Improving design briefing with BIM-based concept generation aiming to enhance building project performance.

Supreet Lama

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

School of Computing and Engineering

University of West London

Supervisors:

Dr Charlie Fu

Prof. Joe Rizzuto

Dr Shamil Naoum

July 2023

Declaration of Authorship:

I, Supreet Lama, declare that this thesis titled, 'Improving design briefing with BIM-based concept generation aiming to enhance building project performance' was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or processional qualification.

Supreet Lama

July 2023

Abstract

Design briefing is an essential stage in the building project process (RIBA Plan of Work) and an important activity to ensure that the design and project meet the clients' requirements, design principles and relevant building regulations. In order to deliver a successful building project, it is crucial to effectively understand and capture the overall requirements of the client, and to integrate design, construction, and operation experience in the early stage of design. However, there are some issues with the design briefing methods and techniques that have not been fully resolved. After reviewing some of the advantages of Building Information Modelling (BIM), this study aims to explore BIM-based design briefing methods and techniques through the development of a BIM-based design briefing prototype to promote the efficiency and quality of design briefing and eventually improve the performance of building projects. The study is based on the principles and research methods of software engineering. It started with a series of comprehensive interviews to capture the existing gaps, demands, functionalities and relevant datasets for this proposed BIM-based design briefing prototype tool. Based on the outcomes of the interviews as well as findings from literature, an integrated system framework has been developed in this project to illustrate the major functions and databases for the proposed tool. Eventually, a prototype was developed with Dynamo based on Autodesk Revit. It partially demonstrates the key functionality of this BIM-based design briefing tool. The analyses and discussions address the effect of this BIM-based design method & tool, and the impact on the design briefing process, the overall building project processes, and the potential

improvements in the performance and sustainability of a building project delivery. This study has made potential contributions towards the identification of issues in the existing design briefing processes and methods, and improvement of the design briefing stage with the development of the system framework and the BIM-based design briefing method & techniques. Through this development of the prototype tool, this study demonstrates the implementation of BIM in design briefing and evaluates the demand and feasibility of BIM-based design briefing. Finally, this study explores the potential behind implementing BIM in AI-based design.

Contents

List of Figures i

List of Tables iii

Abbreviations iv

Chapter 1: Introduction 1

1.1 General Background 1

1.2 Problem statement 2

1.3 Research questions, aims and objectives. 4

1.4 Significance of study 6

1.5 Research methods 8

1.6 Thesis organisation 11

1.7 Summary 14

Chapter 2: Literature review 15

2.1 Introduction 15

2.2 Review of design briefing 18

2.2.1 The principles of design brief 22

2.2.2 Traditional design briefing process 25

2.2.3 Design briefing guidance and tools. 29

2.2.4 Stakeholders' collaboration in the briefing process 35

2.2.5 Issues with conventional briefing process 38

2.2.6 The clients in construction 40

2.2.7 Importance of effective communication in the design briefing process. 42

2.2.8 Identification and management of client requirements 45

2.2.9 Past research on design brief 46

2.2.10 Requirement to improve the briefing process........................ 48

2.2.11 Requirements of stakeholder integration in the briefing stage. 50

2.3 Review of knowledge capture and management in the design briefing process. 51

2.3.1 Knowledge capture in design and construction. 51

2.3.2 Knowledge capture in the design briefing process 56

2.4 Review of Building Information Modelling Technology 59

2.4.1 What is BIM? 60

2.4.2 Benefits of BIM 65

2.4.3 Design briefing and BIM 67

2.4.4 Common Data Environment 69

2.4.5 CDE and design briefing 71

2.4.6 Generative design 72

2.4.7 Transition from traditional design to generative design. 74

2.5 Review of relevant research in design briefing with BIM and design automation.. 77

2.5.1 Design automation in architecture. 79

2.5.2 Levels of automation 81

2.5.3 The use of generative design in early design stages. 83

2.5.4 Potential benefits of automation in architectural design. 85

2.6 Limitations and Technical difficulties identified. 88

2.7 Summary 90

Chapter 3: Research methods 93

3.1 Introduction 93

3.2 Research design 93

3.3 Research methods 97

3.3.1 Literature review and desktop study. 97

3.3.2 Identify research problems and develop research questions.. 103

3.3.3 Develop research aim and objectives. 104

3.3.4 Principles of software engineering 105

3.3.5 Interviews 107

3.3.5.1 Semi-structured interview question design. 109

3.3.5.2 Selection of interviewees 111

3.3.5.3 Methods of capturing interviews 114

3.3.5.4 Methods of analysing interview 115

3.3.6 Conceptual system framework development 117

3.3.7 BIM-based prototype tools development 120

3.3.7.1 BIM-based platform development tools and methods...... 121

3.3.7.2 Database for BIM-Based design briefing 123

3.3.8 Testing of prototype.. 124

3.4 Research method justification... 125

3.5 Research ethics and ethical considerations................................. 128

3.5.1 Privacy 129

3.5.2 Incentives 129

3.5.3 Safety 130

3.6 Summary 130

Chapter 4: User requirement interview and analysis........................... 132

4.1 Introduction 132

4.2 Interview questions development... 133

4.3 Interviewees selection.. 142

4.4 Interview process 145

4.5 Thematic analysis process... 148

4.6 Key interviews outcomes 151

4.7 Thematic analysis 157

4.7.1 The issues in existing design briefing process and outcomes 157

4.7.2 Issues in current methods of design briefing 161

4.7.3 Functionalities of BIM based design briefing tools.................. 167

4.7.4 The impact to the overall project performance and process ... 175

4.8 Findings and discussions 179

4.9 Current applications of BIM in briefing process 191

4.10 Issues with implementation of a BIM-based briefing method 194

4.11 Adoption of BIM in the design briefing stage 197

4.12 What can BIM achieve in the briefing stage? 198

4.13 Summary 200

Chapter 5: Conceptual system framework & Prototype development 203

5.1 Introduction 203

5.2 Stages of conventional design briefing 205

5.3 Stages of Design briefing in a BIM-based method 208

5.4 Process of prototype development 212

5.4.1 Major functionalities of BIM-based design briefing tools 213

5.4.2 Conceptual system framework development 215

5.4.3 Verification of the conceptual systems framework 225

5.4.4 Prototype development 228

5.4.4.1 Data repository 228

5.4.4.2 Input Data 234

5.4.4.3 Data processing 234

5.4.4.4 Output result 242

5.4.5 Debugging, testing and improvement 244

5.5 Proposed user interface 248

5.6 Summary 249

Chapter 6: Analysis and Discussion 251

6.1 Introduction.. 251

6.2 Testing and feedback of the system framework and prototype 252

6.3 The potential impact of BIM-based design briefing........................... 256

6.3.1 Impact on building project process. 257

6.3.2 Impact on quality of projects.. 258

6.3.3 Impact on BIM implementation in the design briefing process 261

6.3.4 Impact of early stakeholder involvement 265

6.3.5 Impact on development time of projects. 266

6.3.6 Effective use of POE information... 267

6.4 Technical limitations and potential for prototype development...... 268

6.4.1 Software and hardware 268

6.4.2 Schema development... 270

6.4.3 Building design 270

6.5 Summary 271

Chapter 7: Conclusions.. 274

7.1 Introduction.. 274

7.2 Review of research aims and objectives. 274

7.3 Summary of the research 276

7.4 Knowledge contribution and implication of the research................... 284

7.5 Limitations of research 286

7.6 Recommendation for future research. 288

7.7 Conclusion.. 289

References.. 292

Appendix.. 315

List of Figures

Figure1.1 Thesis structure 11

Figure 2.1 Extract of Schedule of accommodation spreadsheet tool for secondary schools. 31

Figure 2.2 Model of the four principal communication routes 43

Figure. 2.3 BIM capabilities and users 61

Figure. 2.4 The Wedge 64

Figure. 2.5 Architect's issue to SHARED 69

Figure. 2.6 Structural engineer's issue to SHARED 70

Figure. 2.7 MEP engineer's issue to SHARED 70

Figure. 2.8 Design review of models in SHARED 70

Figure 2.9 The process of generative design 73

Figure 3.1 Research design process 96

Figure 3.2: Prototyping model. 106

Figure 3.3 Basic flow of dynamo interface 122

Figure 4.2 Brainstorm diagram based on interview analysis. 179

Figure 5.1 Traditional method of design briefing and BIM activities. .. 206

Figure 5.2 Stages of briefing and conceptual model development with BIM-based briefing 209

Figure 5.3 Process of prototype development 213

Figure 5.4 Initial conceptual system framework development 222

Figure 5.5 One of the finalised versions of the conceptual system framework. **224**

Figure 5.6 Final version of the conceptual system framework. **227**

Figure 5.7 Schedule of Accommodation (SoA) spreadsheet **230**

Figure 5.8 Structuring data from SoA sheet **231**

Figure 5.9 Nodes used to import spreadsheet data. **234**

Figure 5.10 Corridor isolation and width adjustment **235**

Figure 5.11 Set of nodes used to generate spaces. **236**

5.12 Adding space colours from data MS Excel file **236**

Figure 5.13 Division of spaces **237**

Figure 5.14 Space alignment **237**

5.15 Set location of spaces. **238**

Figure 5.16 Add corridor. **239**

Figure 5.17 Creating surface for spaces. **239**

Figure 5.18 Visualise geometry. **240**

Figure 5.19 Set of nodes that generates mass. **241**

Figure 5.20 Generate permutation of spaces. **242**

Figure 5.21 Examples of conceptual plans generated by the script **243**

Figure 5.22 Conceptual model generated on Revit. **244**

Figure 5.23. Example of an error within Dynamo **245**

Figure 5.24 Misaligned depth of spaces. **247**

List of Tables

Table 4.1: Interview questions 134

Table 4.2 List of interviewees 147

Table 5.1 Requirements from a BIM-based design briefing tool.......... 214

Table 5.2: Issues with the process and methods of traditional design briefing... 217

Table 5.3 Limitations set for prototype development. 219

Abbreviations

AEC: Architectural, Engineering & Construction

AI: Artificial Intelligence

AIM: Asset Information Model

AIR: Asset Information Requirements

API: Application Programming Interface

BB: Building Bulletin

BEP: BIM Execution Plan

BIM: Building Information Modelling

BRE: Building Research Establishment

BS: British Standards

CAD: Computer Aided Design

CAM: Computer Aided Manufacturing

CDBB: Centre for Digital Built Britain

CDE: Common Data Environment

CIAT: Chartered Institute of Architectural Technologists

CIRIA: Construction Industry Research and Information Association

DfE: Department for Education

DoH: Department of Health

EIR: Employers' Information Requirements

FE: Further Education

GCS: Government Construction Strategy

GD: Generative Design

HBN: Health Building Note

IFC: Industry Foundation Classes

IPD: Integrated Project Delivery

ISO: International Organisation for Standardisation

KC: Knowledge Capture

KM: Knowledge Management

NBS: National Building Specification

PAS: Publicly Available Specifications

PIM: Project Information Model

POE: Post Occupancy Evaluation

PoW: Plan of Works

PPR: Post Project Review

PRINCE2: **P**rojects **IN C**ontrolled **E**nvironments

RGB: Red-Green-Blue

RIBA: Royal Institute of British Architects

SoA: Schedule of Accommodation

SME: Small and Medium-sized Enterprises

VPL: Visual Programming Language

Acknowledgement

This PhD journey has been a long one and it would not have been possible without the support of many individuals that have helped me along the way.

I would not have been here, at the end of my PhD journey, without the constant support of my principal supervisor, Dr Charlie Fu, who has guided me through some very stressful periods during my PhD. Thank you for having faith in me especially during times when I had lost faith in myself. And thank you for giving me time week in and week out, encouraging me every step of the way.

I would also like to thank my second and third supervisor, Prof Joe Rizzuto and Dr Shamil Naoum, respectively, for their advice and feedback.

This PhD would also not have been possible without assistance from the Graduate School, particularly, the former Head of the Graduate School Prof Stylianos Hatzipanagos, Dr Pauline Fox and Prof Maddie Ohl, who have been there during my time of need. A special thank you to Ms Maria Pennells, who has helped and guided me throughout the years with various issues and endured through my constant phone calls and emails.

There are a few more individuals that I would like to thank for their help and advice. Prof Ali Bahadori-Jahromi for all the guidance during the early days of my PhD, Dr Efcharis Balodimou for your words of support and encouragement, and finally, my fellow PhD researcher Mukhtar Bello Maigari and my dear friend Neeta for helping me with all the proof readings.

I would like to thank my family and friends, particularly my mother and father for raising me to be in this position today. My late grandmother, who could not see me accomplish one of the greatest achievements of my life. And lastly, my lovely wife, Shikha, for being my constant and support through thick and thin. Thank you for trusting in me through all these years and encouraging me to do my best every day.

List of publications

- Lama, S., Fu, C. (2021) BIM and Design Briefing Integration: Feasibility Study and Conceptual System Framework Development, Journal of Construction Research, Bilingual Publishing Co. https://doi.org/10.30564/jcr.v3i1.2960

- Fu, C., Lama, S. (2021) Contemporary Indoor air quality in education buildings and solutions exploration, 2*nd* International Conference for Global Chinese Academia on Energy and Built Environment, 17*th*-19*th* July 2021 in China
- Lama, S., Fu, C., Lee, A (2022) Indoor Air Quality (IAQ) evaluation of Higher Education learning environments, Journal of Smart Buildings and Construction Technology, Vol 4, Bilingual Publishing Co. https://doi.org/10.30564/jsbct.v4i1.4042

Chapter 1: Introduction

1.1 General Background

A design brief is a formal working document that is developed through a briefing process that contains the client's visions, ideas, needs and requirements, which is translated by the design team into a design for construction. BSI (2015, p.4) defines it as the "*process of identifying and analysing the needs, aims and constraints (the resources and the context) of the client and the relevant parties, and of formulating any resulting problems that the designer is required to solve"*. Depending on the size and complexity of a project a design brief can range anywhere from two sides of an A4 sheet to hundreds or even thousands of pages of bound document.

The importance and value of the design brief and the briefing process have been stressed in various literature (e.g., Green, 1996; Hansen and Vanegas, 2003; Ryd, 2004; Tunstall, 2007; Chung *et al.*, 2009; Merchant, 2015). Briefing helps in identifying and analysing the client's needs, aims aspirations and constraints that assist the design team in formulating the design. Hence, it is crucial that a brief contains everything that the design team requires to begin and complete a design effectively. The RIBA Plan of Works (PoW) 2020 also recognises the importance of improving the briefing process if any improvement is to be made to the project outcome.

A design brief also provides strategic value to a project, acting as a guide and a checklist during various phases of a project's lifecycle (Olatokun & Pathirage, 2015). Depending on the quality of the brief, it outlines and explains to the architect about the client's requirements on which the design needs to be based. Similarly, the brief is also used at the in-use stage of a building in order to verify if use patterns and building performance coincide with specifications outlined in the briefing document. Variation between the two indicates deviation from the brief and difference between client requirements and the architect's design or contractor's work (Koutamanis, 2017).

This research seeks to understand the background regarding design briefing and develop a prototype to demonstrate the implementation of BIM into the design briefing stage. Currently, based on the RIBA Plan of Works (PoW) 2020, BIM authoring tool is not required to be implemented in a project until Stage 2 (RIBA, 2020b). However, since BIM has proven to be extremely beneficial, not only in the design stage but also the construction and management stages of a building's lifecycle, this study will also explore the benefits of implementing BIM in the early design briefing stages.

1.2 Problem statement

The AEC is a very fragmented industry with the design, construction and management team working separately from one another, but towards the same goal (Egan, 1994; Evbuomwan & Anumba, 1998; Baiden, Price & Dainty, 2006; Fulford & Standing, 2014).

Through the review of various literatures, three key research problems were identified that were within the scope of this study.

1. The requirements of clients and users are unstructured, non-digitized and non-semantic when conveyed to the architectural team. These requirements

need to be captured through an iterative process and then manually translated by the architectural team into structured and meaningful data in order to develop a design solution.

2. Stakeholders such as the contractors, suppliers, building operation and maintenance managers possess valuable knowledge, experience and expertise regarding the construction and maintenance. They also possess high levels of unstructured but conventional information. However, they are, traditionally, not involved in the design briefing or even the design process (Latham, 1994; Egan, 1998).

3. Traditionally, information from the design brief and the experience and expertise of stakeholders are implemented independently into the project process with BIM embedded at a later stage. The review of literatures does not provide indications of the use of BIM in the design briefing process. The RIBA PoW 2020 only requires the clients to be informed and educated regarding the benefits of using BIM at this stage. However, the actual use of BIM does not begin until stage 2.

4. Complete integration, which would enable lifecycle and asset management, is still not used in the industry today. Majority of projects today use BIM Level 2 or lower, which utilizes a federated model. This means that there is a lack of use of interoperability and automation, where information and data are not wholly integrated.

1.3 Research questions, aims and objectives.

A set of research questions were developed in order to gain a better understanding of the areas of research i.e., design briefing and BIM as well as various sub-topics with the two areas. Those have been listed below.

