in-depth analysis regarding design models to assist design development process
	20	Maintain and update architectural models, structural models and MEP models to use as regulatory submissions
	21	Development of cost estimates related to MEP services based on the developed MEP model
	22	Using design models to generate detailed cost estimates and BOQs developed as per the agreed standard of measurements
Technical design	23	Delivering technical designs and specifications with sufficient details to export for planning application
Production information	24	Establishing project data with adequate information to assist data sharing while concluding design co-ordination, conducting detailed analysis with subcontractors and to initiate specialized work
	25	Modeling all key building elements referring supplier's information to initiate specialized work
Tender documentation	26	Providing the 3D design model to the contractor for reference while tendering
Tender action	27	Evaluating the proposal by the supplier/ contractor with regard to his approach, proficiency and capability to deliver the required information before contract award

Accordingly, it becomes obvious that each work stage of the preconstruction stage of requires adopting significant activities which becomes essential when implementing BIM technology.

After discovering the main BIM enabling processes within the preliminary stages of a construction project, for obtain an overview of the associated construction practice in Sri Lanka, Sri Lankan construction practice and its BIM involvement is observed in the next section.

2.6 Construction practice of Sri Lanka and BIM

According to Jayawardane and Gunawardena (1998), construction industry in Sri Lanka is one of the main contributors of the country's economic growth which requires significant consideration. Further, as revealed by Chanudha, Disaratna, Ariyachandra and Anuruddika (2017), Sri Lanka is a country which habitually adopts a traditional procurement system to procure construction projects.

While describing BIM adoption in countries, Jayasena and Weddikkara (2012) identified BIM as a technological development which can drive the construction industry towards new era. However, as revealed by Nagalingam et al. (2013), incorporation of BIM in Sri Lankan construction projects can result in deviations to the life cycle of a construction project in terms of traditional construction practice. Further, BIM is not identified as a well-established technology adhered in the construction industry of Sri Lanka (Jayasena & Weddikkara, 2012).

As revealed by Ganah, and John (2014), the construction practice requires proper modifications in case to adopt the BIM level 2 in a construction project. Therefore, it becomes obvious that having an industry where BIM technology is not well adhered, Sri Lanka may have differences in construction practice compared to the BIM adopted global construction industries. However, the existing knowledge obtainable through literature does not provide sufficient details to proceed with the study in comparing the BIM enabling construction practice during preconstruction stage of a Sri Lankan construction project.

Therefore, the research focused on obtaining the awareness and experience of the industry experts who are conscious of the Sri Lankan construction practice.

2.7 Summary

This chapter was focused on identifying the process of global construction practice of executing construction projects. While highlighting the importance, this chapter disclosed the core of a construction project's preconstruction stage. Further, the key work phases and the associated work activities under pre-construction phase were identified. Accordingly, pre-construction stage of a construction project was defined with the intention of setting limitations to the study. Subsequent to identifying the main work stages involved in the pre-construction stage, the study was then focused on revealing the processes required to be adopted in order to implement BIM technology. Further, with the intention of providing an overview of the BIM enabling processes in the preliminary phase of Sri Lankan construction projects, background of the BIM implementation in the construction industry of Sri Lanka was observed. The subsequent chapter elaborates the adopted methodology of conducting the study.

CHAPTER 03

RESEARCH METHODOLOGY

RESEARCH METHODOLOGY

3.1 Introduction

This section mainly focuses on setting out the methodological framework that is used to guide this research with the intention of accomplishing the aims and objectives. Demonstration of the research methodology to be adopted in the study under radical sections of research design of the study is done in this chapter.

3.2 Research process

The experience gained as an Architect in Sri Lankan construction industry and the theoretical knowledge acquired during the degree programme on MSc in Project Management has the praise of generating the initial intention of carrying out this study. Eliciting of the research topic was done by further reading of research papers and relevant documents as well as the guidance of the research supervisor. The procedure of this study which is illustrated as in figure 3.1 is expected to be addressed in terms of background study, literature review, research problem statement, choice of the design and designing.

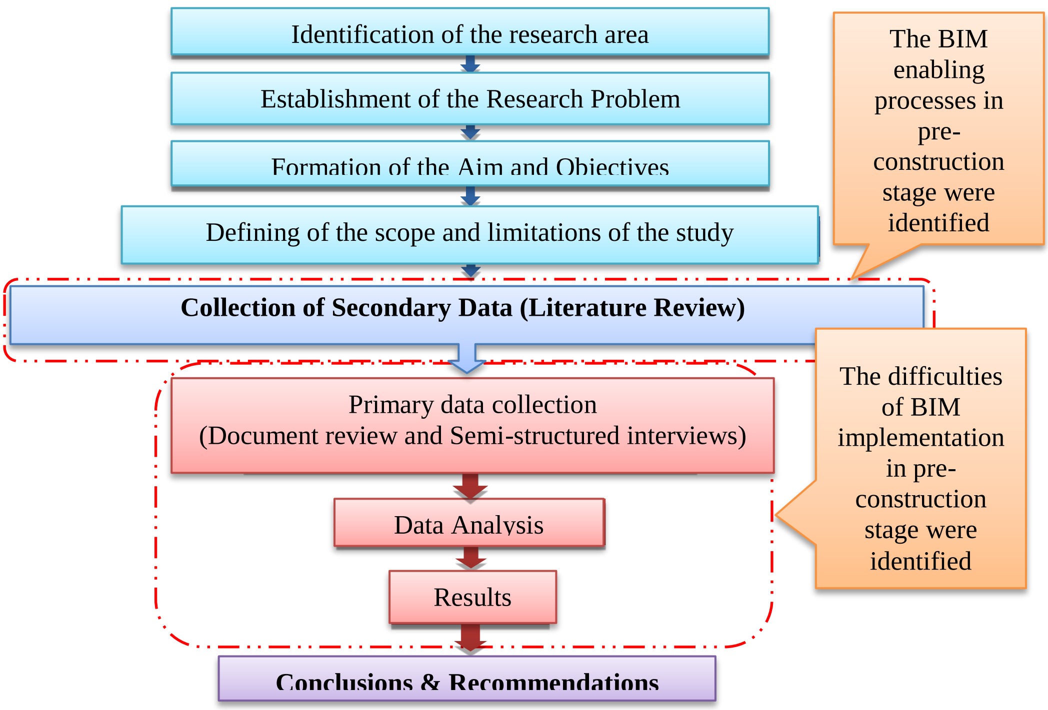

Figure 3.1: Research methodology

3.2.1 Background study

The background study of this research was done with the intention of familiarizing the subject area. In this stage, by referring books, journal publications and other relevant sources it could be identified that the construction industry has not yet focused on identifying the difficulties confronted in the pre-construction stage when implementing BIM in a Sri Lankan construction project. Therefore, an in-depth literature synthesis was undertaken to further clarify this issue.

3.2.2 Literature synthesis

A comprehensive literature synthesis was developed resulting an exploration of the BIM enabling processes in preliminary phase of a construction project and the associated existing practice in Sri Lanka. Further, significance of the BIM technology was discovered as a basis of materializing the research problem. The information was mainly gathered by referring books, research papers publications and journal papers which were published under the subject area. Findings of the literature synthesis were then used to proceed with the research study.

3.2.3 Research problem

Literature review revealed that there is no existing knowledge available with a direct indication of the difficulties that arise in preconstruction stage of a Sri Lankan construction project when implementing BIM technology. Accordingly, with the intention of fulfilling the research gap identified through the literature review, the research problem was defined in a comprehensive manner as 'what are the difficulties that can arise within pre-construction stage when implementing BIM in a Sri Lankan building construction project'. In response to the identified research problem, the research design was established to proceed with the study.

3.2.4 Research design

As per Punch (2005), the combiner between research question and data becomes the design of a reseach. As stated by Noor (2008), nature of the research affects the selection of the method.

According to the elaborated research problem, in order to identify the difficulties in preliminary stage of a Sri Lankan construction project which arise when implementing BIM technology, a detailed exploration of the pre-construction stage of Sri Lankan construction projects becomes compulsory. Therefore, as the initial stage, detailed information such as life cycle of construction projects, main phases in a construction project's preliminary stage, an overview of BIM technology and the enabling processes of BIM implementation in pre-constriction stage of a construction project and associated construction practice in construction industry of Sri Lanka were discussed. Subsequently to analyzing the gathered information, the differences of BIM enabling processes between the global construction practice where BIM is successfully implemented and Sri Lankan construction practice were identified. Based on the identified differences, the difficulties of adopting the global construction practice in Sri Lanka were discovered.

Kraemer (2002) in his research has mentioned that two main categories of methods can be identified for approaching towards a research as quantitative and qualitative. A qualitative study can provide considerable advantages when detailed information is expected (Yin, 2003). Therefore, it can be argued that a qualitative research approach is more applicable for the research as there is a properly organized problem with regard to identifying the differences in construction practice in BIM enabling processes of pre-construction stage between global context and local context to derive the difficulties of BIM implementation in Sri Lanka which requires an in depth study. Accordingly, the study is focused on understanding a specific phenomenon. Further, Feagin et al. (1991) has identified in conditions where general or comprehensive investigation is mandatory, case study can become an ideal methodology. Yin (2003) has also recommended case studies as a suitable method for situations where detailed exploration is expected. As identified by Cousin (2005), the case study method becomes more appropriate for defining cases for better understanding. According to the research problem aims on identifying 'what are the difficulties of implementing BIM technology in pre-construction stage of a Sri Lankan construction project'.

Yin (2003) pinpoints that case study approach becomes more suitable for the research problems which imitate ‘what’ in an explanatory nature. According to Patton and Appelbaum (2003), studies where qualitative data is majorly used can be suitably conducted through case studies. Therefore, based on the above arguments, ‘case study’ method becomes the most suitable method for implementing the study which is elaborated in the subsequent section.

The study interest was on Sri Lankan construction industry in general. While a representative case could give an in-depth understanding, that understanding could be further extended to the industry in general by not limiting the exploratory data to the case as appropriate. The methodology used accommodating this is explained under data collection.

3.3 Case study

According to Noor (2008), main steps of a case study includes selection of cases, conducting interviews, analysis of collected data and writing up of cases.

3.3.1 Case selection

Case selection is mainly focused on two aspects as the identification of unit of analysis and selection criteria of cases.

Unit of analysis

As per Yin (2003), ‘unit of analysis’ becomes the most important aspects in research designs which is interconnected with the way of creating the problem. As the study is focused on identifying difficulties in implementing BIM in preconstruction stage of Sri Lankan building construction project, ‘BIM enabling processes in preconstruction stage of a Sri Lankan building construction project’ is recognized as the unit of analysis for the research purpose.

Number of cases and selection criteria

As identified by Yin (2003), selecting cases for a case study is based on preference, judgment and convenience which become subjective for the research purpose (Yin, 2003). Further, single case can be used when conducting an exploratory case study with the intention of building initial understandings of a situation (Lazar, Feng & Hochheiser, 2017). Since this study requires a comprehensive understanding of the general construction practice adopted in pre-construction stage in Sri Lankan construction projects, single case study was carried out to obtain a frame work to recognize the construction practice in preliminary stages of a Sri Lankan construction project. Accordingly, based on the accessibility for deep information, one case which represents the mostly used procurement method in Sri Lanka with completed pre-construction stage was selected. Data collection is done as the subsequent stage after selecting the cases, which is focused on the next subsection.

3.3.2 Data collection

As identified by Hancock and Algozzine (2017), methods of collecting data including archives, document reviews, interviews, questionnaires, and observations are used in the process of conducting a case study. As per the study, document review and interviews can be identified as the most reasonable and reachable techniques which are depended on the nature of the research as elaborated below.

Document review

Before proceeding with the interviews for data collection, with the intention of identifying the construction practice the selected project in pre-construction stage, reviewing the documents related to the project which described the activities of pre-construction stage had to be done. As revealed by Bowen (2009), document reviews can be identified as a systematic procedure which is used to review or evaluate printed and electronic materials.

Accordingly, main documents available related to the construction practice which included the design presentations, consultancy agreements, e-mails, letters, minutes of meetings, design sketches, design models and drawings, catalogues by the suppliers specifications, submissions for authorities, cost estimates, tender documents, and tender evaluation reports as elaborated in table 3.1 were reviewed to obtain the details construction practice of the selected project.

Table 3.1 Sources referred under document review

Source	Description
Design presentations	Design brief prepared using software such as 'Microsoft PowerPoint' and 'Google sketch up' has been used in the initial stage for introducing the design. Further, physical models could be observed which demonstrated the building envelope.
Consultancy agreements	Agreements between the client and consultants in the project team could be observed. These documents contained the main services expected from the consultant. However, as these documents contained the financial aspects, the document were not fully disclosed for the study
E-mails	The exchanged information through e-mails mainly included drawings; explanations for technical and design issues; and other related matters to the selected project. Further, it could be noted that e-mails which were distributed to several number of recipients had been used as a discussion platform to share ideas and knowledge of the participants through linked e-mails.
Letters	Formal communication among the project team members had been done with the use of letters. Further, letters can be identified as the main mode of communication between the governmental authorities and project team members with regard to the selected project.
Minutes of meetings	Minutes of meetings revealed that the project team has used meetings as one of the modes to communicate the design and technical issues of the project. Knowledge and expertise of the team members for resolving project matters had been shared through meetings.
Design sketches	Handmade sketches which described the design components had been used within the project as explanations exchanged among the project team. Electronic forms of these sketches were stored with regard to the project with the intention of future use.
Design models and drawings	3-D models of the selected project had been developed using software such as ‘Sketch up’ and 2-D design drawings had been prepared mainly using software such as ‘AutoCAD’. Further, both electronic versions as well as hard copies have been shared among the team members to exchange the design details.
Catalogues by the suppliers	Material selection for major elements of the selected building had been done using catalogues provided by the suppliers. The designs had been developed in detail using the specifications and appearance which had been provided through these documents.