1. What is the current sentiment towards the traditional process of design briefing?

2. Can the design briefing process be improved with the implementation of BIM, and if so, how?

3. What kind of functions and outputs would a BIM-based design briefing tool require?

4. What kind of advantages could a BIM-based design briefing method present?

The aim of this study was then developed, which is **to develop a framework and BIM-based prototype which can improve the quality and performance of building projects**. In order to achieve the aim, the following research objectives were then developed.

i. Understanding research background relevant theory and techniques and current research.
ii. Exploring users and designers demands of BIM-based design briefing tools/solutions via interviews.
iii. Based on the demands of BIM-based design solutions, develop a system framework to demonstrate general functionalities and data structures of the design briefing system

iv. Based on the system framework, develop a prototype.

v. Testing and analysis of the prototype and discussions of the overall development and industry impacts.

Currently, the architectural team uses manual methods to capture client and user requirements. This is done over a series of meetings, telephone conversations, emails involving numerous sketches and documents. Information provided by the clients and users are generally unstructured, non-digitized and non-semantic, which then needs to be translated into structured information by the design team into a design brief, which is then used to create the outline and detail designs using BIM.

The conventional briefing conducted by the architectural team only involves the clients and the users of the facility, and these briefs mostly focus on the functional and aesthetical requirements of the building. The proposed research, with the help of BIM, will explore methods and techniques to involve stakeholders such as contractors, structural engineers, building services engineers, and operation and maintenance managers. This is done in order to capture their knowledge and experience along with client and user requirements in order to develop a topological data and model. Their involvement will help develop a more holistic and comprehensive design brief and will play a fundamental role in other objective of this research, which is concerned with enabling automation of attaching space and element information into the process and interoperability of information structure. This can be made possible through the development a BIM-based design briefing model. This will have a significant long-term impact on the effectiveness and efficiency of the building project and will promote sustainability of building maintenance and operation over the life cycle of the facility.

1.4 Significance of study

The significance of this study lies in the enhancement of the design briefing process with the implementation of BIM. For the past decade, BIM has been the focal point of the government's strategy to improve the construction industry. The Government Construction Strategy (GCS) 2011-15 (2011), targeted to reduce the cost of public sector construction by up to 20% i.e., around £8.8 billion, but it was only able to achieve a savings of £3 billion. BIM has widely been regarded as a factor that can significantly reduce this cost and improve output of building projects (GCS, 2011; Zghari, 2013; Barnes and Davies, 2015).

Primarily, the focus of this research is on improving the pre-design stages of building projects, particularly stage 1 of the RIBA PoW 2020. Numerous research have taken place with the aim to achieve project success by either improving the briefing methods, the actual design of a project, using innovative materials, changing management techniques or developing briefing tools. However, only a handful of research has taken place where the aim is to improve the pre-design stage by using innovative BIM technology. Hence, this study has developed a BIM-based design briefing tool that can assist in the implementation of BIM in the pre-design stages.

Secondly, this research sought to understand the benefits of including non-design related stakeholders such as project managers, contractors, suppliers, facility and operations managers in the design briefing process. As

BIM is a collaborative process and this study seeks to implement BIM in the pre-design stages, the involvement of these stakeholder in the design briefing process can enhance the quality of the brief. Furthermore, the client as well as the design team can also benefit from their experience and knowledge in the early stages in order to make decisions. And as the BIM-based design briefing process will generate a conceptual model early in the pre-design stages, these stakeholders can also input and attach data to various elements and component of the model, which can be used in the final design developed by the design team.

Currently, there are a few commercial design briefing tools available, however, they are only capable of structuring and managing briefing data and not generating design outputs for the users to analyse and use in their workflow. The tool is not intended to replace a human designer, but to assist them by developing a more efficient method of utilising the data in design briefs to develop conceptual designs.

Finally, this study will assist the construction industry in taking a step towards BIM Level 3. Also known as Open BIM, this level aims to fully integrate and collaborate the design and construction process, with the help of a single model which is interoperable between all stakeholders. The research will begin the process of integration and collaboration between stakeholders at the design briefing process. Here, all data and information related to space and elements are stored in a single BIM file. This data can later be embedded into a BIM model for ease of designing, accuracy checks and assistance in operation and management of facilities.

1.5 Research methods

As outlined earlier, this study seeks to understand the issues within the design briefing process, identify functionalities for a BIM-based solution and to develop a conceptual system framework for a BIM-based design briefing tool and finally develop a prototype tool for the implementation of BIM in the pre-design stages. Firstly, a literature review and desktop study were carried out in order to gain background knowledge on the topics of this study. The literature review utilised 3 different techniques of literature review, which were, (i) Narrative; (ii) Systematic; and (iii) Scoping in order to an effective review. This is followed by an explanation of the 4 steps used to carry out the review as suggested by Fink (2014).

Then, a qualitative methodology with the use of semi-structured interviews followed by a software development method, namely prototype development has been used, due to the multi-disciplinary approach of this research.

The first method, which involved semi-structured interviews with architectural professionals and academics, was used in order to:

a. Gain an understanding on the current process of briefing.

b. Identify the tools and technology that they used in the briefing process.

c. Identify the issues that they are currently experiencing or have experienced in the recent past.

d. Understand their views on the implementation of BIM in the design briefing process.

e. Capture functionality requirements for the development of a BIM-based design briefing tool.

The use of this method allowed the interviewees to provide a more detailed description of their experiences and perceptions that can then be analysed and used in the development of a BIM-based solution. Due to the open-ended nature of semi-structured interviews, it also provided the researcher with the opportunity to ask further questions based on the answers received and also uncover potential issues that may not have been identified in past research.

In order to analyse the data gathered through interviews, a thematic approach was taken. The recorded audio from the interviews were transcribed and were coded and divided into themes using NVivo before carrying out the analysis.

The second method followed the principles and process of software engineering and used a prototype development process, which is a method of software development, that has been used to systematically develop a prototype of a BIM-based design briefing tool. A prototype development process generally consists of 5 –6 stages of development. Keeping the scope of this research study in mind, only 4 stages were used in the development of the BIM-based design briefing tool’s prototype, which were:

a. Requirements capture

b. Conceptual system framework development

c. Development / coding

d. Testing & improvement

Requirements capture, as mentioned earlier, was carried out during the interview process. The next stage, which is conceptual system framework is akin to a blueprint that is developed as a guideline before the development of the prototype. This was carried out in 5 stages of its own, which were:

a. Identification of problems

b. Setting objectives

c. Establishing constraints

d. Alternative designs

e. Identification of best design

The development of the BIM-based design briefing tool's prototype has been carried out using Autodesk Revit and its visual programming language (VPL) Dynamo, which allows users to develop programs that can be used to complete and automate tasks within Revit.

1.6 Thesis organisation

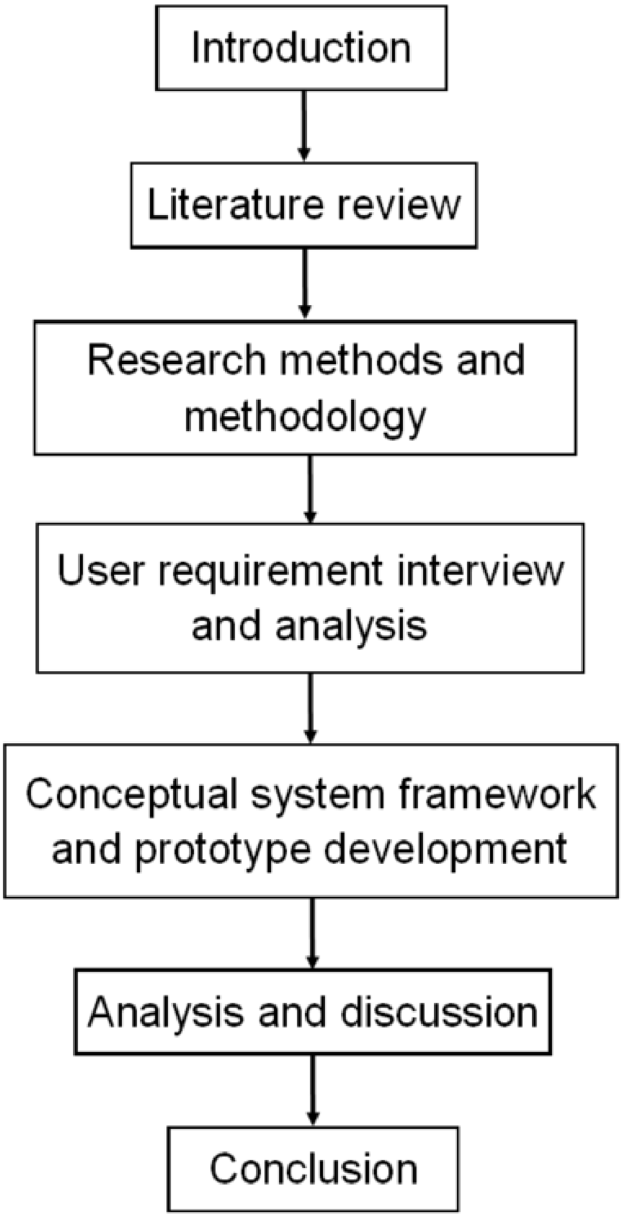


Figure1.1 Thesis structure

This section of the chapter provides an overview of the organisation of this thesis illustrated in Figure 1.1 above. The chapter begins with an introduction to the research, along with the research questions, the aims and objectives, and methods used, thesis structure and the significance of this research.

It then moves on to *Chapter 2*, which consists of the review of literature where various books, journals, articles, blogs etc. have been reviewed by the researcher on the topics of design briefing and Building Information Modelling (BIM). This has been done in order to better understand the background of the topics, build knowledge, identify the existing issues, what has been developed in these field and what gaps in knowledge exists in these areas. This was also used as an opportunity to learn more about research methods and analysis techniques as well as understanding how researchers are applying their learning to solve issues in related fields.

Next, the thesis then moves on to *Chapter 3*, which explains in detail, the research design process, and the research methods. First, the systematic process used to carry out the literature review have been explained in detail. This is then followed by a description of the process of designing questions for the semi-structured interviews, the process of selection of interviewees, the methods of capturing interviews and finally the process of analysing the interviews. Next, the role of conceptual system framework has been explained followed by a brief explanation of the method of developing the BIM-based design briefing tool. This is followed by explaining the method of testing of the prototype that has been used for this study. A justification for the selection of the research methods have then been provided before outlining some of the research ethics and ethical considerations made for this research.

Chapter 4 of this thesis discusses the process of user requirements capture and analysis of interview data. It begins by outlining the interview questions used during the semi-structured interviews, information regarding the interviewees and the process and techniques of interviews. For the analysis of data, a thematic analysis process was used. The 6-step process used for the analysis has been explained in detail. This is followed by the key outcomes from the interview and discussion of the findings.

The thesis then moves on to *Chapter 5,* which discussed the process of development of the conceptual system framework and prototype development using software engineering process. This begins by outlining the stages of traditional briefing and the potential process of BIM-based design briefing. Then the functionalities captured during the interview process has been reiterated followed by an explanation of the development process of the conceptual system framework. Next, the process of prototype development has been explained including descriptions of the nodes and script used in the development of the prototype. The result of the prototype has then been provided along with a description of the testing and improvements made.

Chapter 6 provides a discussion on the testing and feedback of the system framework and the prototype developed, including the potential impacts it may have on the building project process, the quality projects; on BIM implementation in the design briefing process, the impact of early stakeholder involvement and the effective use of Post Occupancy Evaluation (POE) information. This is then followed by discussing some of the limitations of the prototype and potential improvements that can be made for a more effective BIM-based design briefing tool.

Chapter 7 provides a conclusion to this study, which begins by reviewing the aim and objectives of this study. This is then followed by providing a summary of the research and the research implications, and the contribution to knowledge that this study has made. This is followed by a discussion of some of the limitations that were faced and realised in hindsight. Finally, some recommendation for future research have been discussed before providing a final conclusion.

1.7 Summary

Various issues have been identified with the design briefing process in past research, however, these issues have not been properly resolved. This study seeks to implement BIM in the design briefing process in order to resolve or minimise some of these issues and improve the process overall. This study aims to develop a BIM-based design briefing tool's prototype to improve the quality and performance of building projects. In order to achieve this aim, a literature review and desktop study was first carried out. Then professionals from the industry and academics were interviewed to gather data and requirements. Based on the literature review and the outcomes of the interviews a conceptual system framework and a prototype was developed. This thesis provides a detailed explanation of these methods used and a discussion of the findings.

Chapter 2: Literature review

2.1 Introduction

This chapter presents a thorough and systematic review of literature related to the areas of this research, which will assist in establishing familiarity with the topics as well as understanding and evaluating its current state. Additionally, this will also help in finding research that has already been carried out in the past and what has been known and what is yet unknown. Ultimately, this will help in identifying gaps in knowledge that can be fulfilled through this study.

In order to achieve the aim of this study, a thorough review of existing literatures has been carried out and structured into 4 major sections, namely, design briefing, knowledge capture, Building Information Modelling (BIM) and current research and automation.

The design briefing section of the review focuses mainly on the issues revolving around the traditional design briefing process. It begins with a description of the principles of design briefing, the traditional process of briefing and the issues that arises with this process. It then moves on to describe some of the briefing tools that have been used in educational and hospital projects. The next section focuses on the involvement of stakeholders in the design briefing process, the clients, and the need for effective communication in the pre-design stages. Finally, the section shifts focus onto arguing for the need to improve the design briefing process and the involvement of a wide array of stakeholders in this process.

The next section of this chapter reviews knowledge capture (KC) and management in the design briefing process. It was important to review literatures related to KC as it is the process of capturing and structuring a client's ideas, thoughts and needs as well as a professional's knowledge and expertise. KC may give the idea that it is synonymous to design briefing, however there is a fine difference between the two which will be discussed later in the chapter. This section related to KC begins by describing knowledge capture and management in design and construction. It then discusses the importance of effective knowledge management, the techniques that can be used to capture knowledge and finally the relationship between knowledge capture and the design briefing process.

The third section reviews BIM and begins by briefly describing BIM and some of its benefits to the AEC. It then discussed some of the BIM-based tools and platforms and the Common Data Environment (CDE). The review then moves onto understanding the relationship between design briefing and BIM, which is crucial in achieving the aim of this research.

The fourth and final section reviews relevant research on design briefing with BIM and automation, which focuses on finding gaps in knowledge by identifying the kinds of research that have been carried out in the past. It was also realised during the review BIM related literatures that it was necessary to understand a little more about the possibilities of BIM and what new innovative technologies were being developed and in demand. Hence, this section of the review also includes some discussions related to generative design, particularly in the early pre-design stages of a project. Another reason that led to the review of generative design and automation was that these are continuously being researched and developed, particularly by corporations such as Autodesk, and it was necessary to review these as part of the BIM eco-system and to understand how this could contribute to achieving some of the research objectives.

Finally, a summary of the chapter is provided which highlights findings from the literature review including background, issues identified, past research and potential benefits.

Through the review of literature on the aforementioned areas of focus, the researcher was able to gain a deeper understanding about the shortcomings of design briefing particularly those that have been highlighted in similar research caried out in the past; the use of BIM in the past and how generative design can be used in the early design stages to improve the design process.

Due to the rapidly evolving nature of the AEC industry, majority of the literature reviewed in this chapter has come from peer reviewed journals as well as online articles from reputed and reliable websites. Literature in the form of books have also been utilised, however, it was realised that even the latest edition of some of the books were not able to keep up with the latest developments particularly in the field of automation and generative design. Finally, some information from online videos from reliable sources, such as Autodesk Education which uploads discussion videos between industry professionals, have also been cited. The views and ideas provided though those videos have helped the researcher gain an understanding about the requirements of the industry and the general direction in which the architecture and design industry is heading.

2.2 Review of design briefing

Design briefing is the process of identifying, developing, and communicating a client's vision, requirements, and aspirations in the pre-design stage of a construction project (Kamara, Anumba & Hobbs, 1999; Shen *et al.*, 2004). It is one of the most important phases in a design and construction project, and the effectiveness of this process determines the quality of the design brief, based on which a building is designed and constructed. This process also provides the design team with an insight into the client's aspirations, wants, requirements and constraints. The importance and value of the design briefing process have been stressed in a number of literature (e.g. Emmitt, 2002; Hansen and Vanegas, 2003; Ryd, 2004; Tunstall, 2007; Chung *et al.*, 2009; Merchant, 2015). However, over the past decade, only a handful of research have been conducted with the aim of improving the design briefing process.

The result of the design briefing process is the development of the design brief document, which is a corner stone of any project. Whilst the value of the design brief may seem to depreciate after the design process is complete, it should be remembered that this document is concerned with the client's use of asset. Hence, it will re-emerge during the handover/in-use phase of the asset lifecycle, which can be used to verify that the built asset coincides with the client's original requirements in the brief (Barrett & Stanley, 1999).

The document developed as a result of this process is the design brief. Briefing is a crucial part of every project, but it is treated more as an obligatory event than a process (Barrett & Stanley, 1999). The briefing process also provides the design team with an insight into the client's aspirations, wants, requirements and constraints, which are used by architects and design team to develop one or more design solutions. Hence, a structured, holistic, and integrated design brief is crucial to the success of every project (Tunstall, 2007; Bogers *et al.*, 2008; Chung *et al.*, 2009; Merchant, 2015).

The importance and value of the design briefing process and the design brief itself have been stressed in numerous literature (e.g., Barrett & Stanley, 1999; Hansen & Vanegas, 2003; Koutamanis, 2017). However, the briefing process has been undermined and undervalued, and have not received equal devotion and improvement relative to other phases such as design, construction, procurement, management methods and technologies (Latham, 1994; Ryd, 2004; Yu *et al.*, 2006, Koutamanis, 2017). One example of such development is Building Information Modelling (BIM), which has provided improvements to almost all the aforementioned phases but has been left out of the design briefing process (Koutamanis, 2017). Past research in design briefing has focused on improving parts of the briefing process such as communication between stakeholders in the briefing stages (Bogers *et al.*, 2008), data collaboration between the client and the contractor (Ryd & Fristedt, 2007) and the development of a web-based briefing tool (Hansen & Vanegas, 2003) amongst others. However, none of the studies has proposed the implementation of BIM in the design briefing process.

The Banwell Report (1964) was one of the earliest documents to raise concerns regarding briefing practices. The report summarises the client's lack of knowledge regarding their need at the outset, even though they are investing money in the project, as well as the lack of resources in defining project requirements. The Latham Report (1994) reiterated the need to understand the needs of the client and stressed on the importance of spending enough time for a good brief to avoid delays and cost overruns later in the project. The report also suggested getting the brief 'right' as a means of delivering a project effectively, which requires an efficient process of collecting and translating client requirements.

Currently, based on the checklist provided by Royal Institute of British Architects (RIBA) (2020a & 2020b), only 'preparation for use of BIM' in a project is carried out during stages 0-1, with the actual graphical and non-graphical BIM data being added during Stage 2: Concept Design. Hence, this research aims to novelly explore, study, and depict an effective and integrated method to implement BIM design technology and process in the pre-design stage. This can assist the client in making decisions early in the project, realise what may or may not be possible and provide the design team with early support and data from stakeholders that can be integrated into the project.

However, the briefing process has had a number of issues in the Architecture, Engineering and Construction (AEC) industry (Latham, 1994; Bogers *et al.*, 2008; Koutamanis, 2017), due to a number of notorious factors. Bogers *et al* (2008) conducted extensive research in the area of traditional briefing practices and have identified a range of issues with the briefing process for the architects, the design team and the clients. Not only have they concluded that traditional methods of briefing require the design team to spend a lot of time studying and analysing the brief, but it also limits the designer's creativity. They also constantly seek information from clients, which are sometimes missing or inadequate, re-doubling efforts that have already been put into the brief.

One of the initial issues is the sheer volume of the design brief document itself. This can range anywhere from a couple of pages for a residential project to a bound book for larger commercial projects such as hospitals and schools. This usually happens because the brief is over detailed and full of a list of regulations and generic design ideas that are already known to architects. The brief sometimes is a vague wish list, which is incomplete and lacks details of the client's wishes and requirements that can be used in the design stage (Koutamanis 2017).

Another issue is that even in today's day and age of computer and technology, briefing is one of the processes that is mostly conducted with the use of a pen and paper or a word processing software. While most architects and designers may resort to the classic, "*This is how we have always done it"* phrase, it still entails the task of digitizing and structuring of the brief. This may take a little or a considerable amount of time, depending on the size of the project and the client's requirements. Moreover, today, BIM is one of the most talked about and researched topic in the AEC industry and academia than ever before, however, design briefing is one of the phases that is still not part of the BIM way of working.

A lack of structure is another issue with traditional methods. This causes difficulty in reading as well as understanding the brief. Overloading a brief with technical specifications can sometimes obscure strategic requirements of the brief or even act as a design done for the architect. There are also issues with briefs copied from earlier projects which undermines the unique nature of each project. There has been research carried out in the past that seek to resolve or minimise some of these issues. However, most of those studies either developed tools that sought to structure the brief for better management or develop checklists to reduce errors and miscommunications. It has been observed that there is lack of studies using BIM as the proposed solution. This study looks into identifying if BIM can be a potential solution for improving the briefing process.

2.2.1 The principles of design brief

Design briefing is a process through which a client's vision, needs and requirements are defined, elicited, and articulated (Yu *et al.*, 2006; Marchant 2015), the result of which is a design brief document. During this process problems are formulated and solved, while managing change to implement solutions.

There are two schools of thought that exist in the area of design briefing, which are (i) Static & (ii) Dynamic. It is a matter of preference or the organisation's way of working when it comes to choosing which process of briefing, they want to follow. A static method of design briefing considers the brief as a separate entity and requires the brief to be completed and frozen before the development of the design begins (Hyams 2001; Pena & Parshall, 2001; RIBA, 2020; Yu *et al.*, 2007). The purpose behind this method of briefing is to eliminate change which can lead to problems such as increased cost, conflicts, delays, and disputes. This method however may not reflect real-life projects as changes in building projects are inevitable. Particularly in larger projects that run for years, locking in the design brief before the design stage may lead to client dissatisfaction as their requirements or circumstances may change during the lengthy period.

A dynamic method of briefing considers briefing as an on-going process that runs throughout the design and construction process, continuously capturing client requirements and implementing them into the project (Blyth & Worthington, 2010; Othman, Hassan & Pasquire, 2004; Yu *et al.*, 2007). This method of briefing considers the brief as a live document which is constantly developed throughout the project lifecycle. It is also more relatable to real life projects as it expects changes from clients and adapts accordingly. Dynamic briefing is more focused towards client satisfaction by achieving or exceeding their expectations through frequent exchange of information and regular capture of client requirements.

These two methods of briefing eventually boil down to two factors, namely conflict and client satisfaction. Through the review of literatures, it can be concluded that each form of briefing is preferred by different parties. As Bouchlaghem *et al.* (2000) points out, supporters of static briefing, such as the architect and the design team, seek to avoid conflict with the clients as much as possible and once way of achieving this by locking in the brief in the early stages and proceeding to the next stages with confidence. Any changes made after this stage will then cost the client money based on the contract signed by both parties.

Additionally, another factor that can affect the design briefing process is the chosen route of procurement. The National Construction Contracts and Law Report 2022 (RIBA, 2022), reports that traditional procurement is the most common method of procurement in the UK at 40%. This type of procurement is also known as design-bid-build, where an architect appointed by the client designs the building and contractors submit tenders for the construction of the building (Designing Buildings, 2023b). Dynamic briefing under this type of procurement may not be possible as the contractors are not appointed at the briefing stages. However, under a design and build procurement route, dynamic briefing is more favourable. Here, the contractor is responsible for both the design and construction of the building and is also favoured by around 34% of projects in the UK (RIBA, 2022). Hence, the choice of static or dynamic briefing is also dependant of the type of procurement being used in a particular project.

However, it is in the best interest of the client and his/her team to employ a dynamic form of briefing as it is iterative and enables them to define the brief as progress is made with the design and construction of the building. This in turn allows the brief to meet client/user needs, cope with regulatory changes, explore opportunities, adapt to technological improvements, while adding value and managing risks (Othman, Hassan & Pasquire, 2004).

2.2.2 Traditional design briefing process

"Briefing is a process of refinement from a general expression of need to a particular solution." This statement from Blyth and Worthington (2010, p. 13) neatly summarises the essence of briefing. The client has a need for a building and the design team provides the client with a solution in the form of a design that can be constructed. However, the time and effort that goes into the briefing process is much greater than simply stating a problem and finding a solution. Briefing, particularly in unconventional buildings such as schools and hospitals, can be complex and complicated (MacPherson et a. 1992), usually requiring specialist architects and contractors.

Traditionally in the UK, majority of design and construction projects follow the RIBA (Royal Institute of British Architects) Plan of Work (PoW) (Eynon, 2013), which is a reference document and management tool for design and construction activities (Designing Buildings, 2021). This version (2020) of the PoW is customisable based on the procurement, programme, planning etc. and incorporates the need for sustainability and Building Information Modelling (BIM). The PoW is divided into eight work stages (0-7) and each stage has eight tasks with required outputs.

The PoW follows a static method of briefing which means that it requires the brief to be completed and frozen at the end of stage 2. The briefing process itself has been divided into three phases over three different stages (0-2) in the PoW. The first phase is the development of the strategic brief, second is initial project brief and third is the final project brief. Each phase of the brief takes place in stage 0, 1 & 2 respectively.

a. Strategic brief: During the strategic briefing phase, the client outlines their general requirements without too much detail, and this provides a general direction for the project. Additionally, the client also states their vision and objectives for the project, explains why they need this facility built, their short- and long-term needs form the building etc. If a client already owns a site, then these details are provided as well (Meel and Størdal, 2017). A strategic brief is written in simple language that is easily understood by the client and should be able to relate to its contents. This phase of briefing should define the client's problems clearly so that he/she can decide whether should proceed to the next stage (stage 1) or not (Fletcher and Satchwell, 2015).

b. Initial project brief: As the client begins to realise his/her requirements in detail and narrates this to the design team, an initial project brief begins to develop in stage 1 of the PoW. While there is no set format as to how an initial brief should be laid out, one must make sure that it consists of a summary of all relevant discussions, requirements of the client, information related to the site etc (Fletcher and Satchwell, 2015). An initial brief does not require to be too long, however, referencing relevant documents can be helpful for future use. Fletcher and Satchwell (2015) suggest inclusion of the following contents for an initial project brief.

i. Introduction of the project
ii. Client's project objectives and outcomes
iii. Project requirements including relevant standards and sustainability aspirations.

iv. Key issues such as planning issues, site constraints, capacity issues etc.
v. Site information including services, transport, archaeology, heritage etc.
vi. Relevant background information such as feasibility studies
vii. Project programme
viii. Project budget
ix. Team/process/information exchanges

An initial brief may be authored by any of the project stakeholders such as the client/project lead, the project manager, or the architect. Fletcher and Satchwell (2015) suggest engaging end-users as much as possible as this brief will impact these group the most. They also suggest keeping this document dynamic as it needs to be referred to, updated, and signed off at various stages of the project.

c. Final project brief: The final project brief is the foundation upon which the design of every building will be developed. This is the final stage of the briefing process where the development of the most detailed brief is developed in Stage 2 of the RIBA PoW 2020. In addition to the requirements listed in previous briefs, further design requirements are defined in the final brief including any derogations (Ostime, 2020, RIBA, 2020b). This brief is prepared by the architect together with the client with contributions from consultants.

Some of the important that should be included in the final project brief are (Ostime, 2020):

i. Project outcomes
ii. Accommodation requirements
iii. Space standards
iv. Spatial relationships
v. Schedule of functions and activities
vi. Schedule of installations
vii. Environmental policy and requirements
viii. Structure image and quality
ix. Structure lifespan
x. Operational and maintenance requirements
xi. Details of the site, including any constraints
xii. Client organisation structure
xiii. Servicing options, e.g., Deliveries, security, access.
xiv. Budget for all elements
xv. Procurement process
xvi. Time, cost, and quality target, including milestones.
xvii. Risk assessment and management

Once fully developed, the final brief should be approved and signed off by the client. Clients can sometimes change their minds about some of the requirements listed in the brief. In these circumstances, the impact of these changes on the project should be identified, recorded, and approved by the client.

2.2.3 Design briefing guidance and tools.

Design briefing guidance, particularly in the form of checklists have been developed by various researchers, organisations and government bodies that can help ensure that every information required for developing an efficient brief is captured. This may be developed by the client or the client's representative and passed on to the design team to develop a design solution. The use of checklist can be an excellent form of capturing requirements from the client at various stages of the project. The design team may also have their own set of checklists, which can be used to gather information required from the not just the client, but also other stakeholders such as the local authorities and site inspectors that needs to be taken into consideration in order to develop design solutions (Thompson, 2007). This will help them maintain a systematic method of gathering requirements data in every project.

O'Reilly (1987) was one of the earliest authors who suggested and developed a checklist that would aid briefing in the early stages of any project. Latham (1994) in the Latham Report also recommended the development of a checklist for the design briefing process as a guide for clients and professionals. After this various organisation such as the International Organisation for Standardisation (ISO) (BSI, 1995), Construction Industry Research and Information Association (Potter, 1995) and the Royal Institute of British Architects (Rezgui, Bouchaghem, & Austin, 2003) developed their own form of checklists for briefing.

Authors such as Salisbury (1998) suggested the use of checklists in various stages of briefing. Hyams (2001) suggests using at least 4 different checklists depending on briefing method. Thompson (2007) proposed the use of different checklists to gather information from the client as well as any stakeholders whose requirements may have an impact on the design outcome, such as the local planning office. Blyth & Worthington (2010) and Chappell & Dunn (2016) have also advocated for the use of checklist in order to conduct an effective and managed design briefing.

While the use of checklist aims to provide the project with clarity and transparency by providing the all the information required by the design team, the client, depending on their experience, may or may not know their exact requirements upfront.

There are also guidelines that have been developed for particular types of buildings such as schools and hospitals. For example, Building Bulletin (BB) 103 developed by the Department for Education (DfE, 2014) provides area guidelines for mainstream school buildings as well as the site. It seeks to assist the architects, clients as well as other design-related stakeholders to create a design brief while helping potential users understand the spatial needs for teaching and learning activities. This guidance is also accompanied by a spreadsheet-based Schedule of Accommodation (SoA) tool, as seen in Figure 2.1. According to the DfE (2022), this *"…tool can be used to calculate the number and types of spaces recommended for a specific school based on its proposed pupil number, age range and curriculum."* The tool consists of three variations, the first for primary schools, another for secondary schools and the third for Further Education (FE) colleges, as students of different age groups have different learning criteria and area requirements. The SoA tool can be a highly effective tool in the early stages of briefing, particularly for new clients or users who are unsure about the spatial requirements. The user of the tool can simply enter an age range and the total number of students to calculate the required area and the number of spaces including classrooms, student halls, library, staff areas, storage, kitchen, toilets etc.

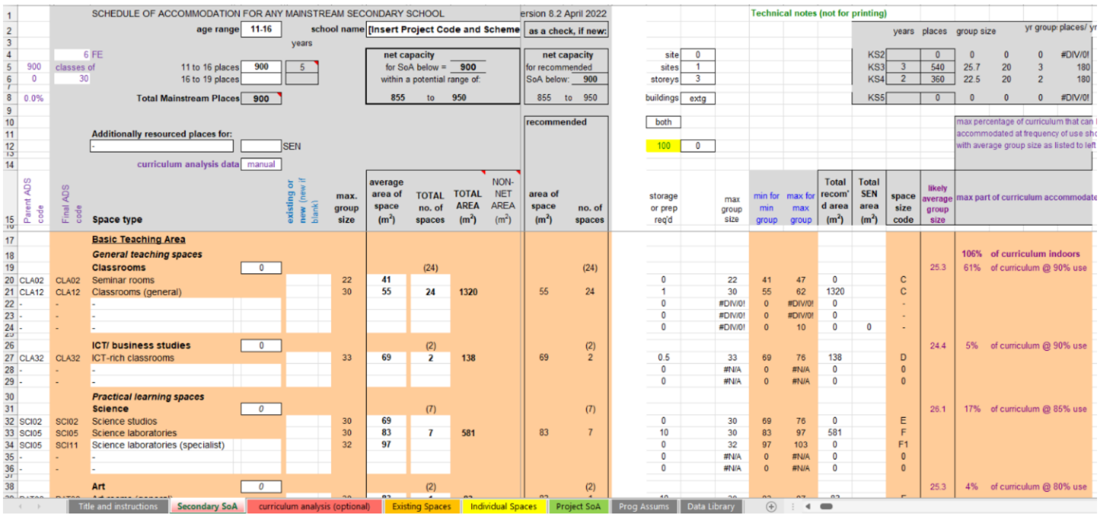


Figure 2.1 Extract of Schedule of accommodation spreadsheet tool for secondary schools.

(DfE, 2022)

Similar to BB 103, guidelines have been developed for design briefing in the health care sector by the Department of Health (DoH). Their suite of Health Building Notes (HBN) provides best practice guidance and information to support the briefing and design process (DoH, 2014). HBN 00-01 provides guidance in designing health and community care buildings such as hospitals.

The importance of design brief and design briefing process was briefly discussed earlier in this section, and it was established that it is crucial for the success of any project that the briefing document is as thorough and accurate as possible. While in the past, numerous design briefs have been developed manually without the use of any computer-based tools, the briefing process has more-or-less shifted to become more dynamic and prone to changes over the design and construction of the project (Othman, Hassan & Pasquire, 2006). In order to keep up with these advances in technology, numerous tools were developed in the 1990s and 2000s that sought to improve or at least assist the process of briefing. Some of the examples include AutoBrief (Kelly, 1997), ClientPro (Kamara & Anumba, 2001), CoBrITe (Bouchlaghem *et al.*, 2000), DIVERCITY (Sarshar, Christiansson & Svidt, 2003), Strategizer (Smith, 2005). Most of these tools were developed before BIM became mainstream, hence they cannot be found on the internet for download and use.