Table 3.1 Sources referred under document review (Cont'd)

Source	Description
Specifications	Architectural, structural and MEP specifications had been shared among the project team members in both electronic copies and hard copies. These documents indicated the specification of materials to be used in construction of the selected building.
Submissions for authorities	Hardcopies of design drawings which were printed in A1 size had been submitted to the authorities for obtaining regulatory approvals.
Cost estimates	Cost estimates of the project could be identified mainly in two documents named as 'Preliminary budget estimate' and 'Bills of Quantities'. The preliminary budget estimate provided a general idea of the client's probable budget which was prepared considering the key building elements based on the gross floor area of the project.
Bid documents	Bidding documents of the project included the conditions of contract, drawings, specifications and other relevant information required for the contractors to prepare and submit their quotation. Further, hard copies of these documents had been distributed among the contractors.
Bid evaluation report	A paper based bid evaluation report for selection of the contractor had been issue to the client which provided the details on recommendations for selecting the most suitable contractor for the project. This document further indicated the justifications for the selection.

The data that could be obtained by the documents referred in table 3.1 have also been considered while conducting the case study data analysis.

Semi-structured interviews

With the purpose of covering the same areas of data collection along with sufficient flexibility of reaching different respondents can be enabled by semi-structured interviews (Noor, 2008). Sekaran (2003) stressed that, face-to-face mannered interviews facilitates the researcher to capture the nonverbal traces from the respondent. Further, as identified by Drabble, Trocki, Salcedo, Walker and Korcha (2016), some researchers have discovered telephone conversations as a viable alternative for conducting interviews for qualitative studies due to its flexibility in scheduling and enhanced logistical convenience. Therefore, both face-to-face and telephone interviews were conducted in semi structured method to identify the local construction practice in relation to the revealed BIM enabling processes through the literature review and to recognize the difficulties that may arise in the case it is accorded with the global practice.

Selecting interviewees

With the purpose of maintaining the eminence of the collected data, main professional parties related to the selected project were interviewed. The professional experience, the time period involved in the project and duties and responsibilities had been given a high consideration in selecting the interviewees as the information required is mainly based on the experience gained through pre-construction stage. In addition, the awareness of the personnel on construction process was considered when selecting the interviewees.

This had to be done with the assistance of the Lead Consultant of the project who was engaged in the project from the initial stage. Accordingly, 10 interviewees including the Client, Architects, Structural Engineers, Quantity Surveyors and MEP Engineers were selected. The general information of the selected interviewees and the mode of interview are described as in the table 3.2.

Table 3.2 General information of interviewees and mode of interview

Interviewee reference	Designation in the selected project	Experience in construction industry	Mode of interview
CR	Client's Representative	7 years	Telephone
LC	Lead Consultant	15 years	Face-to-face
AR1	Architect	8 years	Face-to-face
AR2	Architect	6 years	Face-to-face
SE1	Structural Engineer	10 years	Face-to-face
SE2	Structural Engineer	4 years	Telephone
MEP1	MEP Engineer	8 years	Face-to-face
MEP2	MEP Engineer	3 years	Telephone
QS1	Quantity Surveyor	12 years	Face-to-face
QS2	Quantity Surveyor	4 years	Telephone

Further, to capture the data in an appropriate way, an interview guideline has been prepared referring to the literature review.

Interview guideline

The interview questions were developed in a manner that covers several objectives of the study. The findings of the document review were considered while preparing the interview guideline to maintain the quality of the interviews.

Other than endorsing the findings of document review and understanding the characteristics of the preliminary phase of the Sri Lankan construction projects through the selected project, the foremost intention of the guideline was to focus on identifying the differences between the global and local practice in BIM enabling processes. In order to generalize the findings of the study, the inquiries were extended to explore the interview's general practical knowledge and experience. Therefore, the structure of the interview was mainly based on the process as illustrated in figure 3.2.

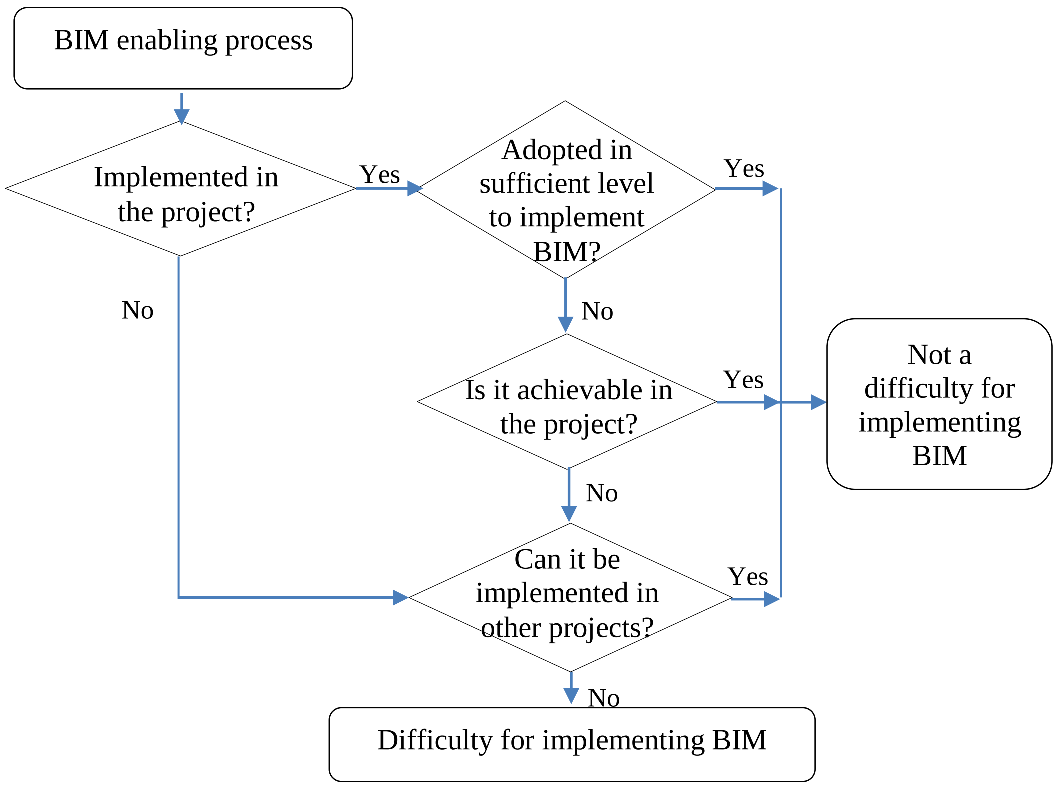

Figure 3.2: Flow of semi-structured interviews

As elaborated in the figure 3.2, each identified BIM enabling process was examined within the local construction practice. The initial concern was to identify the implication of the BIM enabling process in the selected project. In case it is available within the local practice, the extent of its implementation was explored identify its applicability for BIM implementation.

In case the enabling process did not meet the requirements up to a level to implement BIM, the applicability of the same in other projects was inquired to ensure the globalized opinion of the selected industry professionals. Accordingly, the reasons which limit the implementation of enabling processes were strained for identifying the difficulties on implementing BIM technology in preconstruction stage of a Sri Lankan construction project. As the involvement of some professionals were limited to specified project stages, BIM enabling processes were inquired from the interviewees based on their involvement in the project (see Appendix A for an interview guideline)

Interview process

The interviews were conducted in semi-structured manner with professionals selected under subsection 3.3.2. With the permission of the interviewees, the conversations were tape-recorded to assist in developing accurate interview transcripts (Appendix B).

In this research, 10 interviews which each typically continued for 15 minutes to 75 minutes were carried out. The following subsection elaborates the analyzing process of the collected data from the study.

3.3.3 Analysis of the collected data

The purpose of analyzing the data gathered was to understand the differences in construction practice between global context and Sri Lanka in terms of BIM enabling processes. The BIM enabling processes extracted through the literature review were identified as codes while proceeding with the research analysis. The data analysis for this research is done with the use of 'content analysis' as described subsequently.

Content analysis

As identified by Guthrie, Petty, Yongvanich and Ricceri (2004), content analysis is a technique which codifies the qualitative information in to predefined categories which can be introduced as 'codes'. These codes made it convenient patterns while presenting and reporting the information.

Qualitative data analysis can also be done through qualitative data analysis software available. While carrying out the analysis of this research, version 12 of the software program 'NVivo' launched by QSR (Qualitative Solutions and Research Ltd.) is selected as it facilitates better management of complexly structured data and comprises more features than the other versions. Researchers like Johnstone (2007) discovered that NVivo has the ability of handling very complex coding of texts. Therefore, it can be argued that this computer generated software which facilitates convenient interpretation of relationships is a greater advantage for this research.

Conclusion drawing and verification

Miles and Huberman, (1994) stated that conclusion drawing and verification involve clarification and extracting significance from the provided data. Uncovering patterns, determining meanings, establishing conclusions and building theories are identified as the utmost goal of a case study (Patton & Appelbaum, 2003). Therefore, emphasizing of the findings of the study; the interrelationships with existing literature and intentions of this study to both theoretical and practical aspects is done under conclusions.

3.4 Validity and reliability of the research

As identified by Golafshani (2003), when carrying out a design of a research; analyzing the extracted results; and judging the eminence of the research, validity and reliability are two important aspects to be considered. Yin (2003) has recognized four tests that can be used to appraise a qualitative research as construct validity, internal validity, external validity and reliability which can be elaborated and related to the study as in table 3.3

Table 3.3: Validity and reliability of the research

Test	Procure in the research
Construct validity	*Applying multiple data collection and analysis methods*: The multiple data collection includes document reviews and semi-structured face to face interviews. Different kind of literature, qualitative data analysis through content analysis
	Selection of interviewees: The selection had been done in a manner where the most suitable interviewees are selected related to the case
Internal validity	*Linking data to the framework*: Analytical framework in conducting the study *Logical analytical process*: Reference to literature while result generating

Table 3.3: Validity and reliability of the research (Cont'd)

Test	Procure in the research
External validity	*Logical case selection:* Adapting logical criteria for selecting the case
Reliability	*Well-defined research methodology*: Following rational order of steps

While proceeding with the study towards the achievement of objectives, several difficulties had to be overcome which are explained in the next section.

3.5 Difficulties of the research

Identification of the BIM enabling activities under the pre-construction stage can be recognized as one of the main difficulties confronted while proceeding with the study. This has been caused due to the various definitions provided by the research authors while identifying the preliminary stage of a construction project.

With the intention of overcoming this difficulty, before proceeding with identifying the BIM enabling activities, study was carried out to establish and define the pre-construction stage which included the characterization of each work stage. Further, selection of a suitable case for the study has been challenging as disclosing project details to collect in-depth information was limited. With the intention of overcoming this challenge, a building project with a multi-disciplinary consultancy team and access to documentation has been selected. Further, in order to access productive information of the project, the attention was directed to selecting a project which has recently completed the pre-construction phase.

3.6 Summary

Establishing the research design and the data analysis procedure was the main purpose of this chapter. According to type of the study, a qualitative approach has been selected. Case study methodology was selected to get a qualitative outcome which was implemented through document review and semi-structured interviews. Furthermore, the measures adopted to heighten the validity as well as the reliability in the research were described. In order to conclude the chapter, the difficulties confronted while proceeding with the study were disclosed.

CHAPTER 04

RESEARCH FINDINGS AND ANALYSIS

CHAPTER 4

RESEARCH FINDINGS AND ANALYSIS

4.1 Introduction

The methodology of the research study has been discussed in the Chapter three and this chapter aims on explicating and analysing the findings of the empirical study. As the data collection had been conducted using two methods, this chapter presents findings and analysis of the research in accordance with the research design. As described in the research methodology, a document review which was followed by semi-structured interviews was conducted in order to reveal the local construction practice of BIM enabling processes in pre-construction stage and its differences when compared with the global practice in a descriptive manner, and to reveal the difficulties in achieving the global practice in Sri Lanka. To proceed with the data analysis, the background of the selected project was discovered as elaborated in the subsequent section.

4.2 Background of the selected case

The empirical study was carried out focusing on one selected project where details could be achieved to discover the construction practice in the pre-construction stage of the project. Further, the availability of involvement of experienced professionals under the pre-construction stage was given priority while selecting a case. Main details of the designated case can be summarized in table 4.1.

Table 4.1: Details of the projects

Aspect	Details
Type	Mixed development project
Project status	Ongoing
Project Cost (Rs.)	815 Million
Project Duration	18 months
Duration of the pre-construction stage	4 months
Involved key parties in the pre-construction stage	Client, Lead consultant, Architect, Quantity Surveyor, MEP consultant
Procurement method	Conventional method (separated)
Scope	Mixed development including office complex and apartments
Location	Colombo

After identification of background of the selected project, data relevant for the study was collected through the document review and interviews with project team of the selected case. The analysis was conducted considering the main work stages of pre-construction stage as identified through the literature review which can be demonstrated in figure 4.1. Accordingly, the data analysis was carried out to identify the associated processes in preliminary stages of existing construction practice in Sri Lanka; to compare the identified construction practices to determine the differences influencing BIM implementation; and to examine the difficulties of implementing the samenas described in the subsequent sections.