After the adoption of BIM over the past few years, building projects have also become more complex and are using BIM authoring software such as Revit to develop designs and models. Hence, naturally, the briefing process has also adopted a certain level of digitisation and several design briefing tools for use with BIM have been developed by various academics and organisations. These tools, primarily, assist in the structuring and development of the design brief and making the briefing process more efficient. The majority of these briefing tools were developed for hospital projects that are relatively large with a large set of requirements (Meel & Størdal, 2017). A few of these design briefing tools that are commercially available have been discussed below.

a. dRofus is a requirement structuring and management tool, which makes requirements information readily available and traceable. As a result, this also enables designers to monitor requirements during the design development and assess whether the requirements have been met (dRofus, 2021). There are some limitations to this software as identified by Soliman-Junior *et al.* (2020), such as a lack of feature that would enable the designer to understand impacts on other requirements when a change is made; lack of support for capturing and analysing requirements; difficult to categorise subjective requirements; and a lack of suitability for modelling process requirements.

b. BriefBuilder is a web-based requirement management tool developed in the Netherlands by a multidisciplinary team of researchers, software developers and construction professionals (BriefBuilder, 2020). Like the other briefing tools, BriefBuilder also helps structure and manage requirements. Additionally, it also carries out requirements analysis and risk identification by flagging requirements that presents risks or are ambiguous. However, a study conducted by Traversari *et al.* (2016) concluded that dRofus and BriefBuilder were too detailed, and a layered approach was too generic for use during the early design phase. Whilst these are both highly useful tools when it comes to structuring and managing data as well as using these data to verify design solution later in the design phase, these tools are not very useful in helping develop spaces and generic design solutions.

c. CodeBook is another tool that provides various tools that can be used from inception through to the design and construction as well as 'in-use' phase of an asset. Among the various products offered by CodeBook, Room Data Collector (RDC) is used to capture data with their customisable form (CodeBook, No Date). Similar to the previous tools, this tool also helps on structuring and sharing of data with project stakeholders.

One of the common themes observed among these briefing software, apart from their ability to structure and manage requirements data, was that all of these software stored requirements data natively in their own program or their cloud server. This in itself is not a major issue. But if the briefing tool requires any interaction with a BIM-authoring software, then user needs to manually load the plug-in and then coordinate data from the brief with the developed model. For example, the data for a hospital bedroom may consist of 7 components that would be required in that room. With the use of a briefing tool this data can be captured easily and incorporated into a model as well, however this would not be an automatic process and the user is still required to manually link that particular set of requirements to a room.

One alternative approach that could be considered involves the use of PRINCE2 (Projects IN Controlled Environments), which is a structured project management method that highlights the division of a project into more manageable and controllable phases (PRINCE2, 2019). This study has utilised the RIBA PoW 2020 as the most popular project management framework applied in the AEC industry in the UK, which also breaks down the overall project process into 8 manageable stages (0-7 stages). However, PRINCE2 provides benefits such as consistency, scalability, regular reviews as well as improved communication, accountability, and involvement of stakeholders in decision making (PRINCE2, 2019), which could also potentially be used to manage design and construction projects. Thus, PRINCE2, as a generic project management model, is fundamentally similar to the RIBA PoW 2020 in principle. The latter one, however, is a dedicated project management model widely adopted in the UK construction industry.

2.2.4 Stakeholders' collaboration in the briefing process

Collaboration between stakeholders is one of the key factors in the efficient delivery of projects. Projects are increasingly developing technologies, environments, and methods of collaborating that can help in achieving a higher standard of quality assurance and more importantly, the reuse of stakeholders' knowledge and experience (Barnes and Davies, 2015). One of the main goals bels behind the development of these collaborative environments is to provide the different teams the ability to communicate and efficiently share data while minimising miscommunication and avoiding loss of data. However, due to the lack of collaboration during the early design briefing stages, these goals are not always fulfilled.

A traditional design briefing session generally involves the client or representatives from the client organisation, users (if known), the architect and the design team, and an in-house contractor in design and build projects (Blyth and Worthington, 2010). An experienced client, such as a housing developer, may approach the design firm with a pre-drawn design brief, if they build similar developments regardless of the location of the site. If not, then the client may employ an experienced brief writer to write up the brief or approach a design firm with whom the client can draw a brief from scratch. However, apart from those listed earlier, there are no other stakeholders involved in the briefing process. Latham (1994), when talking about allowing plenty of time in the briefing stage for the client to express their wishes, suggests involving other advisers such as engineers and mechanical designers in the early stages.

Even with the involvement of other stakeholders, the architect and the design team tend to dominate the briefing process, and rightly so, as they need to gather as much information as possible from the client in order to come up with a design solution. But just because they are experts in the field of design does not mean that they are familiar with the details of the entire construction process (Kamara & Anumba, 2001). Hence, there is a requirement for early involvement of other stakeholders who possess knowledge and experience in other fields of design and construction such as project managers, structural and service engineers, operation and facility managers, and surveyors to contribute towards the design brief. Their added knowledge can strengthen the brief and minimise or eliminate the chances of errors occurring. Additionally, they can also assist the client in making an informed decision regarding the project.

According to Fletcher & Satchwell (2015), the strategic briefing carried out in Stage 0 of the PoW is about strategic principles rather than testing detailed feasibility or design. The stakeholders usually involved at this stage are the client, design team, independent client advisor (in-house or external), designers and engineers for site appraisals and legal, planning, property, and business advisors. However, they do not provide a list of stakeholders for the development of a strategic brief, and it can only be assumed that they see some or all of the personnel involved in Stage 1 to be involved in the briefing process. When the project moves on to the formulation of the initial project brief in Stage 1 of the PoW, Fletcher and Satchwell (2015, p.141) advises *"…collaboration of a number of parties, with one person identified as lead…"*

This method of collaborative or integrated working has been promoted in the AEC. Deutsch (2011) discusses the subject of Integrated Project Delivery (IPD) in detail and argues for increased integration among stakeholders, particularly with projects utilising BIM. He further shares some of the prerequisites for an integrated method which includes cooperation between all stakeholders; trust among all parties from the beginning; sharing of all information to maintain transparency and sharing of risk and reward.

There are various benefits of using an integrated approach due to the close connection between different teams as outlined by Deutsch (2011) which includes:

i. Increased likelihood of meeting project goals
ii. Eliminate waste and time overruns.
iii. Lower costs through optimisation and coordination
iv. Increased communication between parties
v. Increased productivity of both the design and construction teams, where the required information is provided when necessary.
vi. Reduced conflicts between various teams.

However, one of the issues that may arise through an integrated approach is that the architect and the design team may feel that they are taking on more risk than usual and are sharing the design role with other stakeholders as every party would have a say in the development of the project (Deutsch, 2011; Rodrigues & Lindhard, 2021).

2.2.5 Issues with conventional briefing process

Research carried out by Kamara, Anumba & Hobbs (1999), identified a number of limitations in the current method of briefing practices which have been listed below.

i. Inadequate involvement of all relevant parties to a project.
ii. Insufficient time allocated for briefing.
iii. Inadequate considerations of the perspectives of the client.
iv. Inadequate communication between those involved in briefing.
v. Inadequate management of changes to requirements.

Similar issues and limitations have also been identified in various other research and literatures that have been further discussed below.

As one of the earliest stages of a project, getting a brief right is of utmost importance. However, there are some major issues related to briefing in the design and construction industry (Latham, 1994; Bogers *et al.*, 2008; Koutamanis, 2017). One of the most notorious of issues with traditional briefing method is the amount of paperwork it entails. Depending on the size of the project, a briefing document can range from a few pages to hundreds or even thousands. Koutamanis (2017) explains that in many cases, this is the biggest issue of all. This leads to an array of problems including incomplete briefing documents or an uncertain and vague wish list that may have to be discarded during design. This poses the obvious problem of going through hundreds of pages to find a small piece of information that may or may not be present.

Bogers *et al.* (2008) have conducted extensive research in the area of traditional briefing practices and have identified a range of issues with the briefing process for the architects, the design team, and the clients. Not only have they concluded that traditional methods of briefing require the design team to spend a lot of time studying and analysing the brief, but it also limits the designer's creativity. They are also constantly seeking information from clients, which are sometimes missing or inadequate, re-doubling efforts that have already been put into the brief.

Other issue faced by the design team is the lack of a complete brief or one that is too detailed. Koutamanis (2017) has also pointed out this issue stating that even well-crafted brief suffers from incompleteness and redundancy. In bigger projects, there can be inconsistencies and contradictions, which can result in delays. However, Chung *et al.* (2009) cites Barrett and Stanley (1999) claiming that briefing usually reaches a level of satisfaction than an optimal level. This statement clarifies the level of detail at which briefing needs to stop, i.e., it needs to be satisfactory enough for the client to convey their ideas and for the design team to understand their requirements.

A lack of structure is another issue with traditional methods of briefing. This causes difficulty in reading as well as understanding the brief. Overloading a brief with technical specifications can sometimes obscure strategic requirements of the brief or even act as a design done for the architect.

There are also issues with briefs copied from earlier projects which undermines the unique nature of each project.

Issues also arise when the client does not know what they want and need or are ill-prepared or presents the design team with an inadequate brief. This kind of client and brief requires changes to be made or information to be added which might result in negatively affecting the budget and schedule of the project (Latham, 1994).

Finally, the amount of time allowed for briefing is one of the causes of the previously mentioned problems. However, usually it is the client rather than the contractors who is too eager for the project to move to the next stage. Research carried out by Shen & Chung (2006) found that clients (in Hong Kong) seek to reduce time for briefing in order to allow construction to begin as soon as possible. Due to this lack of time, the project is poorly defined and may affect the final construction. Latham (1994) also stresses on the importance of spending enough time for a good brief in order to avoid delays and cost over-runs later in the project.

2.2.6 The clients in construction

Clients play a crucial role in the development of an asset, particularly in the design briefing stages when their needs and requirements are elicited for the development of design solutions. However, clients are not always a single person, hence it is important to understand the types of clients in a construction project and how they can affect the design briefing process.

In general terms, a client is a person, or an organisation has a requirement for a new property and, hence, commissions other parties for its design, supply and construction (Atkin & Flanagan, 1995). In larger projects such as a school or hospital construction, a group of senior-level individuals from within the organisation who have an interest and control over the project act as the client (Designing Buildings, 2019). Hence, in these cases a client may also be referred to as the employer, developer, owner, authority etc.

Clients play a major role in the success of a project. Contrary to common belief, a client's role demands a lot more than just commissioning a project and funding it. However, not all clients are experienced or sometimes their experience is in a different type of construction such as a housing developer seeking to build a high-rise office block. Hence, Higgin and Jessop (1965) categorise clients as 'sophisticated' and 'naïve' based on their level of experience in particular types of construction projects. Their level of experience will then determine the nature of the design brief, the building team, the timeframe of the project and how communications are carried out.

While an inexperienced client may struggle with the idea of developing a design brief and the process of briefing, an experienced commercial clients can develop a highly detailed brief and present it as a business strategy (Ryd, 2004). However, both types of clients have their own positive and negative impact on the design brief or the design briefing process. An inexperienced client may provide a poor, incomplete, or inadequate brief that the design team may struggle with, but at the same time it is also provides opportunities for the design team or any concerned stakeholder to add/suggest directions or changes. With an experienced client, they may be knowledgeable with the process of briefing and better understand the process, but the brief may be over-detailed and may restrict the designer's ability to develop design solutions.

2.2.7 Importance of effective communication in the design briefing process.

Communication lies in the heart of any project, be it construction, manufacturing, automotive or some type of service. However, unlike some of the other industries, every construction project is different from another, sites are different, regulations vary, and there are differences in the standards. Hence, communication between the client/user and the design team as well as between the various levels of professionals within the design and construction team is imperative in the briefing stage. Effective communication early in the project will not only help improve the quality of the project but will also help define the nature of the relationship between client and designers.

Communication is a two-way process where one party relays information and the other party acts upon that information and relays it back to the first party. Blyth and Worthington (2010) express this phenomenon in the form of a four principal communication route model illustrated below.

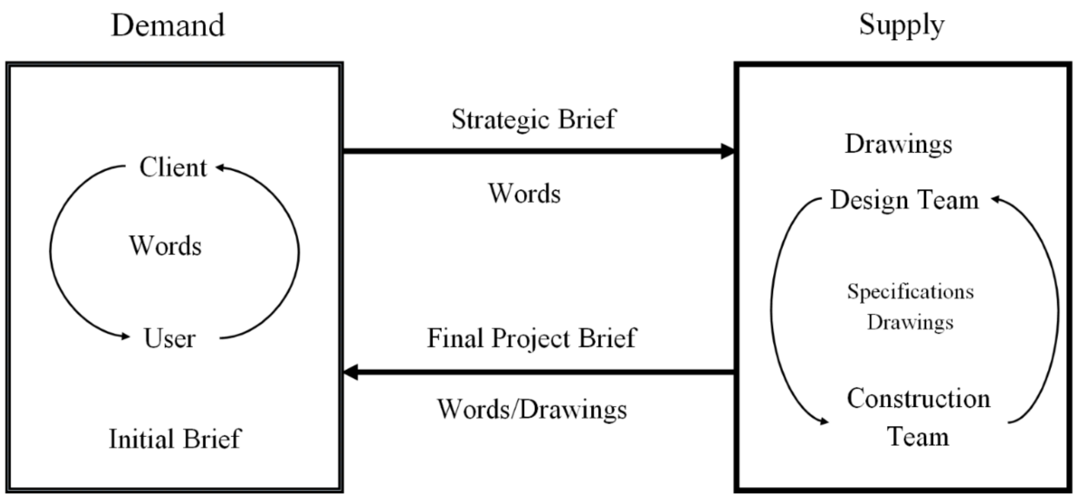


Figure 2.2 Model of the four principal communication routes

(Adapted from Blyth and Worthington, 2010)

In the illustration above in Figure 2.2, there are four principal communication routes: client and user communication; design team and construction team communication; client and user with design and construction team and vice versa. Communication can occur in various forms between various parties involved. The client organisation communicates mostly with words (verbal and written) which can come in the form of a strategic and initial brief. The design team responds with words, sketches, and concept drawings in response by developing a final project brief based on the client's requirements. However, requirements written in the brief may not always match the client's actual expectations (Bogers et.al., 2008), hence, face-to-face meetings between the client and the design team is crucial as it helps both parties clarify if they have correctly interpreted the written and illustrated communication.

These communication routes between various parties may look effective on paper, however, within each team there are multiple professionals at different levels performing various individual tasks. Depending on the procurement route adopted, these professionals may also be design contractors and client representatives, who are not traditionally part of the core design team. At this micro level is where the lack of communication affects the project the most. Barrett & Stanley (1999) provide an example of this kind of miscommunication, where new information was revealed during the feasibility study or case study but was communicated only with one member of the consultant team that would have been affected by this information. Meanwhile, decisions could be taken by other member of the team without any knowledge of the new information. By the time that new information is finally communicated with the entire team in the next meeting, hundreds of decisions could have been taken place, all of which might be affected in light of this new information.

Communicating with a client may also prove to be difficult if they are new to construction or are representatives from a client organisation who do not have previous experience with briefing, architecture, or construction. In cases like this, the design team should educate the client on their role and responsibilities through the various stages of design and construction. This may seem odd at the beginning, where the designers inform the client about the role they need to play, however, first time or new clients may not always understand that they have a bigger role to play than simply paying for the project (Salisbury, 1998). The design team also need to ensure that they fully understand the client's requirements set out in the strategic brief before moving on to the next stage.

The design brief document itself is also a means of communication, where the client or a representative develops a brief as a means of communicating their needs and requirements to the design team. Communicating the requirements set out in the briefing document, with not just the lead architect but passing down this communication with professionals at various levels of hierarchy ensures every personnel is up to date with all available information. This might also help identify any mistakes that may have been overlooked or provide new ideas.

2.2.8 Identification and management of client requirements

In any type of project, domestic or commercial, fulfilling the requirements of clients and users is arguably the most important aspect of a successful project. In a design and construction project, client's covey their requirements through various stages of design briefing. Initially, these requirements may simply be a vision for the project and what they would want the final development to achieve. This initial brief is then taken further and developed into a more detailed list of requirements that the design team can use to develop design solutions. However, as simple as this process of identifying client requirements seem, where the clients provide their requirements and the designers develop design solutions, there can be numerous complications related to accurately conveying client's actual needs and requirements.

Studies carried out by Hudson *et al.* (1991), Barrett & Stanley (1999) and Kamara & Anumba (2001) all suggest that the vastness of project information compiled throughout the briefing process and mistakes made in accurately identifying and conveying a client's actual requirements may lead the final design brief to be inaccurate and not reflect the client's true requirements.

More recent studies such as Robertson & Robertson (2006), Li *et al.* (2011) and Jallow *et al.* (2014) have also concluded that, amongst other issues, inaccurate identification of client requirements and lack of effective communication between the client/user and other stakeholders, related to client's requirements have been one of the root causes of multiple project failures.

In order to overcome these issues, Shen *et al.* (2003) proposed a structured framework that can facilitate a systematic identification of client requirements that can assist in the formation of accurate and explicit representation of client's requirements in the briefing process. Jallow *et al.* (2014) also proposed the development of a framework to manage complexities of client requirements with the help of a web-based central repository that can facilitate collaborative and distributed access to client requirements.

Both of these studies emphasize on the importance of accurately identifying the requirements as well as effective management in order to avoid conflict later in the project. Moreover, it also highlights the importance of collaborative working between the client and the stakeholders.

2.2.9 Past research on design brief

In previous sections, it has been established that design brief is one of the most crucial part a project and plays an important role in its success. And this role of briefing has not gone un-noticed in the field of research either. In comparison, design briefing may not have received as much attention as

Building Information Modelling (BIM) has in recent days or some design or cost related issues. But there have been considerable amount briefing related investigations carried out in the past.

One of the earliest attentions that the brief and the briefing process received was in the report 'Constructing the team' famously known as the Latham report of 1994. In the report briefing was one of the stages of design and construction suggested for improvements. Some of the main suggestions were "*getting the brief right for effective delivery of the project"*, briefing being an "*iterative process"* and "*allowing enough time for a good brief to be devised in order to avoid subsequent delays and cost overruns"* were highlighted.

From this point forward, briefing became the focus of multiple research and studies, such as Bouchlaghem *et al.* (2000) and Rezgui, Bouchlaghem & Austin (2003), where they argued that the briefing process could be improved through the efficient and effective use of information technologies (available during that time) that can support the client and the design team. This indicates the need for a more structured approach to design briefing and the issues that may arise with the vast amount of data processed manually by humans.

Kamara, Anumba & Evbuomwan (2000) and Kamara & Anumba (2001), focused on the development of an IT based tool that facilitates the systematic definition, analysis, and mapping of client requirements to design specifications. Along with this the tool also incorporates and prioritises the perspective represented by the client as well as determines the importance of their requirements.

Olatokun & Pathirage (2015) delve further into design briefing and study the knowledge capture process and identify the importance as well as barriers that are associated with knowledge capturing during the briefing process. They also highlight the impact that a poor design briefing process has on the final construction of buildings.

The study carried out by Koutamanis (2017) is more relatable to this research as it is one of the few studies that propose the incorporation of BIM into the design briefing process. The author (Koutamanis) considers briefing as a source of information that can be fed into BIM, which can then perform automated analysis.

However, the scope of this research and the need for originality is what differentiates this research from previous studies. The study carried out by Hansen and Vanegas (2003) and Koutamanis (2017) relates to this research the most. However, the final aim of this research is to develop a new method of BIM-based briefing which was outside the scope of the study by Koutamanis (2017).

2.2.10 Requirement to improve the briefing process.

After extensive review of numerous literatures including past research, the researcher is able to confidently state that there is a need to improve the briefing process which can significantly improve the overall design and construction process. The previous section laid out several past research carried out into the briefing process where a number of highly skilled researchers proposed a several methods of improving the briefing process. Similarly, this research will seek to utilise the powers of Building Information Modelling (BIM) in order to improve the process of briefing.

The briefing process is currently carried manually where the client provides the design team with a brief that needs to be designed and constructed. One of the first issues with this method of briefing is that it is carried out by people and humans are prone to errors. It was established earlier that one of the major issues of the briefing process was the amount of errors found in a briefing document which would subsequently lead to added cost and time towards the project. Limiting human action or implementing digital technology on a briefing project may be able to resolve this issue as proposed by Rezgui, Bouchlaghem & Austin (2003).

Fragmentation in the construction is a matter of concern, where the design team, engineering team, construction team and management team all work on the same project almost independently. These professionals all hold considerable amounts of knowledge and experience and could make valuable contributions to the project from an early stage. However, current methods of traditional briefing do not require them to be a part of the briefing process (Fletcher & Satchwell, 2015). With the implementation of BIM and the early availability of a Common Data Environment (further explained in below) these stakeholders can begin to make early contributions to the project brief, allowing the designers to develop more comprehensive design solutions.

2.2.11 Requirements of stakeholder integration in the briefing stage.

The AEC is a very fragmented industry, where the design team and the construction teamwork independent from one another (Emmerson, 1962; Latham, 1994; Kamara, Anumba and Evbuomwan, 2001; House of Commons, 2008; Naoum, Lock & Fong, 2010; HM Government, 2013). This fragmentation eventually affects the outcome of a project or holds a project back, when the outcome could have been better.

Naoum, Lock & Fong (2010) further explain that this culture of fragmentation may not just be between the design and construction team, but also between members of the design team which may include the architect, structural, mechanical and electrical engineer etc. An architect and the design team may develop a design and layout of a building without consulting any members of the engineering team, who would then design the substructure and frame based on the architect's design.

There may also be similar fragmentation within the construction team. For example, on large projects such as schools, hospitals and high-rise office blocks, the client may employ a contractor and supplier (Tier 1) who in turn may employ multiple sub-contractors and suppliers and so on (Tier2 – Tier n). Naoum, Lock & Fong (2010) suggest that involvement of the construction team could avoid delays and interruptions by advising on utilising methods that are more cost effective, quicker to build and of better quality.

Integration to an extent has been achieved through the use of BIM and the Common Data Environment (CDE), where information (bother graphical and non-graphical) is stored, managed, and shared for use and consultation of the entire project team. However, with the current method of carrying out a project, a CDE is only created and utilised from Stage 2 of the PoW.

2.3 Review of knowledge capture and management in the design briefing process.

This section of the literature review will briefly discuss knowledge capture (KC) and knowledge management (KM) in the design and construction industry. It will also present and discuss the importance of KM and KC techniques. The rationale behind reviewing KC and KM is the valuable contribution they make to the design briefing process and the effect it has on the outcome of the design brief.

2.3.1 Knowledge capture in design and construction.

KC is the process of identifying and examining knowledge from the source based on the organisation's strategy and implementing relevant techniques to retain, filter, disseminate and update that knowledge through an iterative process. (Hari *et al.*, 2005). In other words, KC is the process of extracting knowledge that are within a person's mind (tacit knowledge) and noting/structuring that knowledge into a physical/digital format that can be accessed by others (explicit knowledge). It is crucial that the required knowledge and the source of knowledge is identified before capturing. It may initially seem that the client or the client team are the only sources of knowledge as they are the party who provides all the requirements. However, knowledge in a design and construction project can also be sourced from various stakeholders involved in a project as well as an organisation's past experiences, documentation such as Post Occupancy Evaluations (POE), meeting minutes etc. (Kivrak *et al.*, 2008).

It goes without saying that tacit knowledge, that is not recorded, is lost as time goes on. Fruchter (2002) discusses the importance of capturing the vast amount of tacit knowledge possessed by various stakeholders involved in a design and construction project to be used for the benefit of future projects. Failure to capture this knowledge may mean that the majority of information is lost, and only partial information may make it into the next project. This sentiment is shared by Falqi (2011), who states the importance of capturing knowledge from stakeholders through appropriate techniques and feeding it forward into projects in the future. These techniques can be as simple as recording knowledge from past experiences, or it can also be a more formal technique with a target of creating explicit knowledge. These techniques of capturing knowledge that can be used during the design briefing process have been summarised below.

a. Observation: One of the common methods of capturing knowledge, observation is a process of observing, recording, and interpreting an expert to develop solutions (Awad & Ghaziri, 2007). The idea behind this method of capturing knowledge is related to understanding their habits as well as observing their process of workflow in addition to any explanation they may have provided beforehand. This also allows the observer to closely observe the expert's steps and process that they may not be able to describe with words.

b. Brainstorming: This is an unstructured and consensus-based process that helps develop solutions to problems. The participants in brainstorming are experts of one or multiple fields within the scope of the session. The goal here is to consider all solutions equally and agree on a solution (Hari *et al.*, 2005). The explicit knowledge here is recorded in the form of a textual list of ideas and the general consensus regarding each of the ideas generated during the brainstorming process.

c. Interview: Capturing knowledge through interviews is a common and effective technique of eliciting knowledge and requirements. During the design briefing process interviews are held in the form of meetings between a client and the design team. The idea behind this technique is to simply ask the client about their requirements and recording their responses (Neve, 2003; Shokri-Ghasabeh & Chileshe, 2014). The questions should generally be open-ended that will allow the client to freely answer the question without feeling pressurised into providing answers that could please the architects. The questions should not be generalised as every project is different and every client has varying needs, although in practice there may be a pre-set set of questions that the design team may ask as part of their own process of understanding the requirements of the clients (Neve, 2003). Sometimes the client is an organisation who may have more than one representative or there are a group of end-users being interviewed. In cases as such, the design team may need to better prepare and manage the interviews and record information extracted from all the participants more diligently.

d. Consensus decision-making: This technique follows a similar pattern as brainstorming, where the difference is that this process is more structured. A group of experts are presented with the issue or problem and are asked to develop solutions. Once a number of proposed solutions are gathered and are voted on individually until a consensus is reached. Through this process, knowledge is captured from multiple experts even though only one solution is used (Awad & Ghaziri, 2007).

e. Nominal group: A nominal group technique is a bridge between brainstorming and consensus decision-making. Here the problems are stated, and alternate solutions are also provided. The group of experts then compile a list of advantages and disadvantages which are then ranked in order to select the best alternate solution. This approach helps provide clarity to the proposed alternate solutions and take a more weighted approach in finding the solution and capturing knowledge (Hari *et al.*, 2005; Awad & Ghaziri, 2007).

f. Delphi: A Delphi technique utilises questionnaires aimed at experts in order to gather responses to develop solutions to a specific problem. The contribution from each expert is shared with the other experts by using results of one questionnaire to develop the subsequent questionnaire (Awad & Ghaziri, 2007; Chu & Hwang, 2008). This method of capturing knowledge can be highly effective as the results are anonymous allowing the responders to answer more freely. The responses can be analysed statistically and also allows the feedback to be controlled by the providers (Nevo & Chan, 2007).

g. Post-project reviews: One of the most effective lessons learned capturing technique is via a Post-Project Review (PPR), where the aim is to capture project knowledge in order to improve the performance of future projects

(Shokri-Ghasabeh & Chileshe, 2014). PPR is carried out upon the end of a project where the reviewer seeks to identify the overall success of a project and also assess the factors that contributed towards the success or failure of the project. There should not be any biases towards successful projects when capturing knowledge from past projects as failed projects also provide equal knowledge (Von Zedtwitz 2003). Through the use of PRR organisations can learn and recall the factors that went well, which can be used to recreate further success and avoid mistakes in subsequent projects (Carillo, 2005).

h. Stakeholder involvement: Involvement of expert stakeholders in a project is another technique for capturing and sharing knowledge. The AEC is well known for its fragmented approach with different stakeholder teams working individually with minimal communication. A collaborative approach to capturing knowledge, particularly in the design briefing stages, gives the stakeholders a sense of commitment towards not only the project but also one another and also encourages cooperation and knowledge sharing (Bhargav & Koskela, 2009). However, during a collaborative approach, it needs to be ensured that a stakeholder does not overshadow others as this will discourage sharing of ideas and knowledge and may also lead to clashes between two or more stakeholders. If the client is also part of the collaborative discussions, then, this may cause them to lose faith in those groups of stakeholders (Patel *et al.* 2012; Peng *et al.* 2017).

2.3.2 Knowledge capture in the design briefing process

The process of Knowledge Capture (KC) involves the intricate dance of recognizing, examining, and retaining knowledge from a source for future use and dissemination amongst relevant stakeholders (Hari *et al.*,2005). KC provides abundant opportunities for organizations to innovate, improve project methodologies, cut costs, save design time, and reduce time to market. However, one must acknowledge that knowledge is an exceptionally complex concept that consists of information and skills acquired through experience.

Capturing a client's requirements using KC techniques during design briefing is crucial for the competitiveness of an organization as well as its overall performance. The decisions made by the design team are entirely dependent on the quality of information elicited from clients during the design briefing process (Hari *et al.*, 2005). Explicit knowledge is factual information that is relatively easy to document, such as a list of experts, telephone numbers, and details of previous contracts for a particular client, or methods of repairing a common fault. Tacit knowledge, on the other hand, is much harder to address. It refers to the more subjective approaches people take in situations where there may be no single right or wrong answer.

Tacit knowledge is seen as one of the keys to why a particular organization is successful. Knowledge capturing in the design briefing process involves the use of both tacit and explicit knowledge. One of the key benefits of knowledge capturing in the design briefing process is the ability to elicit requirements from clients, which is knowledge embedded in the mind of the clients in relation to the anticipated building they have in mind. These requirements need to be properly documented (explicit) in such a manner that the design team can produce quality designs.

It has been identified that one of the major reasons behind defective designs can be due to inadequate time given to the briefing process. This can account for the high level of increased cost and delay in project delivery. Demaid & Quintas (2006) suggests that knowledge capture could lead to better problem solving and higher client satisfaction, resulting in improvement in the design briefing process in the pre-design stage of construction projects. As a result, giving adequate time to the design briefing process can reduce the level of design mistake that occur in the construction process and also improve the quality of output produced at the end of the project.

However, no matter the amount of time given to the design briefing process without the right knowledge capturing tools and techniques, it could most likely lead to a frustrating activity which could impact on the overall objective of the briefing process. This goes to highlight the importance of knowledge capturing in the design briefing process and shows that no matter the quality of knowledgeable professionals and client present at a briefing meeting, the knowledge management strategy used to address the process has a major significance on the productivity of the process.

Faatz (2009) reveals that the minuscule process of briefing alone costs a mere 1.5% of the entire life cycle costs of the project, yet this seemingly small amount engenders a major influence on the performance of the overall costs, skyrocketing up to more than 80% of the total life cycle cost. The cost of changes to the project is initially slight when a project is first underway, but with time and progress, the cost of changes increases exponentially. Thus, capturing the necessary knowledge available at the early phase of the project by eliciting requirements and documenting them properly becomes crucial for successful project execution.

However, a fundamental challenge in modern construction is the lack of willingness of today's clients and professionals to invest in the pre-design phase. To overcome this obstacle, adequate communication between clients and professionals is required. A client's ultimate goal is to build a building that fulfils their requirements, but defining excellence remains a subjective and elusive task that varies between different decision makers and planners. The design briefing process incorporates various knowledge capturing methods to understand these diverse interpretations and unify the stakeholders' diverse imaginations.

The design briefing process not only facilitates basic discussions but also supports the development of clearly defined goals. Gould & Joyce (2009) stress the significance of involving both the client and the users in the writing of the brief since they possess unique and specific requirements for that particular project. However, since clients' understanding may differ when it comes to building processes, professionals hired to produce the design brief and the design must sometimes provide guidance and assistance to owners who seldom occupy themselves with building projects. In contrast, owners familiar with the building process do not require as much assistance as they are already well-versed in other building projects. This does not negate the importance of the design brief and effective requirement elicitation process.

Once the decisions have been made in the pre-design stage, changing them in other stages becomes arduous. Therefore, the early stages are critical to the project's success, necessitating the involvement of all stakeholders, clients, and the expertise of the design team (Wapukha, 2013).

It is in the pre-design stage where the most significant decisions regarding the construction decision-making process are made. If the knowledge that exists between the professionals and the clients is not elicited and documented accurately, it may lead to deficiency in performance output and unsatisfied clients, resulting in a bad reputation for the organization. In conclusion, while the cost of briefing appears minuscule, it is a vital aspect of the construction process, and it is imperative to invest in proper and effective communication between clients and professionals to ensure project success.

2.4 Review of Building Information Modelling Technology

In the past 6-8 years the design and construction industry has seen significant rise in the use of Building Information Modelling (BIM). One of the most talked about term in construction worldwide, it has particularly gained popularity in the UK due to the government's BIM mandate which required all public sector projects to utilise BIM Level 2 from April 2016. How much of, and how successful this mandate has been, will be discussed in a later chapter.

BIM is a very well-researched topic in academia, possibly due to its popularity, significance and government touting. There are numerous books, papers, journals, reports and research papers written in the field of BIM. But of these many, only a few have thought about or tried to implement BIM in the briefing process (e.g., Koutamanis 2017 & 2017b), which this thesis endeavours.

2.4.1 What is BIM?

Majority of professionals in the construction industry are familiar with the term BIM, but there still are plenty of confusion and misunderstandings regarding the actual meaning and use of the term. One of the earliest misconceptions assumed BIM to be a modern name for Computer-Aided Design (CAD) (Kensek and Noble, 2014; Kumar, 2015). But the difference between the two is not just limited to 2D and 3D drawings. CAD is a drafting tool, whereas BIM is a way of collaborative working, which assists in carrying out the process and making decisions, rather than an application (Enscape, 2022). Another misconception is that BIM is only a 3D model, which again is not completely correct. However, BIM is a 3D representation of a facility, but it also holds vital structured information related to all building elements and objects including design, construction, operation, cost etc within the 3D model. Nevertheless, BIM means different things to different users depending upon their needs. Figure 2.3 shows the various uses of BIM as well as the potential users.

The final misconception is that it is often believed BIM is simply Revit, which is completely false. This misinterpretation is often seen in students and professionals who are new to BIM. Yes, Revit plays a major role in developing the graphical as well as non-graphical elements of a BIM model but Revit in itself is not BIM. It is a BIM authoring tool used to create the model itself.

Figure. 2.3 BIM capabilities and users

(Source: Winstanley and Fraser, 2013).

To answer what BIM really is, there are a number of definitions that can be found on various literatures. Kumar (2015) presents the idea of breaking down each acronym in order to define and understand BIM.

Building: As a noun this would mean a structure or dwelling, but in BIM; building should be thought of as a verb meaning *to build*. In this case, *to build* an information model.

Information: This is the part of BIM that makes it stand out from CAD. Information are data held within the model objects that conveys a meaningful message that can be accessed by all parties. Kumar (2015) describes this as the medium that enabled BIM to be semantic.

Modelling: This is an act of representing a designed facility to improve understanding and further develop.

However, one of the most accurate definitions is provided by NBS (2016) which states, "*BIM or Building Information Modelling is a process for creating and managing information on a construction project across the project lifecycle.*" The definition could not be clearer. BIM is a process where graphical and non-graphical information is created using various BIM authoring tools that is used to manage information on all levels of a project's lifecycle, including the in-use and even demolition phase.