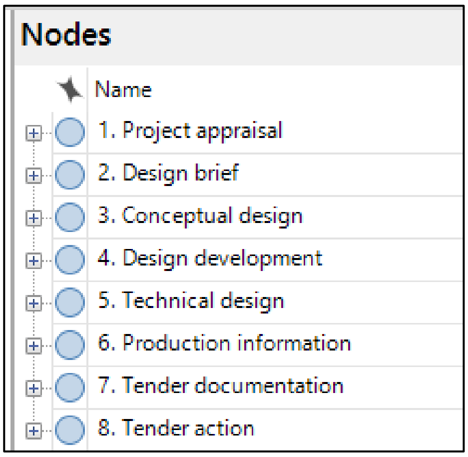

Figure 4.1: Work stages in preliminary phase of a construction project
(Please refer Annexure C for complete coding structure)

4.3 Project appraisal stage

As revealed by the literature review, BIM enabling processes carried out in project appraisal stage mainly include identifying the life cycle of the selected project; expected facilities management desires; and potential restrictions that can be confronted on the development which can be illustrated as in figure 4.2.

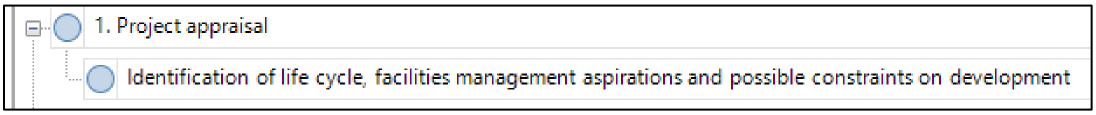

Figure 4.2: BIM enabling processes in project appraisal stage
(Please refer Annexure C for complete coding structure)

4.3.1 Identification of life cycle, facilities management aspirations and possible constraints

The document review revealed that there are no proper documentations which indicate the identification of facilities management aspirations or feasibility in the selected project. According to CR, the intention of initiating the selected project was to invest on a profitable business. Therefore, after investigating the site location and the market conditions, the company management has decided to proceed with an office complex as the project. Further, as per CR, a need of identifying the life cycle or facilities management aspirations has not arisen in the initial stage when the decisions were made to select an office complex. In addition, while explaining the appraisal stage of the project, LC stated that client did not indicate his requirements regarding the identification of project life cycle, facilities management and project feasibility. This was further confirmed by his statement ‘Client had only a basic idea about his requirements. The scope was not finalized in this stage’. Further, as disclosed by LC, a feasibility study which is normally carried out before initiating a project in Sri Lanka was not done in the selected project as the client was in firm decision to proceed with an office complex building. However, as per LC, the required permissions from the government authorities were obtained before proceeding with the project design. In addition, LC mentioned that the client’s focus was mainly on the profitability of the project which resulted in changing the project scope in the design stage from office complex to mixed development expanding to include both office space and apartments. This was further confirmed by his statement *‘client changed his mind based on the market conditions’*. In addition, while elaborating his industrial exposure, LC stated that in-detail identification of project life cycle, requirements related to facilities management and forthcoming limitations is not done in general practice of Sri Lanka. Consequently, it becomes obvious that even though literature findings revealed that the life cycle of the project, desires of facilities management and expectable limitations of a construction project should be properly defined in the initial stage, replicating the Sri Lankan general practice, the selected construction project has not firmly adhered in identifying the same descriptively.

However, as revealed by LC, this process could have been achieved in the selected project in the event adequate time and cost is allocated by the client which can be identified as a difficulty as the client was unable to afford and was under a strict time frame.

Therefore, as per the empirical discoveries, it can be identified that providing adequate time and funds as difficulties in achieving the global practice under identification of project life cycle, establishing requirements related to facilities management and evaluating possible restrictions in Sri Lankan construction practice.

4.4 Design brief stage

The BIM enabling processes adopted in the design brief stage include identification of project scope and formal agreement on desires, intentions, procedures and results of the project plan; identification of project organization structure and defining roles, responsibilities and authorities; creating and maintaining project specific names and codes; adopting a CDE approach; agree on data exchange processes; proper defining of the EIR and key decision making requirements through contracts; and conducting site analysis which can be presented as in figure 4.3.

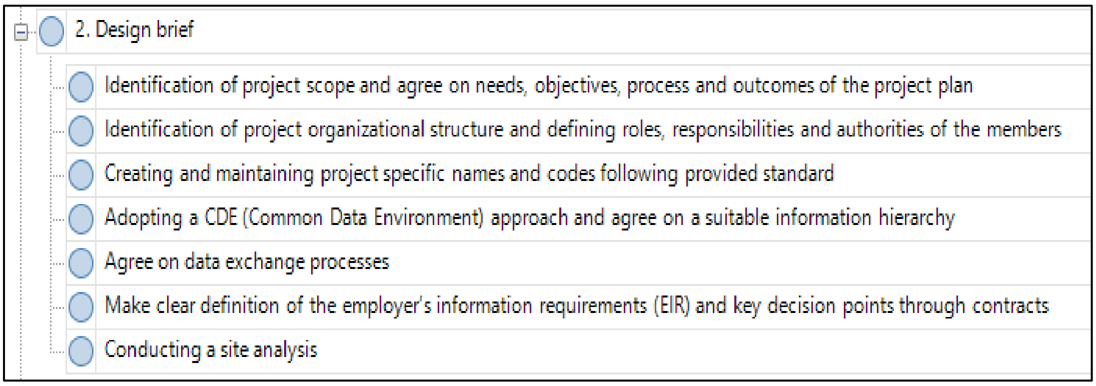

Figure 4.3: BIM enabling processes in design brief stage
(Please refer Annexure C for complete coding structure)

4.4.1 Identification of project scope and formal agreement on desires, intentions, procedures and results of the project plan

The document review disclosed that design presentations which were mainly prepared using software such as 'Microsoft PowerPoint' and 'Google sketch up' have been used by the LC in the selected project to demonstrate initial design concepts in the design brief stage. It could be observed that the presentation was mainly focused on introducing the project design aspects to the project team members and as revealed by LC, the decisions on selecting the design concepts from the provided possible alternatives have been done in this stage.

However, proper identification of the project scope and formal agreement on desires, intentions, procedures and results of the project plan could not be visible during this stage. As stated by LC, the project requirements cannot be considered as finalized in this stage as the client tend to change the scope of the project during the conceptual design stage considering the available market condition. This was further confirmed by the CR's comment *'we had to think about the financial side of the company and profitability of the project outcome'.* It was the opinion of LC that the client should be provided with possible alternatives while implementing a project. Therefore, it becomes obvious that even the literature findings revealed that the scope of a construction project should be properly defined in the initial stage in order to properly adopt BIM which is formally agreed to be adhered through a BIM execution plan, the practice in the selected project has not achieved the expected level.

As stated by CR, scope of the project could not have been confirmed in this stage as the focus was mainly on obtaining a profitable building within a minimum duration due to an internal concern in the company. Therefore, based on the empirical findings, it becomes obvious that allocating adequate time for decision making has become a difficulty in adopting the identified BIM enabling process to the expected level can be achieved in the local construction practice.

4.4.2 Identification of project organization structure and defining roles, responsibilities and authorities

As stated by CR, formal assignment of the team members was handled by the LC. Further, as elaborated by LC, the team was suggested for the client's approval and the selections were made based on the selections of the client. As revealed by LC, even though the main consultants including the structural engineer and quantity surveyor were selected in this stage, the MEP consultant was selected during the conceptual stage. Consultancy agreements between the client and the consultant team members observed under document review revealed that the main duties and accountabilities of each and every member of the project team had been assigned in terms of contractual contract.

However, the terms and conditions of the contractual agreements do not provide any details regarding creation, development and ownership of project models which is identified as one of the main aspect considered while assigning roles, responsibilities and authorities in a BIM implemented project. As revealed by the AR1, the consultancy agreement contained only the main duties to be followed by the team members and role and responsibilities were not provided in writing. This was further affirmed by SE1 who stated *'the duties were not given in writing, but the main role was given in the initial stage'*. Further, it was noted that requirement of design models was not conveyed by the client in this stage. However, as revealed by AR2, considering the goodwill and the relationship with the client, the design team has delivered a 3-D model of the building envelop to the client in design development stage without imposing additional chargers. Document review revealed that the MEP consultant has submitted a BOD (Basis of Design) for the client's comments which indicated the services provided by the MEP consultant. However, indication of time-line for delivery of each service or requirements on 3-D model delivery was not referred in this document. The same was indicated referring to the consultancy agreement by MEP1 by stating *'consultancy agreement indicated the major duties. But the time lines were not given'*.

Accordingly, it becomes obvious that even though BIM implementation requires a project to possess a properly defined organization chart to ensure the roles, responsibilities and authorities are assigned and adhered throughout the project implementation, local practice in identification of project organizational structure and defining responsibilities and authorities of the team members does not meet the requirements of the global practice.

As revealed by LC, defining the roles and responsibilities in detail becomes difficult in local practice as the team members become reluctant to get certain responsibilities such as coordination with other disciplines. However, as per MEP2, being a project consultant, agreeing on duties provided through a written document in a descriptive manner can be followed in local practice without confronting unavoidable difficulties.

Therefore, it can be identified that even though local practice does not meet the required level of identification of project organization structure and defining roles, responsibilities and authorities in design brief stage, the same can be matched to the global context without major constraints.

4.4.3 Creating and maintaining project specific names and codes

As revealed by the document review of the project, even though the team members use same name for the project, the project codes followed by each party within their internal team differed. Accordingly, numbers and codes used in documents including drawings can be identified as different based on the originator which can be exemplified through figure 4.4.

Figure 4.4: Difference in code systems used by different consultants

This difference in numbering system was further confirmed by SE2 who stated *'the coding system we used for this project was totally different from what other parties used'*. Further, as explained by the MEP2, numbering system of the MEP drawings issued for the selected project was based on the internal reference numbers. However, as revealed by the QS2, the drawings provided by the LC contained the same pattern including the drawing dockets. This was further explained by the SE1's statement *'the drawings were sent to the LC for coordination. So using different codes was not an issue to proceed with the project'.* In addition, as revealed by LC, team members of different disciplines who develop the project design use different codes when naming 'layers' of design in software such as 'AutoCAD'. Therefore, even though adhering to accepted project names and codes is identified as one of the main requirement when adopting BIM in a construction project, it was noted that the selected project has not followed the same to meet the requirement of BIM implementation.

SE2 stated that *'adopting the same code will make the work complicated. It will require training the draftsmen which will take a long time. But it is not impossible'.* Further, as revealed by AR1, using different coding systems in a single company which handles several small projects becomes confusing for the employees. As a result, there is a tendency for making the internal works more complex. Further, LC stated that getting the agreement of other team members on this regard can be difficult as it lead to complications. However, while sharing the details of his professional experience in the construction industry, MEP1 stated that there are some projects where all team members used the same name and codes for developing the designs. Further, LC stated that a motivation or obligation imposed by a government authority for adopting this system as a standard becomes essential for obtaining the agreement of all construction professionals for using same coding systems in a project which is not convenient in the local context. Therefore, it becomes obvious that absence of the government initiative for imposing information standards is a difficulty in local context for achieving the global practice.

4.4.4 Adopting a CDE approach

As revealed by the document review, the information including design drawings and models among the team members has been shared using communication methods such as e-mails and letters. This was further confirmed by SE2 who mentioned *'e-mails were used for data sharing of the project'*. Further, MEP1 stated that the team members were not agreed on a specific method for data sharing within the project. In addition, document review revealed that consultant meetings have taken place in relation to the selected project for resolving design concerns. This was assured by LC who revealed that while e-mails were used for exchanging the drawings and details, design issues were shared and during the discussions carried out in consultant meeting. Moreover, as per QS1, letters were shared when informing formal concerns by a team member.

However, while sharing his industrial exposure in the Sri Lankan construction industry, MEP2 revealed that software such as 'Aconex' have been used for data sharing in local projects which facilitates the requirement of a CDE (Common Data Environment). In addition, MEP2 revealed that while adopting such facilities can become costly, it can require a considerable effort on training of the company employees which most of the local clients cannot afford. Therefore, it becomes obvious that although establishing a CDE (Common Data Environment) which facilitates data sharing in a secured platform is an essential requirement for implementing BIM in a successful manner, the selected project has not adopted the same in a satisfactory level. However, as per the empirical findings, CDE can be properly adopted in local context in the event adequate funds can be allocated and required training can be provided to the local employees which can be identified as a difficulty in the local context.

4.4.5 Agree on data exchange processes

No documentation could be observed through the document review which indicates the agreement among team members with regard to the data exchange process of the project.

Non-availability of an agreement on data exchange process within the project was further confirmed by MEP1 who stated that *'nothing regarding data exchange process was mentioned in the consultancy agreement'*. As stated by LC, mutual understanding of the team members is used in the selected project for exchanging data within the project. Even though BIM adoption requires agreeing on a data exchange process in the initial stage of the project, the same has not been followed in the selected project.