Some people might ask why use BIM when construction has been able to sustain without it all these years. A simple answer to this question is that construction projects have not been as successful in the UK. The UK Industry Performance Report 2017 shows that while client satisfaction has achieved a record-high rating of 90%, profitability and productivity growth of the industry as a whole has been on a decline since 2009 (Glenigan, 2018). There can be various reasons for the lack of success in construction. However, Rossiter (2016) explains that one of the reasons things often go wrong is due to the way information is shared between stakeholders. Rather than sharing the right information, only part of or just enough information is shared, which leads to a lack of or confusing information, which is then carried on to the next process.

The need for collaborative working was suggested, among others, in the 1998 Egan Report (Egan, 1998), which also stressed on the need for change in structure and culture in order to achieve higher potential. The same idea was recommended again in the Wolstenholme Report (Wolstenholme, 2009).

Successful construction of a building does not equate to a successful project. Success of a construction project is measured in terms of time, cost and quality. Only when all three are achieved together can a project be deemed successful. A famous example of this is The Sydney Opera House. This was a project that was scheduled to be completed within four years' time, with a budget of AU$ 7 million. But it took 14 years to be completed and ended up costing AU$ 102 million (Martin, 2012). It probably met the quality needs of the client but failed quite miserably in terms of time and cost.

Going back to the original question, why use BIM? If the Opera House was constructed in today's day and age, the use of BIM would have substantially improved the management of information, flow of communication and sharing of all information between teams and the client right from the start of the project. Also, the generation of a 3D model would have clearly shown all complications that were likely to arise during construction of the building.

Hence, BIM is the process of building a semantic, information rich model that all necessary parties (design and construction) can access at any time. However, BIM can mean different things to different professionals such as architects, contractors and managers. So, there are various ways BIM can be perceived based on individual needs.

BIM in itself covers a wide range of terms, describing the process, protocol, standards and tools in creating a digital model of a facility. Hence, it has been divided into 4 levels (0-3), known as the BIM maturity levels. Figure 2.4

is a diagram of the maturity levels originally created by Mark Bew and Mervyn Richards in 2008 also known as iBIM referring to its highest level of maturity or the Wedge due to its shape. The different levels of maturity assist an organisation in easily identifying its current level of BIM.

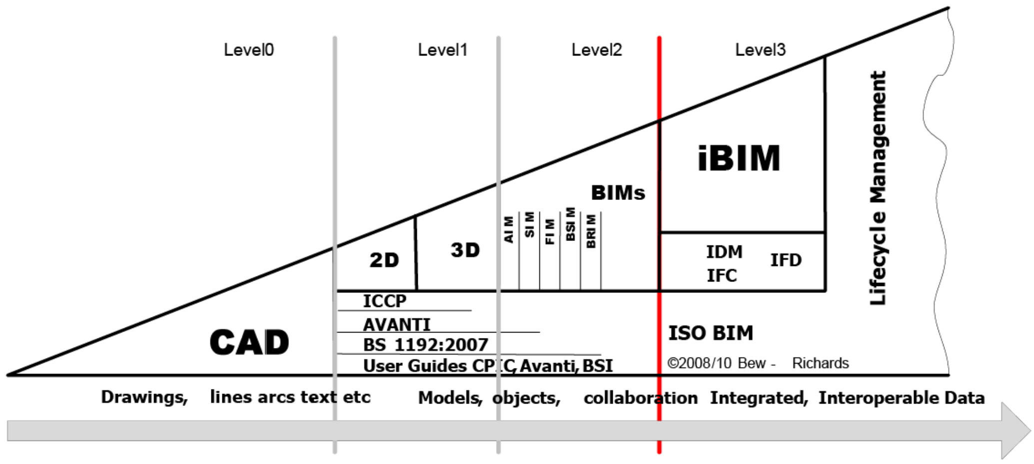


Figure. 2.4 The Wedge

(Source: BIM Think Space, 2015)

Level 0: is mostly defined by unmanaged CAD, usually 2D, where information shared between stakeholders is either in old-fashioned paper format or digital drawings usually in PDF format (Kumar, 2015; Mordue, 2016).

Level 1: is defined by managed CAD in both 2D and 3D format using BS 1192:2013. It makes use of collaboration tools that provides a Common Data Environment (CDE) in order to share models between relevant stakeholders (Kumar, 2015).

Level 2: is the managed use of collaborative 3D environment with attached data, created in separate BIM discipline models, hence making use of federated models. A full set of guidance for attaining level 2 has been set out in Publicly Available Specifications (PAS) 1192: Part 2 and 3: 2013, which will be converted into full British Standards after the completion of the early adopter programmes (Kumar, 2015).

Level 3: includes a single collaborative model on a single online server or the cloud, with fully open process and data integration enabled by IFC (Industry Foundation Classes). Also known as iBIM (Integrated BIM), its requirements are yet to be defined in full and its strategy is still aspirational and visionary, which is documented in the Digital-built Britain Strategic Plan (Mordue, 2016; Designing Buildings, 2017).

At the moment, level 2 is the minimum required for all public construction projects in the UK. This came into force in April 2016 as set out in the mandate. Whether or not this has been achieved is still disputed (Boutle, 2017), but around 70% of practices have achieved level 2 by 2017. The overall BIM adoption has been rising with around 71% of practices using BIM on some of their projects (NBS, 2021).

2.4.2 Benefits of BIM

BIM has been a revolutionary boon for the construction industry, providing benefits not just for designers, but also for contractors, clients as well as facility and operation managers. It not only reduces effort, errors and conflicts, but also improves productivity and overall quality of the project (Rodriguez, 2017). Chevin (2018) reports on a savings analysis carried out by PricewaterhouseCoopers LLP (PwC, 2018), who have now quantified the benefits of BIM for the first time.

BIM (Level 2 and above) encourages a collaborative work approach, primarily between the design and construction team. This has not only helped in producing and testing designs in a BIM enabled tool but has also supported in reducing waste and number of errors in real life construction. Production of accurate data can prove to be vital in achieving improved and accurate bids, reducing risk allowance as well as lump sum bids, which in turn helps the client in controlling costs (PwC, 2018). Moreover, due to reduction of errors and accuracy of information, re-works and claims made by other stakeholders can also be reduced or prevented.

One of the greatest benefits of BIM has been on collaboration between various stakeholders. BIM, by enabling architects, engineers, contractors, and other stakeholders to access and modify the same digital model, ensures that everyone has a grasp of the most recent version of the design. The advantages of collaboration through BIM are numerous and include improvement in communication, a reduction in errors, and enhanced decision-making.

The most significant benefit of collaborative work through BIM is the improvement in communication between stakeholders. BIM provides a standardized platform and a universal language for all stakeholders to exchange and share information (Liu et at., 2017). This reduces possible misunderstandings, which, in turn, leads to the optimization of the construction process. BIM also facilitates real-time collaboration among stakeholders, enabling them to make necessary changes and adjustments when necessary. This feature significantly reduces the time required for rework and changes, resulting in considerable cost savings.

Another benefit of collaboration through BIM is the decrease in errors during the construction process. Since all professionals work on the same digital model, there is a reduced likelihood of design conflicts and errors. BIM-authoring tools can detect potential clashes between different building systems, such as electrical and plumbing, before they occur, ensuring that any issues are identified and resolved early in the design phase (Bryde *et al.*, 2013). Consequently, this reduces the need for expensive and time-consuming changes later in the construction process.

Collaboration through BIM also enables better decision-making throughout the construction process. All stakeholders have access to the same information and can make informed decisions about the design and construction of the building (Al-Ashmori, 2020). BIM allows stakeholders to evaluate various design options and scenarios, helping them select the most effective solution. This results in a more efficient and cost-effective construction process.

2.4.3 Design briefing and BIM

In the past few years, a number of professionals have grazed past the idea of utilizing BIM methodology to conduct design briefing. For instance, Race (2013) puts forth the idea of compiling a design brief along with a maintenance and operations manual, which BIM would preserve and sort all this information in an appropriate form for later use. The author does acknowledge that majority of information at this stage may not be graphical, but stresses that same BIM principles can be applied to the data at a later stage.

This is a valid idea. One of the issues with the method of design briefing is that the results are unstructured, vague, and confusing (Barrett & Stanley, 1999). But by using BIM methodology, information can be structured into order, which can be at hand when required. Furthermore, this non-graphical data gathered at the beginning of the project can always be linked to graphical models and drawings, at a later stage which will only enrich the data available to designers and contractors.

Another issue of design briefing is related to the difficulty in communication between the client and the design team (Barrett & Stanley, 1999). However, as mentioned previously, BIM represents the latest and most advanced technology applied in the contemporary AEC industry. It is a powerful design, engineering and management technology, which can present all of building products in 3D visual environments, attach comprehensive production information onto building products and components, and simulate building construction and management processes (Sacks *et al.,* 2018).

Finally, the design briefing process as well as the design brief itself is prone to errors (Barrett & Stanley, 1999), possibly due to the above-mentioned issues. Through the use of BIM technology and the development of a BIM-based design briefing tool, errors could be minimised. For these reasons the researcher has concluded that BIM could be a solution for improving the design briefing process and reducing some its prevalent issues.

2.4.4 Common Data Environment

A formal definition for Common Data Environment (CDE) is provided in PAS 1192-2 (BSI, 2013, p. 3) as, "*single source of information for any given project, used to collect, manage and disseminate all relevant approved project documents for multi-disciplinary teams in a managed process."*

CDE is a shared digital online space used to collect, manage, and share information that can be accessed by all authorised stakeholders in a project. This digital space can be located anywhere from a project server to an extranet, or a cloud server depending on the project size and needs. In this space, data, information, models, and documents related to the project are stored for easy access. However, on level 2 BIM all information and data are federated, which means that each individual stakeholder creates their share of the model that is later combined together in order to form a complete model. Figure 2.5 - 2.8 provide an example of design federation and how data is moved between various stakeholders in the CDE.

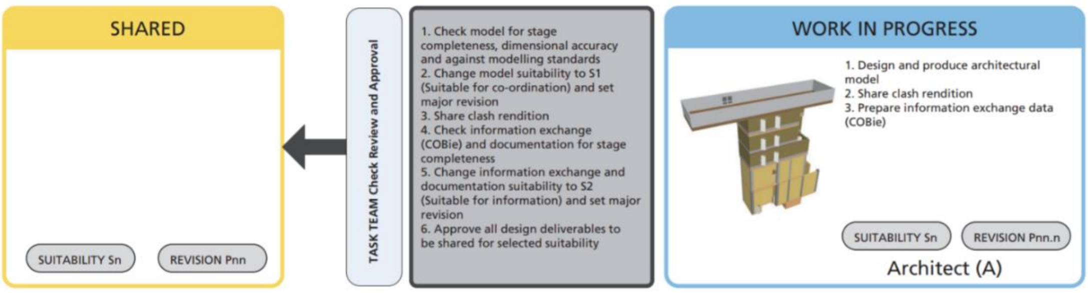


Figure. 2.5 Architect's issue to SHARED

(Source: BSI 2013)

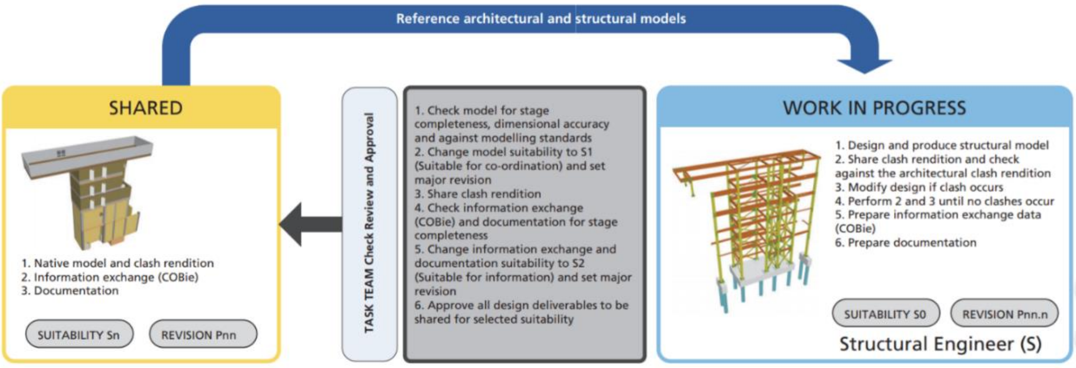


Figure. 2.6 Structural engineer's issue to SHARED

(Source: BSI 2013)

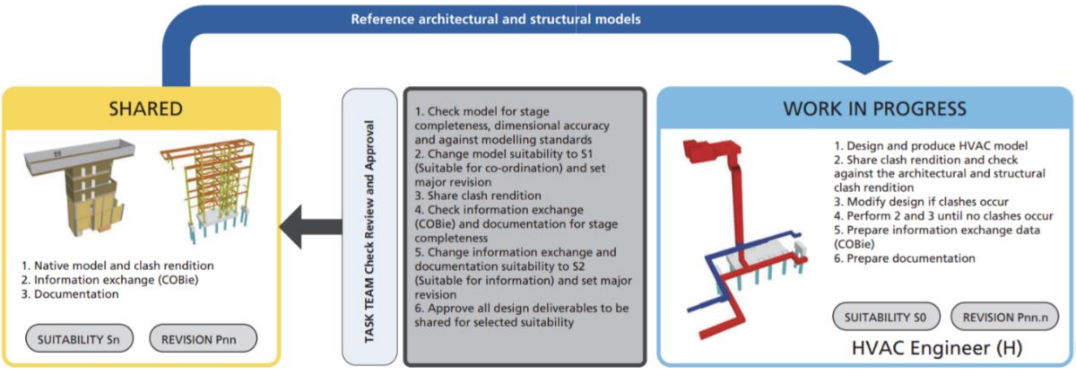


Figure. 2.7 MEP engineer's issue to SHARED

(Source: BSI 2013)

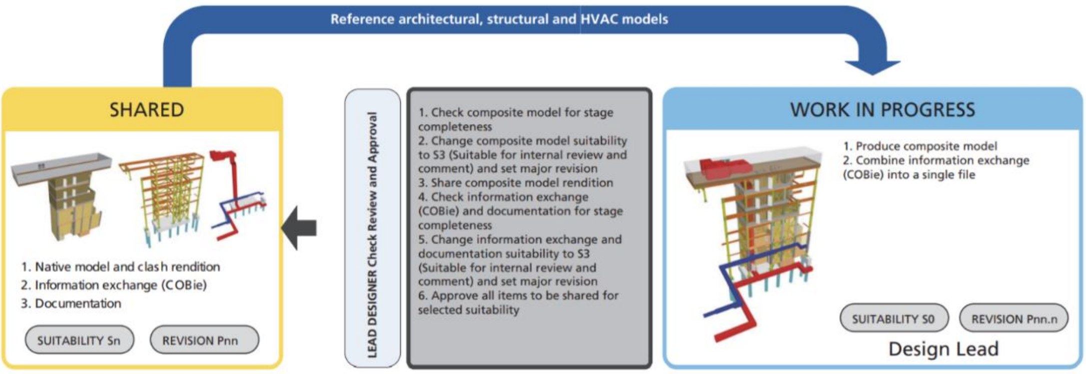


Figure. 2.8 Design review of models in SHARED

(Source: BSI 2013)

The use of a CDE provides multiple benefits, however, one of the major benefits is that it provides a centralised platform for stakeholder collaboration. This not only enables all authorised stakeholders to exchange project information and documents but also facilitates the tracking of changes and management of workflows (Sacks *et al.,* 2018). The use of CDE can also promote greater transparency in projects by providing stakeholders with access to the same information and data in real-time, which helps in reducing misunderstandings and conflicts between stakeholders. Moreover, the centralized platform for project data that CDE provides enables stakeholders to monitor and track project changes, resulting in greater visibility into the project's progress (Allen, 2021).

2.4.5 CDE and design briefing

An element of this research is collaboration of stakeholders in order to improve knowledge that is being introduced into the briefing stage. The sharing of information is not just between the client and designers but also the contractors, sub-contractors, suppliers and the operations and facility managers, in order to create an improved and more effective design brief using BIM. While producing models and information collaboratively, it is crucial that information is shared from an early stage, through a transparent and controlled process (BSI, 2013). However, with the current briefing practice, collaboration rarely begins at the briefing stage (Koutamanis, 2017), i.e., BIM strategy is only introduced and agreed with the client at RIBA Stage 1 and implemented at stage 2 or sometimes even 3.

CDE is one of the significant pillars of BIM. Particularly BIM level 2, as it requires collaborative and integrated teamwork which can only run smoothly over a CDE. The idea behind briefing with BIM will greatly rely on a CDE that will collate all briefing information, which can be used to define spaces, objects and elements, as well as verify designs and test plans (Meel and Størdal, 2017). Currently, with traditional briefing methods, a CDE is not developed until stage 2 in the RIBA PoW 2013 (Fletcher & Satchwell, 2015). Hence, only the final design brief document becomes part of the CDE, if at all.

2.4.6 Generative design

Traditionally in architectural design, an architect uses basic design techniques such as sketching, digitally or on paper, to give life to the ideas in their minds. For example, drawing a wall and placing a door or window in it. The designs are developed based on a number of factors such as the amount of natural lighting required, circulation, proximity as well as keeping in line with various regulations. Depending on the client's experience and the size of the project, this process may take days or weeks of developing tens or hundreds of design variations (Vermeulen, 2021). One of the most recent and efficient methods to expedite this process of designing is Generative Design (GD).