However, as per MEP2 and SE2, as a team member of the project, adhering if there is a requirement for agreeing on a data exchange process within the selected project can be done without confronting difficulties. Conversely, while elaborating his opinion, AR2 stated that *'agreeing on a data exchange process that is suitable for all team members can be agreed if responsible government authorities can be directed to establish proper guidelines or laws, which is not easy'*. Accordingly, it becomes obvious that an agreement on data exchange process which is required effective BIM implementation has not been followed in the selected project. However, adoption of the same in a manner for BIM execution can be expected in the event where proper guidelines are provided by the regulatory authorities which can be challenging to attain in local context.

4.4.6 Clearly defining the EIR and main decision making requirements through contracts

Even though consultancy agreements, certain e-mail communications and minutes of meeting identified through the document review indicated the employer's requirements, sufficient material on the employer's requirements in relation to information acquiring could not be extracted through these documents which can be used as the EIR for BIM implementation. This was further affirmed by CR who stated *'our requirements on information on project during this initial stage of the project were not clear as our main concern was achieving the financial targets'*. Further, as revealed by MEP1, even though there were no requirements defined by the client, as the MEP consultant of the selected project, MEP services including developed drawings were offered under the consultancy service.

In addition, SE2 stated that there was no requirement by the client for providing 3-D models in relation to structural design of the selected project. Moreover, AR2 stated that although a clear definition of client's requirements on information was mentioned in the consultancy agreement, the drawings required to be delivered in each stage of the design development has been denoted. In addition, as per AR2, in order to maintain the goodwill and business relationship, architectural 3-D models of the selected project have been shared with client by the architectural team, without imposing additional chargers, upon receiving a request by the client in design development stage. Therefore, although establishing clear definitions of the EIR (Employer's Information Requirement) in the design brief work stage is identified as a main requirement to implement BIM in a construction project, the selected project has not fulfilled the same in a satisfactory manner.

AR1 stated that *'generally Sri Lankan clients are not aware about the information that can be obtained from a construction project. They need to be educated about the receivable information in order to define the information requirements in the initial stage of the project'.* Moreover, LC stated that if the information requirements of the client were informed in the initial stage of the project, the same could have been defined and agreed through contracts with consultant team subject to an additional fee.

Accordingly, it becomes obvious that even though the client's requirements and key decision points are not defined in a satisfactory level in the early stage of the selected project for appropriate BIM implementation, the same can be achieved by making the client aware about information adoptability and allocating required funds which can be difficult based on the attitude of the client and his financial restrictions.

4.4.7 Conducting site analysis

The document review revealed that there is a 3D model which illustrates the actual site condition of the project including contours. Further, the soil investigation report and survey plans which can be treated as a site analysis provided sufficient details to satisfy the requirements for BIM implementation as revealed through the literature survey.

The conducting of site analysis for the selected project to create a 3-D model was confirmed by the LC by his statement *'we created a 3-D model using Google sketch up for identifying the actual site condition of the selected project for deciding the building orientation'*. Accordingly, it becomes obvious that conducting site analysis in the project to be used in creating a site model for successful BIM implementation has been achieved satisfactory in the selected project.

4.5 Conceptual designing phase

BIM enabling processes in conceptual design phase be illustrated as in figure 4.5.

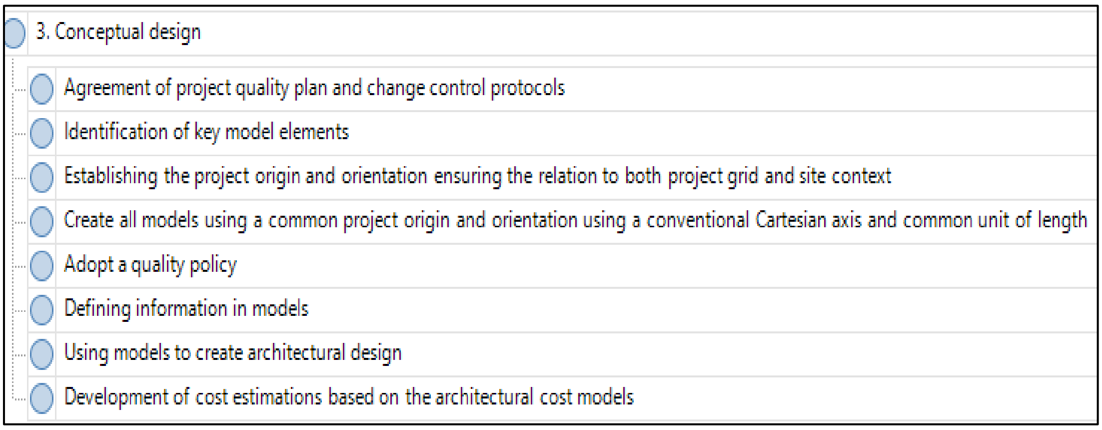

Figure 4.5: BIM enabling processes in Conceptual design stage
(Please refer Annexure C for complete coding structure)

As per figure 4.5, these processes include formal agreements established for adopting project quality plan and change control protocols; identification of key building elements for modelling; establishing the project origin and orientation ensuring the consistency of project grid and site context; create all models referring equivalent project origin and alignment; adopt a quality policy; defining information in models; using models to create architectural design; and development of cost estimations based on the architectural cost models.

4.5.1 Formal agreements established for adopting project quality plan and change control protocols

Documents review carried out referring to the project documentation revealed that there are no formal agreements on project quality plan or change control protocols in the selected project which are required for proper BIM implementation.

This was further confirmed by LC's statement *'there was no written document about the quality plan or change control of the project. But quality of the end product was considered when preparing the material specifications'*. Further, as revealed by SE2, even though there was no formal agreement on change control, in practice, the minor changers had been addressed without imposing additional costs to the client. In addition, SE2 stated that *'the term minor is not defined anywhere'*. Moreover, AR2 revealed that schematic design drawings were used for BOQ preparation of the project which confirmed that client was properly aware about the possible variations in the construction stage. Describing the construction practice in conceptual design stage of the local context, AR1 stated that *'Sri Lankan architects do not depend on the documentation. They prefer going to the actual site and impose design changes while the construction work are in progress. Therefore, the designing is a continuous process throughout the project'.* As stated by AR1, a finishing schedule had been adopted in the selected project which was firmly followed throughout the design stage. Further, as per AR1, this schedule can be identified as an attempt for controlling the quality of the project. In addition, LC disclosed that quality plans are not formally established in the initial stage of a local project. Accordingly, it becomes obvious that even though design changes were expected and controlling the quality was required, a formal agreement on controlling the design changes or adhering to a project quality plan in the pre-construction stage were not established in the selected project.

However, as revealed by LC, if there is an agreement on quality plan and change control, the decision making of the project would have been much convenient. As stated by MEP1, in the event these agreements were established, as a team member of the selected project, adhering to the same would not require confronting any difficulties within the local context. Therefore, it is discovered that a quality plan and change control protocol of the project can be agreed in the design concept stage without confronting major difficulties.

4.5.2 Identification of key model elements

Document review of the study revealed that design elements were mainly shared in 2-D formats through 'pdf' of 'dwg' files. This was further confirmed by AR1 who mentioned that designs were developed using drawings instead on 3-D models. Further, AR1 stated that *'3-D models created for the project were not shared formally with the other consultants. They were only used for explaining the design aspects'*. Further, as revealed by AR2, the design architect uses handmade pencil sketches to create the 3-D views of the designs to develop design drawings saving the effort and time which requires for 3-D model development to achieve the same outcome. In addition, SE2 stated that structural 3-D models were not created for the selected project as there was no requirement.

However, MEP1 exposed that certain MEP systems including AC system, lighting system and water system were created in 3-D models for clear demonstration of the design. Further, MEP1 mentioned that *'we prefer using design calculations and 2-D drawings over 3-D models as developing a 3-D model takes more time and effort where we can get the same result by using calculations and drawings'*. Accordingly, it becomes obvious that even though BIM enabling requires identification of key model elements, the selected project has used 2-D drawings as a substitute for 3-D models in conceptual design development stage.

Nevertheless, as revealed by AR1 and AR2, 3-D modelling of the project can be conducted if the required software for modelling can be provided. As stated by AR1, *'I don't think the currently used 3-D modelling software like Google sketch up can be used for 3-D modelling of building elements as it takes a lot of time. Instead, software like Revit Architecture can be used, but it needs properly trained team members and it is very costly'.* As revealed by the research findings, it can be stated that creating 3-D models in conceptual stage can be achieved by adopting a suitable modelling software and providing proper training for the design team members which can be identified difficulties in the local context.

4.5.3 Establishing the project origin and orientation ensuring the relation to both project grid and site context

Design drawings discovered through the document review revealed that the project design is developed under different disciplines using the same grid lines. This was further affirmed by SE1 who stated 'we referred the same grid lines provided by the architect in his architectural design drawings'. Further, as revealed by AR1, *'orientation of the building was decided considering the climatic conditions, from façade, rear façade and contextual responses'*. Accordingly, it becomes obvious that the local practice in establishing the project origin and orientation was done in a manner to satisfactorily achieve the practice level of global context for successful BIM implementation.

4.5.4 Create all models referring to the same project origin and orientation using a conventional cartesian axis and common measurement unit

As per the findings from the document review, it could be observed that design development was mainly based on 2-D drawings. Further, a limited number of 3-D models were available which demonstrated the design of the selected project. This was reiterated by AR1 by stating *'working out on space and form required 3-D models. But these were not detailed models. Only the envelope of the building was shown with these models to explain the design to other members'*. In addition, representing the Structural design development teams, SE2 stated that models were not created in the project. However, as per MEP1, certain elements of the project were created as 3-D models and the orientation of the models was created based on a common axis and using the same measurement unit.

Therefore, empirical data revealed that creating all models referring to the same project origin and orientation using a conventional Cartesian axis and common measurement unit which is identified as a BIM enabling process in conceptual design stage was adopted in the selected project in the available 3-D design models.

4.5.5 Adopt a quality policy

Through the document review, a limited number of 3-D models could be observed in the selected project. As stated by AR1, when developing the design models, the main focus was on the overall finish of the model. Further, AR1 mentioned that *'there were no standards adopted when creating the design models. Only the framework established within our company to maintain the work quality was followed'*. While explaining the effort on maintaining the model quality, MEP1 stated that *'as per the current practice, quality of the models created by each team member is not argued by the others. So having a proper policy can help in maintaining the required model quality'*. Therefore, it is obvious that even though successful BIM implementation required adhering to a quality policy, the selected project has not adopted a quality policy for maintaining the quality of the created design models.

However, according to MEP1, in the event such requirement is imposed, it can be adhered without reluctance. Therefore, it becomes obvious that if the project design is developed using 3-D models, adopting a quality policy without confronting difficulties to ensure the quality of the 3-D models can be expected in local context.

4.5.6 Defining information in models

As revealed by the document review, 3-D models created for the selected project does not contain definitions of information. Explaining the reasons, AR2 revealed that *'as Google sketch up is used for creating models, defining the details is not easy and very time consuming. A huge effort is needed for that'*. Further, SE2 stated that defining information in model was not required in the project as the structural design was created using 2-D drawings. Accordingly, it becomes obvious that practice in the selected project does not involve information defining of the project model.

However, AR1 stated that *'if the right software can be provided, defining information in models will not be difficult'*. As further elaborated by AR1, software such as 'Autodesk Revit' provides in-built facilities to define information in the model in a convenient manner. Moreover, as per AR2, engaging properly trained team members who can work with 3-D modelling software can assist in defining information in 3-D models.

Therefore, empirical findings revealed that defining information in 3-D models which is identified as a BIM enabling process can be implemented in local context in the event proper software and training is provided which is identified as difficult to attain.

4.5.7 Using models to create architectural design

Document review carried out for the selected project revealed that architectural designs were demonstrated using 2-D drawings. This was further confirmed by AR2 who stated *'normally we used pencil sketches and drawings to do the design'*. In addition, AR2 mentioned that basic design of the building has been illustrated using a 3-D model. However, it could be observed that the models only contained the basic building envelope which demonstrates the design concept of the project.

Accordingly, it becomes obvious that using models for creating the architectural design which is required for implementing BIM in a successful manner in a construction project has not been followed in the selected project.

AR2 stated *'using models for creating the design is a heavy work load which needs suitable software and adequate knowledge in using them'*. Further, as revealed by AR1, *'Architects who use free hand sketches for developing the designs would be reluctant to use software for their work'*. Accordingly, as revealed by the study, it can be stated that the difficulty in adopting 3-D models for creating the architectural design in local context can be mitigated by providing required software and training which is identified as a difficulty in Sri Lankan context. Further, changing the attitudes of well-established professional architects practicing in Sri Lanka can be a difficulty in adopting the BIM enabling processes.

4.5.8 Development of cost estimations based on the architectural cost models

Findings from the document review of the study revealed the availability of preliminary cost estimate of the project. While elaborating the process of preparing the cost estimate, QS1 stated *'fully detailed architectural model or cost models were not shared with us and we used the 2-D drawings for the estimation. But some 3-D model images were informally given to us to understand the design concepts'*.

Therefore, it can be observed that development of cost estimations based on the architectural cost models has not been followed in the selected project.

While explaining the difficulties of using 3-D models for deriving cost estimations, QS2 stated that cost estimations cannot be effectively prepared with the available software in local context which are used to create 3-D models by the architects. Accordingly, QS2 stated *'3-D models can be used to provide cost estimations if the correct software and required knowledge can be provided'*. Therefore, based on the empirical findings, it can be identified that development of cost estimations based on the architectural cost models which is identified as a BIM enabling activity in pre-construction stage can be promptly followed in the event suitable software and required training can be provided which is identified as difficult to adopt in local context.