GD has been given various definitions by authors, researchers, and organisations. Krish (2010, p. 90) defines it as "…*a designer driven, parametrically constrained design exploration process, operating on top of history based parametric CAD systems structured to support design as an emergent process".*

Vermeulen (2021) from Autodesk defines GD as, *“…a goal-driven approach to design that uses automation to give designers and engineers better insight so they can make faster, more informed design decisions.*

Lately, GD has been gaining popularity in the architecture industry, particularly due to its adoption by Autodesk, one of the leading providers of architecture and BIM authoring software such as Revit and Dynamo. However, the concept of GD was pioneered over 50 years ago by Frazer (2002). Since then, several academic research have been carried out in the field of GD regarding framework development, implementation, and adoption.

In its most basic form, GD builds on parametric concepts, which enables a modelling assistant, such as Revit, to transform into a design generating system based on a defined set of rules (Shea *et al.*, 2005). These rules are defined by the user, some of which will have been borrowed from various design principals as well as building regulations. The aim of GD systems is not only to generate design solutions, but also to help the designers spark new ideas, solve complicated tasks, provide assistance where required and to extend their design abilities.

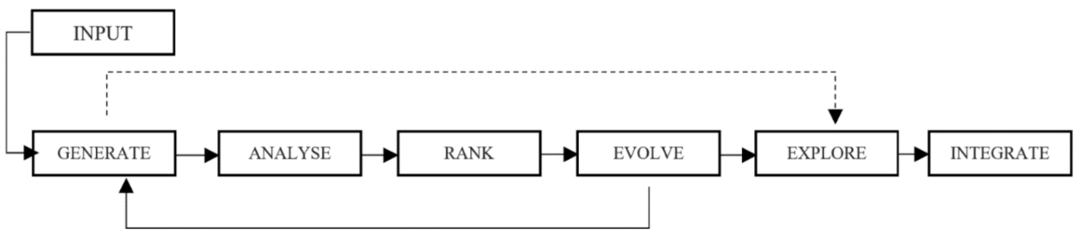


Figure 2.9 The process of generative design

The GD process is designed to create an integrated workflow between the user and the system, where both have their series of steps that they need to perform in order to chieve results. Vermeulen (2021) has categorised these steps into six stages as illustrated in Figure 2.9 and explained below.

i. Generate: The designer specifies their parameters, and the system generates multiple design options.
ii. Analyse: An analysis is carried out to identify how well the design options meet the designer's goals.
iii. Rank: The design options are then ranked based on the results of the analysis. The higher the rank the more feasible the design option is for the project.
iv. Evolve: Based on the ranking of the design options, a number of designs are selected for further development. Generally, the option with the higher ranks is chosen, however this might also depend on the preference and perspective of the designer.
v. Explore: The designer compares the designs and evaluates the results.
vi. Integrate: Upon choosing a favourable design, the designer integrates the design into the project.

2.4.7 Transition from traditional design to generative design.

Over the past few decades, the tools and methods used to develop design solutions have progressed tremendously. This progression has been relatively rapid since the development of Computer-Aided Design (CAD) in the 1960s (Gedded, 2020). Currently, the AEC industry has been progressing towards GD with the use of software such as Dynamo for Revit and Grasshopper for Rhino. This section briefly discusses the transition of design methods over the years.

i. ***Traditional design*** is the most basic form of designing where the designer draws what is in his/her mind. The technique here is basic such as sketching/drawing by hand or with the use of CAD tools (Fakhry, Kamel & Abdelaal, 2021). A simple example of traditional design is drawing an external wall with a door and window.

ii. ***Parametric design*** is a step up from traditional methods and uses software such as Revit to function. It is a process based on algorithmic thinking as a methodology to express parameters and rules that collectively establish, encode, and clarify the connection between design intent and design response (Jabi, 2013). Unlike AutoCAD, where each element is a combination of points and lines that do not share any relationship with one another, here a relationship is created between two or more elements based on the parameters defined by the software or the user (Oxman, 2017). For example, once the designer creates a wall and inserts a door/window into that wall, the door/window will move if the wall is moved.

iii. ***Design automation*** provides the designers the ability to program parametric designs with the use of scripts. Generally, scripts and programming are carried out using programming languages such as Python or C#. However, in the field of architecture, where majority of the designers are not familiar with using programming languages, a visual programming language such as Dynamo are used. This enables a designer to create automation programs by manipulating elements rather than typing them textually (Vermeulen, 2021). An example of design automation is inserting a door every X mm in a wall.

iv. ***Computational modelling*** is similar to design automation and the only differentiating factor being the ability to evaluate the designs (Caetano, Santos & Leitão, 2020). Using the previous example, here the system inserts the required number of doors in the wall and also evaluates the number of exits per X mm.

v. ***Option generation*** allows the designer to explore numerous design options based on a set of rules. For example, the system can produce design options will all the possible places a door/window could be placed on a wall. Depending on the criteria set by the user, the system can generate hundreds or thousands of possible options for the user to choose from.

vi. ***Design optimisation*** can help the designer define their goals and allow the system to explore all options that are in line with that goal (Ramage, 2022). For example, finding an optimum location for a door on a wall that is closest to an exit.

vii. ***Machine learning*** is the ultimate form of generative design where the designer inputs the desired outcome, and the system generates results that matches the requirements based on historic data and regulations (Tamke, Nicholas & Zwierzycki, 2018). For example, the system generates positioning of doors in a floor for quick exit. Unlike the previous systems, machine learning systems seeks for patterns that are inferred instead of those that are explicitly stated using learning datasets.

2.5 Review of relevant research in design briefing with BIM and design automation.

The idea of linking design brief with BIM is a relatively new concept. The topic has been considered in some literatures such as Koutamanis (2017) & Meel and Størdal (2017), however an actual outcome has never been achieved combining these two fields. There are number of briefing tools such as dRofus, BriefBuilder, Codebook etc. that structures the vast set of client requirements and assists in making the process of briefing more efficient. However, there is a lack of an actual link that can directly connect the design brief with the digital models.

The word BIM, its uses and its capabilities have been interpreted in various manners. BIM can mean different things to people with different professional backgrounds. Some perceive it as a software tool or technology, while others view it as the 3D model that can be generated by that software. The researcher agrees with Vanlande *et al.* (2008) & Eadie *et al.* (2013) that BIM is a "*process of generating sorting, managing, exchanging, and sharing building information in an interoperable and reusable way."* The definition suggests that BIM is incorporated in all stages from inception to use and maintenance of the asset. However, after an extensive review of literature, it was concluded that currently BIM is not implemented in the pre-design stages, particularly due to the lack of 3D model development and collaborative working. One of the prominent BIM-related tasks in stage 1 of the PoW is the development of Employer Information Requirement (EIR) and a BIM Execution Plan (BEP) (RIBA, 2020), which is one of the elements of BIM but is different from the design brief. EIR is a document that defines the information that the employer will require from their internal team as well as from the suppliers, which will be used for the development and operation of the building (Designing Buildings, 2023). Whereas BEP is a plan prepared by the suppliers in order to explain how the information modelling aspects of a project will be carried out. (NBS, 2017). There is no requirement for the development of conceptual 3D drawings or models as this is carried out in the conceptual design stage.

For projects to be considered BIM Level 2 compliant, as a minimum, the development of building information needs to be carried out collaboratively in a 3D environment with the possibility of attaching data to the models (Barnes & Davies, 2015; Sacks *et al.,* 2018). Similarly, in order to implement BIM in the pre-design stages, development of conceptual 3D mass/model along with the ability to attach information will be necessary. As collaborative work is one of the key requirements of BIM, early integration of stakeholders may also be required for implementing BIM in the design briefing process.

Some significant studies have been undertaken within the field of design briefing and BIM, such as Shen *et al.* (2013), which developed a method of enhancing the designer-client communication with the use of BIM, user activity simulation and requirement management techniques. Baldauf (2020) proposed a set of guidelines for using BIM in the management of client requirements in social housing projects. Innovations such as BriefBuilder is a requirements management tool, which among many other features allows the structuring and analysis of requirements. This tool can also be used to link requirements with models in Autodesk Revit that can be used to check for compliance with the brief.

This study, however, seeks to integrate the briefing process with BIM, by structuring client requirements into an Excel-based format, which can be imported by the aspired prototype and developed into a conceptual design. The goal of this development is not to replace the human element from the design process, but to assist in the decision-making process by automating some of the preliminary design process.

2.5.1 Design automation in architecture.

Automation is a widely discussed topic, not just in the field of architecture and construction but also in everyday general lives. One of the key beginnings of this discussion stems from a study by Frey & Osborne (2017), which concluded that 47% of the jobs in the US are at risk of being lost to some form of automation. However, the same study gave architects 1.8% chance of being replaced, which is one of the lowest in their list of occupations. Currently, automation seems to be happening in numerous industries, particularly in manufacturing, retail, and automobiles. Even in the field of architecture and design a certain level of automation has been achieved with the help of BIM software. This section of the study will discuss automation in the architectural industry, the current levels of automation and potential benefits that can be achieved with automation. It should be noted at this point that any argument made for automation is not a suggestion of replacing the architect and designers but creating systems and tools that can assist the professionals with routine tasks, generating alternative designs, checking for errors, optimisation, managing projects etc.

Automation can be described as the use of technology thereby reducing human input and intervention (Sharma, 2017). Automation should not be confused with just hardware that can completely replace a human, but as any hardware or software technology that can partially assist in performing tasks, which can consist of multiple levels (Frohm *et al.* 2008).

In the AEC industry, automation can be traced as early as 1883 when Warren Johnson invented the “electric tele-thermoscope”, a bi-metal thermostat which was used as an automatic room temperature control device (Delaqua, 2021). The device activated a light in the boiler room when the temperature inside the building fell, which prompted the workers to add coal into the furnace in order to increase and maintain heat inside the building. While this may not be considered automation relative to today’s technological standards, back in the 19^{th} century this was a revolutionary device.

It is widely known that trends in the construction sector are usually borrowed from the manufacturing sector. However, due to the size of buildings and variation in designs from one building to the other, a completely automated construction has been challenging. But with advancements in imagery data, 3D printing of materials and a wider adoption of off-site construction, automation in the field of construction has been gaining traction. Most repetitive tasks such as cutting and assembling, especially in case of prefabrication, can be automated in a controlled factory like environment to improve efficiency and quality thereby reducing cost. Automation is also being tested and used for on-site construction with the help of robotics. An example of this is the FieldPrinter by Dusty Robotics (2021), which can read

CAD/BIM models and print the plans directly onto the building surface on a 1:1 scale, saving the workers hours of marking the floor with chalk.

Automation in the field of architecture, however, has been less prominent than that of construction itself. One of the most significant reasons for this could be because architectural design is a dynamic process that requires skills, judgement and emotion that cannot be replicated by a software. Moreover, there are common issues such as conflicts and disputes that can only be resolved with human intelligence and interaction with peers and clients. While digital software can greatly assist designers and architects, improve quality of their work and save time, these are still only ‘assistive’ technology and may not be fully autonomous.

2.5.2 Levels of automation

Automation is generally thought of as an instant switch from manual work to fully automated without any other levels in between the two processes. However, in reality the process of change from manual work to fully autonomous consists of at least. The field of architecture or construction is yet to reach a high level of automation, and perhaps due to the nature of design and construction, there is a lack of research into the area or the levels of automation that can be used in these fields. As manufacturing is one of the most automated industries and since the AEC has borrowed methods from this field in the past, the levels of automation discussed further in this section has been compiled from research carried out in the field of manufacturing.

Over the years, there have been multiple levels of automation developed for various industries. Endsley and Kaber (1999) developed 10 levels of automation that was suitable for manufacturing, air traffic control etc. Lorenz, Nocera & Parasuraman (2001) proposed 4 levels of automation that was dependent on the type of automation being implemented. Billings (1997) proposed 6 levels of automation and argued that the level automation may not necessarily progress from manual to automatic but may instead run in parallel between the human operation and automatic operation. Frohm et. Al (2008) developed 7 levels of automation for the field of manufacturing, which have been explained below.

i. Fully manual: Total control by the user where the course of action is developed based on their requirement, experience and knowledge.
ii. Decision giving: The user gets information on what needs to be done. E.g., Work order.
iii. Teaching: A set of instruction is provided to the user on how a task can be completed. E.g., Checklists.
iv. Questioning: The system questions the execution of the user, in cases where the system considers the execution unsuitable. E.g., Verification before action.
v. Intervene: The system takes control over from the user and performs corrective action, in cases where the system considers the execution unsuitable. E.g., Thermostat.
vi. Fully autonomous: The system handles all information and controls all actions. User is not involved. E.g., Autonomous systems.

No evidence of such levels of automation was found that was developed exclusively for the purpose of design automation.

2.5.3 The use of generative design in early design stages.

Automation through generative design (GD) is one of the most significant developments in technology and is being adopted in almost every sector around the world. Researchers in the field of architecture have also been studying and developing generative tools and systems to generate design solutions, explore solution space, apply basic design principles, and reuse existing knowledge. Over the past few years, the adoption of GD in the architectural industry has been rapid, particularly with the innovation of BIM (Lee *et al.*, 2021).

The early design stages, also referred to as the conceptual design, is an important part of the architectural design process. Some of the basic and fundamental decisions are taken during this stage that will shape the rest of the design process and the project as a whole. In projects that utilise BIM, the conceptual design stage might be represented with the use of massing models and 2D element symbols (Designing Buildings, 2021). While BIM software and tools are now extremely smart and are able to perform numerous automatic tasks, such as clash detections, they still are not able to randomly generate design ideas (Renev, Chechurin & Perlova, 2017), particularly in the early conceptual design stage. However, the use of GD has the potential to provide some level of automation in the early phases of design.

Although BIM is applicable throughout the project's entire life cycle, its usages in the design phase are mainly limited in the later design stages (e.g., the design development stage, structural design stage, mechanical, electrical, and plumbing design stage, etc.). In terms of design exploration in the early design stage phase, the capability of BIM is inadequate. However, the use of GD demonstrates the potential to make up this deficiency of BIM.

GD, as a computer-aided design method, mostly focuses on geometrical modelling to quickly explore design. However, the "information" attribute usually cannot be generated. Differently, BIM produces components with both geometry and information attributes to facilitate buildability. Thus, integrating BIM can improve the constructability of design solutions generated by GD.

The integration of generative design and BIM can be beneficial to improve the capabilities of one another by making up mutual deficiencies. This integration can also support automatic and fast design explorations while enabling the buildability of the generated solutions. Moreover, this can also help in extending BIM's capability in the early design phases of a project (Ma *et al.*, 2021).

This integration can be achieved through the use of BIM authoring tools such as Revit which provides generative design capabilities in the latest version (2021) available during the writing of this study. While the generative design functions and features in Revit are still in its infant phase, more can be achieved by accessing its API via Dynamo.

There are, however, still some barriers in the way of developing and implementing generative design such as:

i. System integration: Different user prefer different software such as Revit, ArchiCAD, Vectorworks etc. However, these BIM authoring software are not interoperable and data from one ecosystem of software cannot simply be copied and pasted into another software. Moreover, a single software, currently, cannot achieve overall automation in design and require integration of two or more applications.
ii. Loss of data: Through the use of IFC, BIM data can be exported to a different software, however around 79% data lost may be lost when exchanging info between IFC and Revit (Oh *et al.*, 2015).

2.5.4 Potential benefits of automation in architectural design.

Currently, the AEC industry is in the process of adopting automation and this transformation has multiple effects throughout the industry. One of the most notable effects that automation has had is on the architectural ideas and designs, where visions that may have been thought to have been impossible is now becoming a possibility which has led to bolder design visions. (Autodesk University, 2019). Even though automation is still a relatively new subject in the field of AEC, there are other benefits than just the generation of multiple designs. This section briefly highlights some of those benefits.

i. Automate routine tasks: One of the most cited benefits of automation is the automation of predictable, routine, and repetitive tasks such as importing data, model synchronisation and update, material take off, calculations etc. These functions have more or less been achieved with the help of BIM-authoring tools. However, no proof of automation of parametric design itself has been found.

ii. Design optimisation: Another well-known benefit of automation is the optimisation of designs which allows architects and designers to adjust their designs to achieve a desired outcome. An excellent example of this is the renovation of the Alliance Theatre in Georgia, USA, where 50 large, curved wood panels were installed as the interior of the theatre. Each of those panels were acoustically varied with computationally scripted porosity to provide optimal acoustics within the theatre (Autodesk University, 2019). Without the use of computational design, this optimisation task may have taken an extensive amount of time and money, and the end result may not have been as exceptional.

iii. Improved creativity: Designers and architects, first and foremost, are creators of art that eventually are built in real life. However, their creativity is usually bound by client desires, rules, regulations as well as laws of physics. With the innovation in computational and generative design (sub-categories of automation), they are now able to create designs that no human mind can think of. This statement is not intended to imply that computers can completely replace designers and architects, but rather that computers could be partners with designers where they work hand in hand to develop creative and unforeseeable designs.