4.6 Design development stage

The BIM enabling activities under design development of a construction project as revealed by the literature review can be illustrated as in figure 4.6.

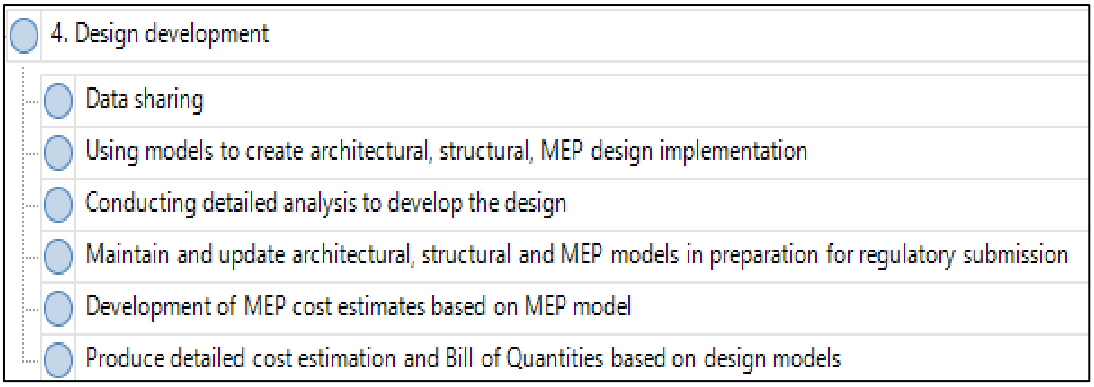

Figure 4.6: BIM enabling processes in Design development stage
(Please refer Annexure C for complete coding structure)

These activities include data sharing; using models to create architectural, structural, MEP design implementation; conducting detailed analysis to develop the design; maintain and update architectural models, structural models and MEP models in preparation for regulatory submission; development of MEP cost estimates based on MEP model; and produce comprehensive cost estimates and BOQs based on design models.

4.6.1 Data sharing

As revealed by the document review, exchanging information for design coordination, analysing technical aspects and improvement of specification data to develop the design within the project has been done using e-mails and consultancy meetings. Further, as per MEP2, phone calls and Whatsapp messages had been used for the same. In addition, AR2 stated that *'a person for coordinating the design was internally assigned within the company'*. Explaining the design coordination process, AR1 mentioned that *'we mark the design changes of drawings and share with each team member. In addition to sending an e-mail, sometimes we give a call to each member to explain the design changes'*. Therefore, it becomes obvious that even though literature review revealed data sharing in BIM implemented project is achieved through a properly established CDE, the modes used in the selected project do not reach the expected advancement.

However, considering the possible returns of adopting an advanced method of data sharing within the project, AR1 shared his opinion as *'having software to share the coordination details would have made this process much easier'*. In addition, as per MEP1, if such advancement is to be adopted in a project, suitable software and required knowledge on usage need to be provided which is not convenient in local context.

4.6.2 Using models to create architectural, structural, MEP design implementation to obtain a coordinated design model

As revealed by the document review, design models have not been used to provide the coordinated design of the selected project. The coordination drawings created in 2-D could be observed which had been used as the coordinated design. However, as revealed by LC, although a coordinated design model was not developed in this stage, the selected contractor for the construction works were assigned to create a coordinated model before proceeding with execution. Therefore, it becomes obvious that using models to create architectural, structural, MEP design implementation to obtain a coordinated design model in the design development stage which is identified as a BIM enabling activity is not achieved in the selected project.

Sharing his opinion, LC stated that in the event models are required for each design by the consultant team members, it may have to be agreed in the consultancy agreement considering the additional fees. In addition, MEP1 stated that *'creating models would require knowledge in software such as Autodesk Revit. Acquiring both the software and required knowledge can be very costly'*. However, as the creation of coordinated design models in Sri Lankan context is evidenced after engagement of the contractor in the selected project, it becomes obvious that using models to create architectural, structural, MEP design implementation to obtain a coordinated design model is attainable in local context subject to providing required knowledge and software to the employees which can be difficult in the local practice.

4.6.3 Conducting detailed analysis to develop the design

Team members' attempt for conducting detailed analysis was revealed by the document review where technical inquiries and clarifications which were exchanged through e-mails and consultancy meetings could be observed. As revealed by AR1, *'we had to go through the designs given by other team members while developing the detailed designs to identify the design clashes'*. Further, as per AR2, '*the analysis of the design concepts was done referring to the drawings provided by the others*'. Accordingly, it becomes obvious that conducting detailed analysis of the design models to develop the design is an enabling activity for BIM technology in a construction project, it could not be identified in the selected project due to the unavailability of design models for developing the project design.

However, as revealed by LC, if the models are used for design development by all team member who possess the required skills and technology, this process could have been achieved in the selected project. In addition, as revealed by AR2, conducting detailed analysis while developing may require additional time for completing the design. Therefore, it becomes obvious that conducting in-depth analysis referring data models to develop the design can be expected in Sri Lankan context in the event adequate time, skills and technology can be provided which is considered a difficulty.

4.6.4 Maintain and update architectural, structural and MEP models for statutory submissions

Document review revealed that submissions for the regulatory bodies for obtaining approvals and permissions for the selected project had been done using paper based 2-D drawings. This was further confirmed by LC who mentioned that *'the government institutions only accept 2-D design drawings. Therefore, 3-D models were not submitted'*. While explaining the process of obtaining regulatory approvals, MEP1 stated that *'we only submitted calculations related to MEP works'*. Therefore, it becomes obvious that even the maintaining and updating architectural, structural and MEP models to refer which preparing submissions for regulatory authorities for approval is required for BIM implemented projects in global context, it is not recognized as a necessity in the local context.

However, as revealed by AR1, if the government impose any requirement to submit 3-D models for obtaining approvals and permissions, proving 3-D models may be required even it become practically difficult. Therefore, as discovered through the empirical data, proving 3-D design models for authority submissions can be achieved in the local context if there is a necessity created through governing laws which is challenging to attaint.

4.6.5 Development of cost estimates of MEP services referring to MEP models

Document review of the study revealed that the development of MEP cost estimates had been done by the MEP consultants assigned for the project. This was further confirmed by QS1 who mentioned *'preparation of the MEP cost estimate prepared in the design development stage was done by the MEP consultant as we did not have the technical capacity give accurate estimates within our company'*. As revealed by the MEP2, the MEP cost estimates were mainly based on the 2-D drawings. Further, as mentioned by MEP2, even though 3-D models were created for demonstrating MEP systems adopted within the project, they had not been directly used for developing the MEP cost estimates. Therefore, it can be observed that even though BIM implementation requires development of cost approximations of MEP services referring MEP model, the same has not been followed within the selected project.

While elaborating the difficulties of developing cost estimates using a MEP model, MEP1 stated that *'using models for getting the estimate will require recruiting people with both technical and software knowledge'.* Accordingly, it becomes obvious that providing software and training for the employees which is difficult in the local context can assist in developing cost estimates of building services based on virtual MEP model.

4.6.6 Produce comprehensive cost estimation and BOQs referring virtual design models

As per the document review carried out within the project, the detailed cost estimation is mainly in accordance with the drawings provided by the design team of the selected project. QS2 who stated *'models were not used for deriving the detailed cost estimate'* confirmed the findings of the document review. Accordingly, the requirement of producing comprehensive cost estimation and generating BOQs referring design models in a BIM implemented project has not been achieved in the selected project.

As revealed by QS1, 'if the estimate to be derived from a 3-D design model, the correct software should be provided. For instance, if the models created with software such as *'Google sketch up' are to be used for cost estimation, it can be very difficult to take measurements as it is not user friendly'*. Therefore, it becomes obvious that producing comprehensive cost estimation and BOQ based on design models of the project can be achieved in local context in the event a suitable software and required knowledge can be provided which can be identified as a difficulty.

4.7 Technical design stage

The BIM enabling processes adopted in the technical design stage mainly include Preparation of technical designs and specifications which can be presented as in figure 4.7.

Figure 4.7: BIM enabling processes in Technical design stage
(Please refer Annexure C for complete coding structure)

4.7.1 Preparation of technical designs and specifications

As per the findings from the document review, it can be observed that technical designs and specifications have been developed within the selected project. Further, it could be noted that certain specifications were referred to the general descriptions available and established in the construction industry of Sri Lanka. Further, it was distinguished that the technical designs and specifications do not contain descriptive details to meet the requirement of BIM implementation. This was further confirmed by MEP1 who stated *'we do not mention the brand names of the products in specifications and only focus on technical requirements to be achieved within the project'*. In addition, confirming the same, SE1 stated that *'we do not provide detailed designs or specifications to recognize planning aspects. We mainly focus on the design aspects'*. Accordingly, it can be identified that preparing technical designs and related specifications with details in a satisfactory level to export for planning application, which is recognized as a BIM enabling activity is not being practiced in the local context.

As revealed by SE2, if providing detailed designs and specifications is a necessity for a project, it would be acceptable if adequate time can be allocated. Accordingly, it can be discovered that technical designing and specification generation with adequate details to export for planning application can be expected in Sri Lankan context if sufficient time is allocated for the process which is however restricted by the client's requirements.

4.8 Production information stage

Literature review revealed that BIM enabling processes adopted in the production information stage include project data development; and modelling all major building elements of the project which can be presented as in figure 4.8.

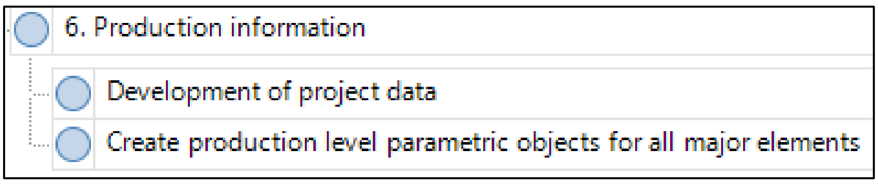

Figure 4.8: BIM enabling processes in production information stage
(Please refer Annexure C for complete coding structure)

4.8.1 Development of project data

Document review revealed that tender drawings performs the role of the concluded coordination drawings of pre-construction stage in the selected project. However, as evidenced by LC's statement *'the selected contractor was assigned to create a 3-D model to minimize coordination issues of the design'*, it is obvious that the coordination of the selected building design has not been achieved in to a satisfactory level in the pre-construction stage. By defending this situation, AR1 stated that *'we were under a strict time line and the details provided by the other team members were not sufficient to conclude perfect coordinated drawings'*. This was further confirmed by AR2 who stated *'client wanted to start the construction work early. So there was less time for completing the design'*. In addition, as revealed by LC, there had not been any engagement of the subcontractors for the selected project in this stage. In addition, it could be observed that no performance specified work has been commenced in the production information stage of the selected project. Therefore, it becomes obvious that development of project data in sufficient detail for sharing data in a manner facilitating the design co-ordination conclusion; and conducting comprehensive analysis with subcontractors to initiate specialized work has not been achieved up to an acceptable level to adopt BIM in the selected project.

However, AR1 stated that *'if the time frame was planned properly, this could have been done'*. Accordingly, it becomes obvious that providing adequate time for completion of the design can result in achieving the requirement of BIM implementation in the local context which is however identified as difficult.

4.8.2 Creating detailed models for major building elements of the project

As revealed by the literature review of the selected project, the details of the specialist suppliers and contractors had been referred through the catalogues published detailing the product and material information. Further, 3-D models which incorporated the information by the suppliers and contractors could not be visible during the literature review. However, as explained by the AR1, the building design which was created using 2-D drawings had been incorporated with the details obtained from the suppliers and specialist contractors.

This was further confirmed by MEP1 who mentioned *'we request details from the suppliers when there is a request for identifying the dimension or match the requirements of the architect. For example, we had to contact several suppliers to get the specifications when designing the lighting system of the project'*. Accordingly, it becomes obvious that even though the building design has been created including supplier's information, creating production level models for key building elements has not been achieved as the design is developed using 2-D drawings. As revealed by SE2, even though no models have been created for the project referring the details received from the selected suppliers, if required software and training can be provided, this can be achieved in the Sri Lankan construction industry.

Therefore, it can be observed that creation of production level models for key building elements including supplier's information can be achieved in local context in the event required technology and knowledge can be provided which is identified as difficult in the local practice.

4.9 Tender Documentation stage

The BIM enabling processes which can be recognized in the tender document stage mainly includes enabling access to design model to contractor which can be illustrated as in figure 4.9.

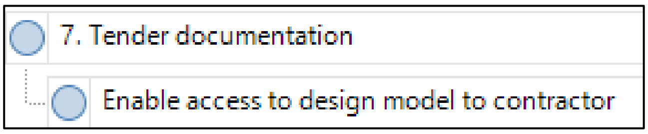

Figure 4.9: BIM enabling processes in tender documentation stage
(Please refer Annexure C for complete coding structure)

4.9.1 Enable access to design model to contractor

As per the findings from the document review, it can be identified that mainly 2-D drawings and specifications had been shared with the contractors who expected to bid for the selected project. This was further confirmed by QS1 who stated that *'contractors were requested to collect the bid documents and these documents mainly included drawings, specifications, BOQ and conditions of contract'*.

While explaining the data sharing with the contractors, LC revealed that *'we did not share any 3-D models with the bidders. All details were given through printed documents. However, softcopies of the drawings were shared in 'dwg' format in later stages'*. Accordingly, it becomes obvious that even though the BIM implemented projects required to share a design model with the contractors during the tender stage, the same has not been followed in the selected project. While explaining the difficulties of providing a design model to contractor during tender stage, QS2 stated that 'Sri Lankan contractors don't have the capacity to use a 3-D model for bidding'. However, as revealed by LC, the contractor who was selected for work execution created a 3-D model of the building using a software 'Autodesk Revit'.

Therefore, it becomes obvious that it is not impractical to adopt this process in Sri Lanka if proper facilities including skills and technologies are provided to the local contractors which is practically not convenient in the local practice.

4.10 Tender action stage

Evaluation of contractors and suppliers in terms of their provided approach, proficiency and capability can be identified as the main BIM enabling processes in the tender action stage. These processes can be illustrated as in figure 4.10.

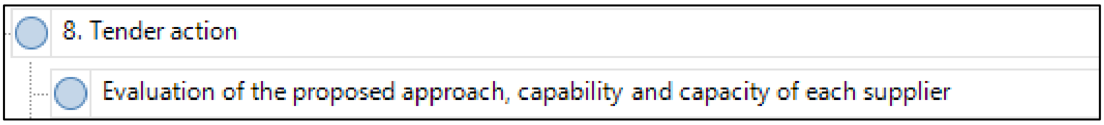

Figure 4.10: BIM enabling processes in tender action stage
(Please refer Annexure C for complete coding structure)

4.10.1 Evaluation of the proposed approach, capability and capacity of each contractor

Literature review of the study revealed that a formal evaluation of the bidders had been done by the QS consultant of the project. As it could be observed, the evaluation has been mainly focused on the final aspect. This was further confirmed by the QS2 who mentioned *'only a cost evaluation of the contractors was done in this project'*.

Therefore, it becomes obvious that evaluation of the tenderers in terms of their provided approach, proficiency and capability to succeed the information requirement prior to contract award has not been sufficiently achieved to meet the requirements of BIM implementation in the selected project.

However, as revealed by QS1, a technical evaluation of the bidders is done in general practice of Sri Lanka. Further, as revealed by LC, *'mainly technical evaluation in Sri Lanka is done for special construction projects like tunnelling. We don't carry*-out *in-detail technical evaluations for normal building and road projects'*. While elaborating the difficulty in achieving the global practice, QS2 stated that *'if an in-detailed technical evaluation is required, it is possible in Sri Lankan projects only when adequate time can be allocated'*. In addition, as per SE1, finding professionals with the required knowledge and expertise to evaluate the technical aspects of a contractor in-depth can be a challenge in Sri Lankan construction industry. Accordingly, it becomes obvious that the requirements for BIM implementation in relation to evaluation of the tenderers in terms of their provided approach, proficiency and capability can be accomplished if the required expertise and time can be allocated which is difficult to achieve in the local context.

4.11 Summary of research findings

Based on the analysis of collected data relevant for the selected project, the summary of findings under local practice of BIM enabling processes; differences between local and global practice under BIM enabling processes; and difficulties in achieving global practice of BIM enabling processes in local context can be summarized as in table 4.2.

Table 4.2: Summary of the research analysis

Work stage	BIM enabling processes	Local practice of BIM enabling processes	Differences between local and global practice under BIM enabling processes	Difficulties in achieving global practice of BIM enabling processes
Appraisal	1 Identification of project life cycle, desires related to facilities management of the building and potential restrictions on development to reflect the importance of identifying of the client's necessities related to BIM including identifying the implementation scope and commissioning BIM surveys and investigation reports.	Basic requirements of the client are identified	project life cycle, desires related to facilities management of the building and potential restrictions on development of a project are not identified in-detail in local practice compared to global context	Providing adequate time and funds
Design brief	2 Identifying the scope of the project and come to an agreement on needs, intentions, procedure and products of the project plan to identify the BIM inputs, outputs and scope and to agree and sign the BIM Execution plan	Decisions on basic design aspects are finalized	Project scope is not finalized in the design brief stage in local practice compared to global context	Providing adequate time
	3 Identification of project organizational structure and defining roles, responsibilities and authorities of the members to define long-term responsibilities including implementing standard methods and procedures; identify the ownership of model early in the project; and to demonstrate the team member's proposed approach, proficiency, capability and skill to achieve the EIR	The main duties of team members are defined through consultancy agreements	Descriptive services provided by the team members are not identified and agreed in this stage of local practice. Local practice does not provide a considerable priority for the 3-D design models compared to the global context.	N/A

Table 4.2: Summary of the research analysis (Cont'd)

Work stage	BIM enabling processes		Local practice of BIM enabling processes	Differences between local and global practice under BIM enabling processes	Difficulties in achieving global practice of BIM enabling processes
Design brief (Cont'd)	4	Creating and maintaining project specific names and codes following provided standards for efficient access of information	Design teams of each disciplines use different names and coding systems within the project	Names and codes used for the project differ depending on the design discipline in the local context compared to global context	Imposing obligations through legal authorities.
	5	Adopting a CDE approach and agree on an appropriate information hierarchy to allow creation, sharing and publishing of project related information within the project team	Information within the project are shared using e-mails, letters and consultancy meetings	Adopting software as a CDE for secured sharing of project information is not generally practiced in the local context compared to global context	Providing adequate funds and training for the employees
	6	Agree on data exchange processes	Data exchange is done based on the team members' mutual understanding	Formal agreement on data exchange process is not established in local context compared to global practice	Establishing guidelines by a regulatory authority
	7	Properly defining the EIR and key decision points using formal contracts to establish BIM execution plan	Client's information requirements are informed throughout the project process	Client's information requirements and key decision points are not defined in the design brief stage in local context compared to the global context	Educating the client about information availability and allocating sufficient funds

Table 4.2: Summary of the research analysis (Cont'd)

Work stage		BIM enabling processes	Local practice of BIM enabling processes	Differences between local and global practice under BIM enabling processes	Difficulties in achieving global practice of BIM enabling processes
Design brief (Cont'd)	8	Conducting a site analysis to create a site model	Soil investigation repots are used for developing a 3-D model of the construction site	N/A	N/A
Conceptual design	9	Formal agreement by the team members on the project quality plan and change control protocols which is required to establish the BIM execution plan	Design changes and quality concerns are mainly addressed in the construction stage. A finishing schedule was established in the selected project for maintaining quality of the project finishes	A formal agreements on project quality plan and change control protocols are not adopted in conceptual design stage in local practice compared to the global practice	N/A
	10	Identification of key elements to create concept level 3D models for all major elements for providing basis for implementing BIM execution plan	Conceptual designs are developed using 2-D drawings and handmade pencil sketches	Key model elements are not identified in local practice compared to the global practice	Providing required software and training for employees on 3-D modelling.
	11	Establishing the project origin and orientation ensuring the consistency of project grid and site context	Project origin and orientation are established considering the to both project grid and site context	N/A	N/A

Table 4.2: Summary of the research analysis (Cont'd)

Work stage	BIM enabling processes		Local practice of BIM enabling processes	Differences between local and global practice under BIM enabling processes	Difficulties in achieving global practice of BIM enabling processes
Conceptual design (Cont'd)	12	Create all models adhering to a common project orientation which comprises a conventional Cartesian axis and same measurement unit	2-D design drawings are used in the conceptual design stage. The basic models used for demonstrating the design in the selected project were based on a conventional Cartesian axis and common measurement unit	N/A	N/A
	13	Adopt a quality policy to ensure the maintenance of models over their life times	2-D design drawings are used in the conceptual design stage. The basic models used for demonstrating the design of the selected project were created as per the quality followed internally by the team members	A quality policy is not adopted in local context for maintaining the quality of the created 3-D models	N/A
	14	Defining information in models	2-D design drawings are used in the conceptual design stage. The basic models used for demonstrating the design in the selected project does not indicate definitions of model information	Information in models are not defined in the local practice compared to the global context	Providing required software and training for employees on 3-D modelling.

Table 4.2: Summary of the research analysis (Cont'd)

Work stage		BIM enabling processes	Local practice of BIM enabling processes	Differences between local and global practice under BIM enabling processes	Difficulties in achieving global practice of BIM enabling processes
Conceptual design (Cont'd)	15	Using models to create architectural design	2-D design drawings are used in the conceptual design stage. A basic models was used in the selected project for demonstrating the architectural design	Architectural design is developed using 2-D drawings in local context instead of 3-D design models	Providing required software and training for employees on 3-D modelling; and changing the attitudes of the local practitioners
	16	Development of cost estimations based on the architectural cost models to deliver preliminary cost estimate	The preliminary cost estimate is done using the 2-D design drawings	2-D drawings are used instead of 3D models in local context for providing preliminary cost estimate	Providing required software and training for employees.
Design development	17	Sharing project data for coordinating the architectural and structural designs; conducting technical analysis; and improving specification details to develop the design	Data required for design development is mainly shared through e-mails, phone calls and consultancy meetings	Basic modes of data sharing is used in local context compared to the global context	Providing required software and training for employees.
	18	Using computer-generated simulations to create architectural, structural, MEP design implementation to obtain a coordinated design model	2-D design drawings are used in the design development stage for developing coordinated design. A coordinated design model was created by the selected contractor during the construction stage of the selected project	2-D drawings are used instead of 3D models in local context for providing coordinated design	Providing required software and training for employees.

Table 4.2: Summary of the research analysis (Cont'd)

Work stage		BIM enabling processes	Local practice of BIM enabling processes	Differences between local and global practice under BIM enabling processes	Difficulties in achieving global practice of BIM enabling processes
Design development (Cont'd)	19	Conducting in-depth analysis regarding design models to assist design development process	2-D drawings are used for developing the design	Comprehensive analysis on models are not done to develop the design in local context as 3-D models are not used for design development	Providing required software and training for employees; and allocating adequate time
	20	Maintain and update architectural models, structural models and MEP models to use as regulatory submissions	2-D drawings are created for regulatory submissions	Architectural, structural and MEP models are not maintained and updated for preparing regulatory submissions in local context as per the requirements of the government	Imposing obligations through legal authorities.
	21	Development of cost estimates related to MEP services based on the developed MEP model	MEP cost estimate is created using 2-D design drawings	2-D drawings are used instead of 3D models in local context for providing MEP cost estimate	Providing required software and training for employees.
	22	Using design models to generate detailed cost estimates and BOQs developed as per the agreed standard of measurements	The detailed cost estimate is created using the 2-D design drawings	2-D drawings are used instead of 3D models in local context for providing detailed cost estimate	Providing required software and training for employees.

Table 4.2: Summary of the research analysis (Cont'd)

Work stage	**BIM enabling processes**		**Local practice of BIM enabling processes**	**Differences between local and global practice under BIM enabling processes**	**Difficulties in achieving global practice of BIM enabling processes**
Technical design	23	Delivering technical designs and specifications with adequate details to export for planning application	Technical designs and specifications are developed mainly focusing on the design aspect	Technical designs and specifications are not sufficiently detailed in local context compared to the global context	Allocating adequate time
Production information	24	Establishing project data with adequate information to assist data sharing while concluding design co-ordination, conducting detailed analysis with subcontractors and to initiate specialized work	Design coordination is finalized in the construction stage. Subcontractors are engaged in the construction stage of the project	Project data is not developed in sufficient detail in local context to conclude the design or analyzing subcontractors	Allocating adequate time
	25	Modeling all key building elements referring supplier's information to initiate specialized work	Basic information collected from suppliers are referred when developing the design in 2-D drawings	Modeling of key building elements including supplier details are not created in local context	Providing required software and training for employees.
Tender Documentation	26	Providing the 3D design model to the contractor for reference while tendering	Contractors are provided 2-D drawings to quote for the project	Contractors not enabled access to design model in local context as 3-D models are not used for design development	Providing required software and training for employees.

Table 4.2: Summary of the research analysis (Cont'd)

Work stage	BIM enabling processes		Local practice of BIM enabling processes	Differences between local and global practice under BIM enabling processes	Difficulties in achieving global practice of BIM enabling processes
Tender Action	27	Evaluating the proposal by the supplier/ contractor with regard to his approach, proficiency and capability to deliver the required information before contract award	Evaluation of the bidders is mainly based on the bid price	In-detail evaluation of the contractor is not done in local context compared to the global context	Providing required expertise and allocating adequate time

As revealed through the table 4.2, among the twenty seven (27) main BIM enabling processes identified through literature, three (3) activities are practiced in the local context up to the level that meet the requirements of BIM implementation. Further, six (6) BIM enabling activities practiced in the global context as described in the study can be adopted in the local construction industry without practically confronting major difficulties. However, among the twenty one (21) BIM enabling processes where difficulties were identified in the process of achieving the global practice in the local context, twelve (12) activities were limited by the constraint 'proving training for the employees'. Further, 'providing required software' and 'allocating adequate time' were identified as difficulties of respectively eleven (11) and five (5) BIM enabling processes. In addition, 'educating the client about information availability', 'providing adequate funds', 'establishing guidelines by a regulatory authority', 'imposing obligations through legal authorities' 'providing required expertise' and 'changing the attitudes of local practitioners' which are based on the identified local construction practice can be identified as the difficulties in achieving the global practice in the local context. As per the findings of the research analysis, the study had been directed towards the achievement of ultimate objective of the study.

4.12 Summary

Findings and analysis of the research was mainly focused in this chapter to drive the study towards achieving the ultimate research goal. As elaborated in chapter 3 of the study, the data collection has been done through document review and semi structured interview with the project team of the selected building project. The analysis of the collected data has been carried out with content analysis. The findings of the research analysis revealed the local practice under each main BIM enabling process identified through the literature review. Further the differences between the local practices when compared with the global context of the BIM enabling processes were identified. Finally, with the intention of succeeding the aim of the research, difficulties in adopting the global practice in local construction industry under each work stage of BIM enabling processes were identified. The next chapter concludes the study with conclusions and recommendations.

CHAPTER 05

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

Preceding chapter has been dedicated to elaborate the analysis and discussion of the research findings. The significant findings of the study which directs the study towards the conclusions and recommendations are elaborated in this chapter. The chapter begins with an overview of the research problem which is cross referred to the literature findings. Subsequently, fulfilment of each objective throughout the study is elaborated descriptively to draw the conclusions of the research. Finally, the recommendations derived from the findings of the study are presented in terms of implications to theory and implication to construction industry. The identification of the new research directions emerging from the study was done to deliver a culmination to the study.

5.2 Summary of the study

The fundamental aim of the study was to identify the difficulties of applying BIM in pre-construction stage of current building construction practice of Sri Lanka. In order to achieve this aim, several objectives had to be established and implemented through the research study.

Objective 1: Identify the enabling processes of BIM implementation in pre-construction stage in building construction projects

The first objective of the research had been to reveal the enabling processes of BIM implementation in preconstruction stage in building construction projects. With the intention of achieving this objective, a literature survey had been conducted as the initial stride of the research conduct. According to the literature findings, the main BIM enabling processes could be identified under eight (8) main work stages of a construction project namely project appraisal; design brief; conceptual design; design development; technical design; production information; tender documentation and tender action.

As the intention of the research was to derive the study towards identifying the BIM enabling activities of preconstruction stage, only the work stages categorized under the process before commencement of the construction works were considered.

Objective 2: Identify the associated processes which enable BIM in pre-construction stage of existing construction practice in Sri Lanka

After the identification of main BIM enabling processes in global context, the literature was focused on identifying the associated processes in the local construction practice which had been limited due to the inadequate literate available in the industry which provides descriptive information to identify the difference between local and global practice under BIM enabling processes. In order to carry out the study towards the next objective of the research, the construction practice of BIM enabling processes of Sri Lankan construction industry had been investigated using a case study.

Objective 3: Determine the differences between corresponding processes identified above

The findings of the research assisted in developing a basis for comparing the practice of BIM enabling processes in preconstruction phase of a Sri Lankan construction project with the global practice. Comparison between local and global practice of BIM enabling activities in the preconstruction stage which could be revealed through the document review and interviews assisted in achieving the third objective of the study.

Objective 4: Identify the difficulties to bridge those differences during pre-construction stage in building construction projects in Sri Lanka

After the identification of differences in practice, the difficulties of achieving the global practice in local context in terms of BIM enabling activities of pre-construction stage were revealed through the interviews carried out in semi-structured manner with the team members of the selected project in order to accomplish the final objective of the study.

Based on the findings from the research study which were discovered through the research objective, the conclusions of the study is elaborated in the subsequent section.

5.3 Conclusion

As revealed by the study, the difficulties of implementing BIM technology in Sri Lankan context under each identified BIM enabling method can be summarized as in table 4.2. As elaborated through the table 4.2, the main difficulties that arise during BIM implementation in project appraisal work stage of a Sri Lankan construction project is recognized as the inadequate time and funds, which are generic to many of technological advancements. However, as per the BIM enabling activities discovered in the design brief work stage, the difficulties of BIM adoption extend to imposing obligations through legal authorities; providing training for employees; and educating the client about information. Further, when it comes to the conceptual design work stage, providing required software and training for employees becomes a significant difficulty in implementing BIM technology. Adopting BIM enabling activities under design development stage leads to difficulties such as providing required software and training for employees; allocating sufficient time and funds; and imposing obligations through legal authorities. Furthermore, implementing BIM enabling activities under technical design stage confronts difficulties in allocating adequate time; and providing required software and training for employees. Moreover, providing required software and training for employees is a difficulty identified in tender documentation work stage. In addition, implementing BIM enabling activities under tender action stage confront difficulties including provide required expertise and providing adequate funds.

5.4 Implications and recommendations

The inferences to both theory and the construction industry can be identified from this study and an accordingly the recommendations can be made.

5.4.1. Implications to theory

According to the ultimate aim of the research, the study examine the adoptability of BIM technology to the existing building construction practice of Sri Lanka, mainly in pre-construction stage where a considerable BIM adoptability is visible as well as which can impose a significant impact towards a project success.

As the results are limited to the preconstruction stage of a building construction projects in Sri Lanka, it draws attention to further research developments to increase the applicability through widening the usable scope (see section 5.5).

5.4.2. Implications to construction industry

The outcome of the research study provides a source where the difficulties of applying BIM in preconstruction stage of Sri Lankan construction practice can be identified. The research findings may become significant to be implicated within the construction industry due to several reasons. According to the objectives of the research, the outcome of the study can be used in identifying the expected difficulties in the pre-construction stage when implementing BIM in a Sri Lankan construction project. As the consideration is on pre-construction stage in Sri Lankan construction projects, an overview of the construction practice in local context can be identified by the local clients. Further, using the identified differences in construction practices in local and global context, clients from the global construction industry who expect to invest in Sri Lankan construction industry would benefit when making decision on project imitation.

5.5 Limitations of the research

Since this research focuses on BIM technology, which is currently narrowed to the building construction industry, only the building construction projects has been referred. Further, selection of the interviewees for data collection under the case study had been limited by the experience of the interviewees within the construction industry and the phase involved in the project.

Accordingly the selection had been restricted to ten (10) interviewees who poses both knowledge on the selected project and considerable involvement in the construction industry of Sri Lanka. In addition, the document review was carried out based on the resources available within the project which had been limited depending on the confidentiality.

After identifying the limitations of the research, the next section elaborates the further directions that can be directed from the study.

5.6 Further research directions

Subsequently to identification of the outcome of the study, it becomes important to explore further research directions as discussed subsequently.

Study the mitigation methods of the identified difficulties of implementing BIM in Sri Lanka

The study exposed the difficulties of BIM implementation in Sri Lanka. For providing a comprehensive basis on the BIM application, a further study can be conducted to investigate the methods of mitigating the identified difficulties.

Focus on BIM enabling activities in construction stage of a project

Though the study had been only focused on identifying the difficulties in BIM implementation in pre-construction stage, it can be further developed by directing the area towards focusing the BIM enabling activities in construction stage.

A study which is focused on other developing countries

As the research is aimed on identifying difficulties of BIM implementation in preconstruction practice of Sri Lanka as a developing country, it can be further extended to identify the same in other developing countries in the world.

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APPENDICES

Appendix A: Interview Structure

INTERVIEW STRUCTURE

Interview Guideline

This interview is conducted in order to achieve a successful fulfillment of dissertation under Degree of Master of Science in Project Management at Department of Building Economics, University of Moratuwa. The information gathered will only be used for the purpose of this particular research and to maintain the confidentiality, actual names of the projects or the interviewees will be not be revealed in this report or any other related documents.

The interview guidelines are structured in 2 main headings as;

- General identification
- BIM enabling activities in pre-construction stage

The interviews will be conducted with eleven eligible professionals of the construction industry who were involved in the selected project.

If the permission is granted by the interviewee, note taking and tape recording will be done throughout the interview to ensure the accuracy of collected data. The selected persons will be interviewed based on the following guidelines.

Name of the Interviewee (Optional): ……………………………………………

Designation in the selected project: ……………………………………………...

Date of interview: ………………………………………………………………..

Venue: …………………………………………………………………………….

Duration: ………………………………………………………………………….

Appendix A: Interview Structure

Introduction to the interview

Developing countries which follow a different building construction practice compared to the developed countries confront difficulties in accepting BIM technology due to numerous practical concerns. Thus, it becomes important to examine the adoptability of BIM technology to the existing building construction practice of developing countries, mainly in pre-construction stage of a construction project where a considerable BIM adoptability is visible as well as which can impose a significant impact towards a project success. Hence, this research intends to fill that research gap by studying the difficulties of applying BIM technology in pre-construction stage of current building construction practice of Sri Lanka. The researchers in the construction industry have revealed BIM enabling processes in pre-construction stage under seven key work stages as Appraisal, Design brief, Conceptual design, Design development, Technical design, Production information, Tender documentation and Tender action.

General Identification

1. How long have you been involved in the construction industry?

…………………………………………………………………………………………

2. In what stage did you engage in the selected project?

…………………………………………………………………………………………

BIM enabling activities in pre-construction stage

Kindly answer the following questions under each BIM enabling process described in table 1.

1. Was this activity followed in the project?
2. Up to what extent it was followed?
3. If not achieved the required level to implement BIM, is it achievable?
4. Can the BIM enabling process be adopted in other projects? If not, Why?
5. If the difficulty could be mitigated, would it have been possible?
6. If the BIM benefits were known, would you have adopted?

Appendix A: Interview Structure

Table A1: BIM enabling processes in pre-construction phase of a construction project

Work stage		Requirements for implementing BIM
Appraisal	1	Identification of project life cycle, desires related to facilities management of the building and potential restrictions on development to reflect the importance of identifying of the client's necessities related to BIM including identifying the implementation scope and commissioning BIM surveys and investigation reports.
Design brief	2	Identifying the scope of the project and come to an agreement on needs, intentions, procedure and products of the project plan to identify the BIM inputs, outputs and scope and to agree and sign the BIM Execution plan
	3	Identification of project organizational structure and defining roles, responsibilities and authorities of the members to define long-term responsibilities including implementing standard methods and procedures; identify the ownership of model early in the project; and to demonstrate the team member's proposed approach, proficiency, capability and skill to achieve the EIR
	4	Creating and maintaining project specific names and codes following provided standards for efficient access of information
	5	Adopting a CDE approach and agree on an appropriate information hierarchy to allow creation, sharing and publishing of project related information within the project team
	6	Agree on data exchange processes
	7	Properly defining the EIR and key decision points using formal contracts to establish BIM execution plan
	8	Conducting a site analysis to create a site model
Conceptual design	9	Formal agreement by the team members on the project quality plan and change control protocols which is required to establish the BIM execution plan
	10	Identification of key elements to create concept level 3D models for all major elements for providing basis for implementing BIM execution plan
	11	Establishing the project origin and orientation ensuring the consistency of project grid and site context
	12	Create all models adhering to a common project orientation which comprises a conventional Cartesian axis and same measurement unit
	13	Adopt a quality policy to ensure the maintenance of models over their life times
	14	Defining information in models
	15	Using models to create architectural design
	16	Development of cost estimations based on the architectural cost models to deliver preliminary cost estimate

Appendix A: Interview Structure

Table A1: BIM enabling processes in pre-construction phase of a construction project (Cont'd)

Work stage		Requirements for implementing BIM
Design development	17	Sharing project data for coordinating the architectural and structural designs; conducting technical analysis; and improving specification details to develop the design
	18	Using computer-generated simulations to create architectural, structural, MEP design implementation to obtain a coordinated design model
	19	Conducting in-depth analysis regarding design models to assist design development process
	20	Maintain and update architectural models, structural models and MEP models to use as regulatory submissions
	21	Development of cost estimates related to MEP services based on the developed MEP model
	22	Using design models to generate detailed cost estimates and BOQs developed as per the agreed standard of measurements
Technical design	23	Delivering technical designs and specifications with sufficient details to export for planning application
Production information	24	Establishing project data with adequate information to assist data sharing while concluding design co-ordination, conducting detailed analysis with subcontractors and to initiate specialized work
	25	Modeling all key building elements referring supplier's information to initiate specialized work
Tender Documentation	26	Providing the 3D design model to the contractor for reference while tendering
Tender Action	27	Evaluating the proposal by the supplier/ contractor with regard to his approach, proficiency and capability to deliver the required information before contract award

I would like to thank you for the information given and time you have dedicated to this research. If you are interested to know the outcome of this research, it would be my pleasure to share it with you.

…………………………….
Final year postgraduate
Department of Building Economics
University of Moratuwa

Appendix B: Sample interview script

INTERVIEW STRUCTURE

Interview Guideline

This interview is conducted in order to achieve a successful fulfillment of dissertation under Degree of Master of Science in Project Management at Department of Building Economics, University of Moratuwa. The information gathered will only be used for the purpose of this particular research and to maintain the confidentiality, actual names of the projects or the interviewees will be not be revealed in this report or any other related documents.

The interview guidelines are structured in 2 main headings as;

- General identification
- BIM enabling activities in pre-construction stage

The interviews will be conducted with eleven eligible professionals of the construction industry who were involved in the selected project.

If the permission is granted by the interviewee, note taking and tape recording will be done throughout the interview to ensure the accuracy of collected data. The selected persons will be interviewed based on the following guidelines.

Name of the Interviewee (Optional): ……………………………………………

Designation in the selected project: *Architect*

Date of interview*: 2nd January 2020*

Venue: *Company premises*

Duration: *90 mins*

Appendix B: Sample interview script

Introduction to the interview

Developing countries which follow a different building construction practice compared to the developed countries confront difficulties in accepting BIM technology due to numerous practical concerns. Thus, it becomes important to examine the adoptability of BIM technology to the existing building construction practice of developing countries, mainly in pre-construction stage of a construction project where a considerable BIM adoptability is visible as well as which can impose a significant impact towards a project success. Hence, this research intends to fill that research gap by studying the difficulties of applying BIM technology in pre-construction stage of current building construction practice of Sri Lanka. The researchers in the construction industry have revealed BIM enabling processes in pre-construction stage under seven key work stages as Appraisal, Design brief, Conceptual design, Design development, Technical design, Production information, Tender documentation and Tender action.

General Identification

1. How long have you been involved in the construction industry?

8 years

2. In what stage did you engage in the selected project?

Design brief stage

BIM enabling activities in pre-construction stage

Kindly answer the following questions under each BIM enabling process described in table 1.

1. Was this activity followed in the project?
2. Up to what extent it was followed?
3. If not achieved the required level to implement BIM, is it achievable?
4. Can the BIM enabling process be adopted in other projects? If not, Why?
5. If the difficulty could be mitigated, would it have been possible?
6. If the BIM benefits were known, would you have adopted?

Appendix B: Sample interview script

Table A1: BIM enabling processes in pre-construction phase of a construction project

Work stage		Requirements for implementing BIM
Appraisal	1	Identification of project life cycle, desires related to facilities management of the building and potential restrictions on development to reflect the importance of identifying of the client's necessities related to BIM including identifying the implementation scope and commissioning BIM surveys and investigation reports. *I wasn't involved in this stage. The client first came to the lead consultant/ principal architect.*
Design brief	2	Identifying the scope of the project and come to an agreement on needs, intentions, procedure and products of the project plan to identify the BIM inputs, outputs and scope and to agree and sign the BIM Execution plan *I didn't receive any details of the project scope or client's needs. The principal architect gave us the instruction about developing the design brief. He is the one who directly handled the client.*
	3	Identification of project organizational structure and defining roles, responsibilities and authorities of the members to define long-term responsibilities including implementing standard methods and procedures; identify the ownership of model early in the project; and to demonstrate the team member's proposed approach, proficiency, capability and skill to achieve the EIR *Usually the consultancy agreement contains the main duties that we need to follow. We sign consultancy agreements for all the projects we handle in our office. Most of the time we draft them. Generally it is about how the payment is assigned. That document doesn't contain any written roles and responsibilities in detail. In my career life, I haven't come across detailed roles and responsibilities in a consultancy agreement.*
	4	Creating and maintaining project specific names and codes following provided standards for efficient access of information *When we prepare the drawing, we follow a method that has been practiced within our project. Our company handles several small projects. So having an easy pattern of names and codes is important for us. We have small team within the company. So when someone is not around, we need to ask the help of people who are available in the office if we need to get any detail. So if the document numbers are not in the same pattern within the office use, it will confuse the staff and we won't be able to get any detail if the responsible person is not there. It will complicate our internal work.*
	5	Adopting a CDE approach and agree on an appropriate information hierarchy to allow creation, sharing and publishing of project related information within the project team *The project didn't have software or any special mode for sharing information. When we had to send some thing, we e-mailed the relevant person.*

Appendix B: Sample interview script

Table A1: BIM enabling processes in pre-construction phase of a construction project (Cont'd)

Work stage		Requirements for implementing BIM
Design brief (Cont'd)	6	Agree on data exchange processes *As per my knowledge we didn't have any agreement on how to exchange the data. Usually we send cad or pdf files to the other. If someone said the version is not compatible, we just convert it and send them. Agreeing on something like that in the beginning of the project is not a big issue.*
	7	Properly defining the EIR and key decision points using formal contracts to establish BIM execution plan *We didn't receive any in-writing document about client's information requirements. I think it's because generally Sri Lankan clients are not aware about the information that can be obtained from a construction project. They need to be educated about the receivable information in order to define the information requirements in the initial stage of the project.*
	8	Conducting a site analysis to create a site model *We prepared a site model to decide the suitable building location. We used the data from the soil report for making this.*
Conceptual design	9	Formal agreement by the team members on the project quality plan and change control protocols which is required to establish the BIM execution plan *Sri Lankan architects do not depend on the documentation. They prefer going to the actual site and impose design changes while the construction work are in progress. Therefore, the designing is a continuous process throughout the project. Our principal architect does his designs using his pencil sketches. This depends on the architect and his practice. So I can't say there was any agreement in this project on how to control the changes in the design stage. In this project, we followed a finishing schedule. It was like a frame work. No matter what, the finishes had to be what were given in that schedule. I think we can say that as a quality control process. But there were no formal agreement on that. But if such agreement is there and it is practical, we can follow it.*

Appendix B: Sample interview script

Table A1: BIM enabling processes in pre-construction phase of a construction project (Cont'd)

Work stage		Requirements for implementing BIM
Conceptual design (Cont'd)	10	Identification of key elements to create concept level 3D models for all major elements for providing basis for implementing BIM execution plan
		When moving forward with the design, more 2D drawings were used compared to the 3D models. This is mainly because when developing the design all consultants used 2D sheets. However the 3D was used only for explaining the design features even that happened in such a way when the other consults came to the office and we showed the 3D from our computers. We never share the 3D and even they didn't ask for it. But sometime we gave some images of the 3D models to them to get an idea. So, the 3-D models created for the project were not shared formally with the other consultants. They were only used for explaining the design aspects. Its better if all consultants could work on the 3D but I don't think the currently used 3-D modeling software like Google sketch up can be used for 3-D modelling of building elements as it takes a lot of time. Instead, software like Revit Architecture can be used, but it needs properly trained team members and it is very costly. Sketchup is little bit easier to work for the architectural team but for structural team they cannot use sketch up for their structural designs and it is same for the MEP engineers. They can't do their drawings or designs through Google Sketup. So I think if the correct software is provided, 3-D modeling can be conducted in the project.
	11	Establishing the project origin and orientation ensuring the consistency of project grid and site context
		We used AutoCAD software to draw floor plans with the site plan in relation to a Cartesian origin point and orientation. Whenever we overlap the drawings they are always corresponding. But with other disciplines it is a not easy. They do not follow the common base point or the orientation. Though, they do not draw on a same base location we however manage to orient and locate it as per our convenience. As far as the other consultants are maintaining the grid, the site context it is not a big issue. The orientation of the building was decided considering various aspects such as the climatic conditions, from façade, rear façade and contextual responses'.
	12	Create all models adhering to a common project orientation which comprises a conventional Cartesian axis and same measurement unit
		Working out on space and form required 3-D models. But these were not detailed models. Only the envelope of the building was shown with these models to explain the design to other members. But definitely, if the project used models among consultants and all are working in different origins and orientations the designing can become a disaster.

Appendix B: Sample interview script

Table A1: BIM enabling processes in pre-construction phase of a construction project (Cont'd)

Work stage		Requirements for implementing BIM
Conceptual design (Cont'd)	13	Adopt a quality policy to ensure the maintenance of models over their life times *As architects, when doing the design models, our main concern is on the overall finishing of the model. We don't usually create 3-D models. And there were no standards adopted when creating the design models. Only the framework established within our company to maintain the work quality was followed.*
	14	Defining information in models *There are various software available in the industry for creating design models. The cost and the level of expertise of using those software differs to each other. Some are user friendly and some are not. For an example, software such as Google sketch up are user friendly but don't provide much functions compared to software like 'Autodesk Revit'. When we talk about defining the information in design models, we can't do it properly with Google sketch up. But 'Autodesk Revit' on the other hand has the required facilities to easily define the information. So, if the right software can be provided, defining information in models will not be difficult.*
	15	Using models to create architectural design *In Sri Lanka, most of the traditional architects are using pencil drawings for designing. In my personal belief, it is easier to think and draw what exactly in your mind. Even our principal architect draws the pencil sketches of 3-D view of building angles. They don't like to sit in front of a computer and work. There are some people I know who do the sketches and ask their juniors to get it in to a CAD file. So imagine you asking someone like that to do the design part using a computer. They would definitely refuse it. So I think the Architects who use free hand sketches for developing the designs would be reluctant to use software for their work.*
	16	Development of cost estimations based on the architectural cost models to deliver preliminary cost estimate *This part was done by the QS team*

Appendix B: Sample interview script

Table A1: BIM enabling processes in pre-construction phase of a construction project (Cont'd)

Work stage		Requirements for implementing BIM
Design development	17	Sharing project data for coordinating the architectural and structural designs; conducting technical analysis; and improving specification details to develop the design *Data sharing for design coordination was mainly done by sharing the drawings by the consultants. Once we get their drawings, we go through them to identify any required design changes. We mark the design changes of drawings and share with each team member. In addition to sending an e-mail, sometimes we give a call to each member to explain the design changes. This process is really hard for the architect. So I think having software to share the coordination details would have made this process much easier*.
	18	Using computer-generated simulations to create architectural, structural, MEP design implementation to obtain a coordinated design model *We used design drawings to create the coordination design. It was all 2-D drawings. There were not 3-D models shared between parties. This could have been done if the design was created 3-D models from the beginning.*
	19	Conducting in-depth analysis regarding design models to assist design development process *As I told you, we didn't use models for designing. But when we developed the design, mainly using 2-D drawings, we analyzed the details provided by each consultant. But this was done manually. We had to go through the designs given by other team members while developing the detailed designs to identify the design clashes.*
	20	Maintain and update architectural models, structural models and MEP models to use as regulatory submissions *Usually we submit drawings printed in A1 size for getting the approval from the council. They don't accept 3-D models. But if there is a law saying that they only accept 3-D models, then we will have to submit models for approvals even it is very difficult to us.*
	21	Development of cost estimates related to MEP services based on the developed MEP model *MEP cost was given by the MEP team.*
	22	Using design models to generate detailed cost estimates and BOQs developed as per the agreed standard of measurements *Cost estimation was done by the QS team. But we did not provide them the models for pricing*
Technical design	23	Delivering technical designs and specifications with sufficient details to export for planning application *Technical designs and specifications were done by the structural engineer and the MEP engineer of the team*

Appendix B: Sample interview script

Table A1: BIM enabling processes in pre-construction phase of a construction project (Cont'd)

Work stage		Requirements for implementing BIM
Production information	24	Establishing project data with adequate information to assist data sharing while concluding design co-ordination, conducting detailed analysis with subcontractors and to initiate specialized work
		The client wanted to start the construction works as soon as possible. So we were under a strict time line and the details provided by the other team members were not sufficient to conclude perfect coordinated drawing. In my opinion, the time was not enough for the team members to provide detailed specifications or drawings. Most of the time this happens in Sri Lankan construction projects. Enough time is not allocated for the designing part. But if the time frame was planned properly, this could have been done.
	25	Modeling all key building elements referring supplier's information to initiate specialized work
		As I told you before, the design of this project was developed based on the 2-D design drawings. The other consultants used the same which was given by the architects as 2-D drawings which were based on hard copies or soft copies. Those are the bases used for design development. So the production details were incorporated in the design drawings. Not the models as we did not create detailed modelsfor this project for that use.
Tender Documentation	26	Providing the 3D design model to the contractor for reference while tendering
		Tender documents were prepared by the QS. But in my experience, I know that the contractors are only given drawings for pricing. Not the sign models.
Tender Action	27	Evaluating the proposal by the supplier/ contractor with regard to his approach, proficiency and capability to deliver the required information before contract award
		Selection of the contractor was based on the evaluation given by the QS team.

I would like to thank you for the information given and time you have dedicated to this research. If you are interested to know the outcome of this research, it would be my pleasure to share it with you.

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Appendix C: NVivo coding structure used for data analysis

Nodes

Name

- 1. Project appraisal
  - Identification of life cycle, facilities management aspirations and possible constraints on development
- 2. Design brief
  - Identification of project scope and agree on needs, objectives, process and outcomes of the project plan
  - Identification of project organizational structure and defining roles, responsibilities and authorities of the members
  - Creating and maintaining project specific names and codes following provided standard
  - Adopting a CDE (Common Data Environment) approach and agree on a suitable information hierarchy
  - Agree on data exchange processes
  - Make clear definition of the employer's information requirements (EIR) and key decision points through contracts
  - Conducting a site analysis
- 3. Conceptual design
  - Agreement of project quality plan and change control protocols
  - Identification of key model elements
  - Establishing the project origin and orientation ensuring the relation to both project grid and site context
  - Create all models using a common project origin and orientation using a conventional Cartesian axis and common unit of length
  - Adopt a quality policy
  - Defining information in models
  - Using models to create architectural design
  - Development of cost estimations based on the architectural cost models
- 4. Design development
  - Data sharing
  - Using models to create architectural, structural, MEP design implementation
  - Conducting detailed analysis to develop the design
  - Maintain and update architectural, structural and MEP models in preparation for regulatory submission
  - Development of MEP cost estimates based on MEP model
  - Produce detailed cost estimation and Bill of Quantities based on design models

Nodes

Name

- 5. Technical design
  - Preparation of technical designs and specifications
- 6. Production information
  - Development of project data
  - Create production level parametric objects for all major elements
- 7. Tender documentation
  - Enable access to design model to contractor
- 8. Tender action
  - Evaluation of the proposed approach, capability and capacity of each supplier
  - Review of construction sequence and information provided by contractors and specialists