An example of this is the ‘Digital Grotesque II’, commissioned by the Centre Pompidou, Paris created by architect-programmers Michael Hansmeyer and Benjamin Dillenburger using algorithms. It is an algorithmically generated grotto (cave) with over 1.3 billion surfaces, built using a specialised 3D printer. Not only is this structure full of intricate details, but the computer also learned to evolve the generated forms maximise its richness and was able to evaluate the generated forms with respect to the observer’s spatial experience (Azzarello, 2017).

iv. Improved sustainability: Sustainability is a key issue in the world of construction, where innovative methods are being used every day to lessen the impact that construction has on the environment. As the regulations around sustainability are tightened the problem of trying to construct while remaining within these regulations begins to become more and more difficult. However, with the use of generative design, professionals are able to come up with innovative solutions that, again, may not be perceived by the human mind.

    Haley (2022) notes that the key to improving sustainability is to build products that survive longer, and this can be achieved using generative design that can help make decisions early in the conceptual design phase. It can guide the designers towards developing a more sustainable solution by, for example, generating a building that can later be turned into a building with different use without demolishing and rebuilding.

v. Reduction in errors and risks: In the field of AEC, errors and various types of risks have always been a major factor that contributes to the failure of a project. And unfortunately the reason errors occur is due to human involvement (Barrett & Stanley, 1999).Through the use of CAD/BIM systems and functions such as clash detection, the number of errors that may be present in a design has reduced (Hisham, 2018), but depending on the size of the project, there is still a risk that minute errors may be overlooked or even overwritten by users that may accumulate and result in a large and expensive issue (Autodesk University, 2019). With the use of automation and generative design technology, these errors can be further reduced by maximising the assistance received by the designers.

2.6 Limitations and Technical difficulties identified.

During the literature review process, the researcher came across many research papers that were within the scope of this study. Majority of them were related to BIM and the various ways of utilizing and integrating BIM in the design and development of building projects. The studies related to design briefing were relatively older than those of BIM and focused mainly on improving the briefing process with various means such as developing checklists, guidelines, and software tools for automatic structuring of data. However, it was realised that there was almost no research conducted in the field of design briefing where BIM was utilised from the early pre-design stages to improve the process of briefing.

Few design briefing tools have been developed by other researchers based on their pilot study, however, the majority of those tools were developed as CAD-based applications that helped structure the design brief, particularly for larger projects with numerous specific requirements such as hospitals and schools. There are a few commercially available web-based design briefing tools, however, these tools require the user to manually attach information to the 3D model, which has also been manually developed.

A closely related study was carried out by Koutamanis (2017 & 2017b), which seeks to integrate design briefing with BIM, where the design brief is considered as a source of information for BIM and then utilizes BIM functionality to automatically analyse the brief. However, the scope of his study does not extend to any form of development of frameworks or tools that can be used in the briefing process.

Another closely related study by Abrishami, Goulding and Rahimian (2020) addresses the deficiencies of BIM in the conceptual design stage and explains the development of a generative BIM prototype to support the early conceptual design process. However, this study does not seek to directly integrate BIM and the design briefing process and utilizes manual methods of data entry for the generation of conceptual designs.

It has been observed during the review of literature that even though researchers agree that there are prevailing issues with the design briefing process, most of the studies have resulted in the development of guidelines, checklists, methods, and structuring tools. While these developments have been crucial in the path of improving the design briefing process, no evidence of any type of technical development of tools involving BIM to enhance the briefing experience has been found. An explicit reason for this lack of consideration for BIM in the briefing process was not found either, however, one of the reasons for this may be the portrayal of BIM as a modelling tool rather than a ‘process’ of creating and coordinating information in a structured manner. This means that BIM is still viewed as a tool that can be extremely beneficial after the development of a design, but not as useful in the pre-design stages. This can also be seen in project guidelines, such as the RIBA PoW 2020, which does not require the implementation of BIM until the development of designs has begun in stage 2.

There are tools available that can automatically generate designs based on the algorithms, such as Autodesk Revit’s Project Refinery tool. This tool allows the user to optimise the design by creating multiple design options based on various constraints set by the user and generate draft designs early in the project, which can be used in the design briefing process to improve the understanding and quality of the design brief. However, the refinery tool does not read the data provided in the design brief and requires the user to develop a set of constraints based on which the software will provide design solutions.

2.7 Summary

The literature review in this chapter was carried out in order to gain an understanding regarding the areas of this study i.e., design briefing, knowledge capture, BIM, generative design and automation as well as to identify existing research and gaps in knowledge in these fields. Additionally, reviewing of literature has also helped the researcher learn about various concepts; research methods and techniques; methods of presenting and discussing findings that are commonly used in research projects in the field of AEC.

After reviewing a number of books and research papers, various issues with the design briefing process were identified. The Latham report from 1994 was one of the earliest papers to highlight that the design briefing process could be improved and suggested improvements in quality of the brief and spending enough time developing the brief in order to avoid errors which could lead to delays and cost overruns. This report then made way for further research which revealed multiple shortcomings in the design briefing process. Some of the major issues identified were:

i. The briefing process is not given enough time, which may lead to a document that lacks accurate or correct information.
ii. There is a lack of format or framework for carrying out the design briefing.
iii. Majority of the stakeholders of a building project, such as the contractors, suppliers, facility, and operations managers etc. with extensive knowledge in their particular fields are not included in the briefing process.
iv. Majority of the clients are not experienced in construction projects and are usually a high-level executive of the contracting organisation.
v. Clients usually are not sure regarding their needs and requirements, and sometimes they are not even the end user.

Most of the past research into improving the design briefing process involved the development of a software solution such as AutoBrief, ClientPro, CoBrITe, DIVERCITY etc., which sought to structure the design brief into a more manageable digital document, analyse and assess the client requirements and facilitate a mode of interaction and communication between the client and the design team through a virtual reality environment. These tools were developed in the early 2000s when CAD was the preferred tool in the AEC and pre-dated the industry-wide adoption of BIM. Some of the more current tools that are intended to work alongside BIM are dRofus and Briefbuilder. In addition to structuring the requirements data from a design brief, the user can also use these tools to transfer data into the BIM model and use them to assess and verify design solutions.

Although numerous research has been carried out in the field of design briefing and even more on BIM, there was surprisingly low number of research carried out regarding the use of BIM in the design briefing stages. This study will look at how useful the implementation of BIM is in the design briefing process and develop solutions that will seek to resolve or minimise any problems identified.

Chapter 3: Research methods

3.1 Introduction

The scope of this chapter is to outline and explain the research methods including process of literature review, data collection methods used to capture data, process of data analysis and the process of system development. The chapter begins by outlining the research design process used in this study, which is then followed by the discussion of the research methods used, which includes the interview and software development process. The interview process consists of the question design, selection of interviewees and the methods of capturing data and analysis used by the researcher. This is then followed by discussing the software developmental process of the conceptual system framework and the BIM-based prototype.

The chapter also provides justification for the chosen research method as well as reasons for the unsuitability of other research methods for this particular research. The final section discusses the research ethics, bias and ethical considerations made during this research followed by a summary of the chapter.

3.2 Research design

Research in many fields seeks to explain two fundamental questions: *(i) What is happening?* and *(ii) Why is it happening?* (NYU, 2014) However, in the field of science and technology, the question of *How can it be fixed/improved?* also takes equal importance. A research is about identifying issues and reasoning, but it is also about solving known issues or finding ways to improve current methods and/or techniques. This research has a similar agenda. Identification of an issue; reasons behind it and developing an alternate method of carrying out the task.

NYU (2014) convincingly defines the function of a research design, *"…is to ensure that the evidence obtained enables us to answer the initial question as unambiguously as possible."* Hence, before carrying out the research itself and to avoid haphazard collection of data, a research design was carried out to create a research framework in order to answer the research questions. Through the literature review process, gaps in knowledge were identified in the design briefing process as well as the lack of use of BIM in the early stages of building projects. Hence, the following research questions were developed.

1. What is the current sentiment towards the traditional process of design briefing?
2. Can the design briefing process be improved with the implementation of BIM, and if so, how?
3. What kind of functions and outputs would a BIM-based design briefing tool require?
4. What kinds of advantages could a BIM-based design briefing method present?

Based on these research questions, a research aim was developed, which is to develop a framework and prototype to improve the quality and performance of building projects using innovative BIM based design-briefing methods. In order to achieve the aim, the following research objectives were developed.

1. Understanding research background relevant theory and techniques and current research.
2. Exploring users' and designers' demands of BIM-based design briefing tools/solutions via interviews.
3. Based on the demands of BIM-based design solutions, develop a system framework to demonstrate general functionalities and data structure of the design briefing system
4. Based on the system framework, develop a prototype.
5. Testing and analysis of the prototype and discussions of the overall development and industry impacts.

In order to achieve the relevant research objectives, this study utilizes 3 major research methods which are:

1. *Literature review* in order to gain knowledge and understanding of the research area as well as to identify problems and questions.
2. *Interview* in order to understand the views of professionals in the industry, analyse their collective response and capture requirements.
3. *System development* using a partial prototype method to develop a prototype based on a conceptual system framework.

As mentioned previously, this research utilises qualitative methods, which is different in a few ways than quantitative methods, where more attention given to research design and controlling conditions and external variables that are not part of the study but influence the phenomenon being studied

(Flick, 2015). Research design under quantitative methods diverts more focus towards sampling, planning data collection, understanding the participant's views and ideas analysis and extracting empirical materials to be able to answer the research question (Creswell, 1998). The research was designed keeping this point in mind which have been illustrated in Figure 3.1. Each of the points outlined in Figure 3.1 have been discussed through the rest of this chapter.

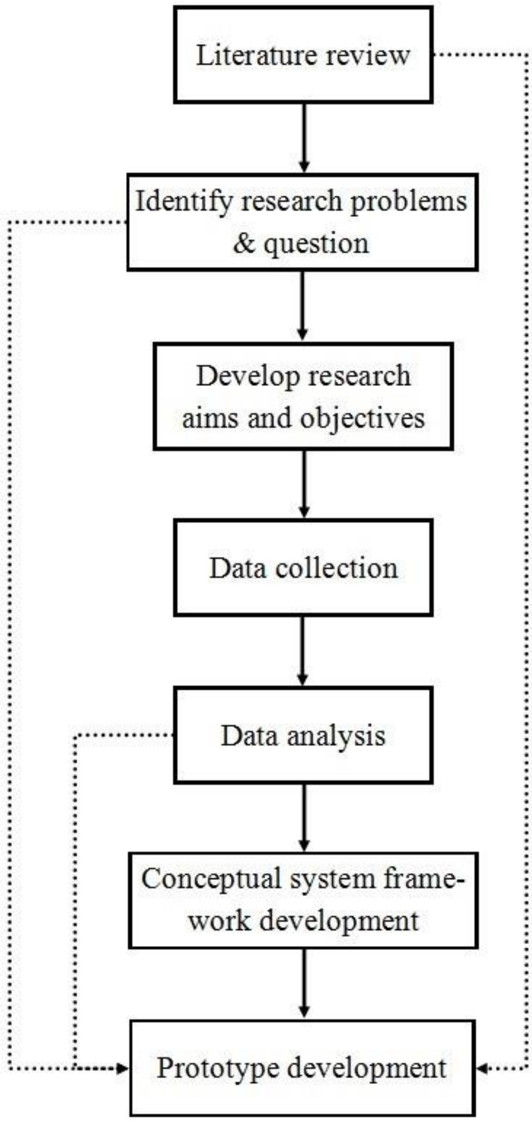


Figure 3.1 Research design process

3.3 Research methods

This section of the chapter outlines and explains the steps taken to carry out the research, which begins with the review of literatures, then the identification of research problems and questions. Next, the development of research aims and objectives and the process of data collection is discussed. This is followed by a discussion regarding the process of analysing data, then the development of the conceptual system framework and finally the development of the prototype and its testing.

3.3.1 Literature review and desktop study.

The first step towards any research is to carry out a literature review, which is done for multiple reasons based on the researcher's need. For this research, it was crucial that the researcher understood:

i. Concepts and definitions
ii. Development history & background
iii. Design theories and principles
iv. Relevant regulations and legislations
v. Current technologies and industry practices
vi. Current relevant research and case studies
vii. Relevant research methods
viii. Gaps in knowledge
ix. Addressing research problems and questions within the research area.

Additionally, carrying out an effective literature review creates a strong theoretical base on which the research can be based and carried out (Gough, Oliver & Thomas, 2017). Moreover, the review of literatures and identification of gaps in knowledge has enabled the researcher to develop research questions and subsequent aims and objectives.

During the early stages of the research, various types of literature review were identified, namely; narrative (e.g., Baumeister & Leary, 1997), systematic (e.g., Tranfield *et al.,* 2003), scoping (e.g., Peters *et al.,* 2015), argumentative (e.g., Coleman, 2017), integrative (e.g., Torraco, 2005), and theoretical (e.g., Abdi, 2015). All these types of literature review have their own advantages and disadvantages, and using one type of review may not necessarily help the researcher achieve their objectives. Hence, in order to carry out an effective literature review, a mixture of narrative, scoping and argumentative literature reviews were used, which have been explained below.

a. Narrative literature review: Arguably the most common type of literature review, narrative literature review helps the researcher collect, understand, and critique different types of literatures within the research area. A topic of interest will have been identified but will lack predetermined research questions and strategy under this type of review (Demiris *et al.,* 2019). However, due to the relatively ad-hoc approach of this type of review where any type of literature related to the research area is studied, it can be useful in identifying gaps in literature.
b. Systematic literature review: A systematic literature review follows a process of identifying and critically appraising relevant research, while also analysing and comparing findings from those research (Liberati *et al.,* 2009). This type of review aims to answer one or more research questions by identifying evidence from past research that fits specific criteria.

Systematic review generally divided into two categories, namely, meta-analysis and meta-synthesis. This study takes the meta-synthesis approach as it takes a non-statistical approach by integrating, evaluating, and interpreting findings from selected qualitative studies, which was more appropriate in answering the research questions.

c. Scoping literature review: This type of literature review is a relatively new and is generally used to identify and map evidence available in the research area. It also helps clarify concepts and definitions, examine research methods used for certain type of fields/topics, identify characteristics related to a concept as well as identify knowledge gaps (Munn *et al.,* 2018). Scoping review was used in this study to find research carried out in recent years with relation to design briefing and BIM, particularly, to identify parameters and gaps in knowledge that this study could fill.

Literature review was carried throughout the entire process of this PhD research due to the dynamic nature of the AEC industry today where BIM is a popular and heavily researched topic. New ideas, technologies and information related to BIM emerge on a regular basis, particularly on the internet on websites dedicated to BIM such as BIM+, Centre for Digital Built Britain (CDBB), BIM Crunch etc. and BIM related blogs such as ‘There’s no BIM like home’. Hence, the researcher felt that it was important to keep the literature review chapter of this thesis up to date until the end.

The process of carrying out a literature review involved 4 methodological steps that are based on the steps outlined by Fink (2014), which have been described below.

i. Selecting a research question: Based on the research aims and objectives, a number of research questions were selected that would guide the review process and assist in keeping the process on track. Adjustments had to be made along the way as it was realised that the current questions may not be entirely suitable in achieving the aim of the research.

ii. Selecting literature, database, and search terms: The selection of relevant literature was an important step in order to find the correct information. Most of the search for books/e-books were carried out using the library website provided by the university. The search for journals were carried out using online database websites such as ScienceDirect, ResearchGate, CORE, CIS etc. in addition to the university library database and Google Scholar. The search terms used to find relevant resources began with simple words such as 'design briefing', 'issues with design briefing' to find basic information. Then the search criteria were increased to a combination of words such as 'design briefing and use of BIM' or 'design briefing and RIBA Plan of Work'. Further literatures were also identified using the reference list used by authors in their journals. Majority of the literature referred came from primary sources such as original research in journals and conference proceedings. Secondary sources such as review articles, systematic reviews, meta-analysis and various guidelines were also referred to. Finally, tertiary sources such as online articles from reliable sources were also referred to, in order to gain the most current knowledge in the field of AEC.

iii. Automatic and manual screening: Carrying out online search for literature, however, was not the end as these searches yield hundreds and thousands of results, most of which were not relevant or ideal for this research. Hence, in order to only view relevant papers, first an automatic screening was carried out using functions such as refining by year of publication, type of article, subject area, publication title etc., which are provided by the database websites. Manual screening was then carried out by reading the title of the books/journal paper and the abstract to evaluate its relevancy. If the researcher felt that the paper was relevant and within the scope of this study then further reading of the paper was done and relevant portions were used, cited and referred. This process of screening allowed the researcher to identify the most relevant literature and keep this study on track. For topics such as BIM, which are rapidly evolving, more recent papers were favoured first, in order to gain the latest information. If no new information was found, then a descending order by date was followed to find information.

iv. Carrying out the review: Upon the discovery of reliable and relatable paper or book, notes were taken using OneNote, and a draft version of each section was created, reviewed, and corrected. The literature review chapter was reviewed and revised a number of times as new information, particularly in relation to BIM, became available. The structure of the chapter was also amended a number of times in order to create a better flow for the reader.

The literature review of BIM investigated the process of using BIM in the AEC through the RIBA Plan of Works 2020, BIM frameworks, methods of implementation in non-design and construction phases of a building lifecycle such as building operation and management and post occupancy evaluation (POE). Understanding how BIM is currently applied to projects has helped formulate research questions and identify gaps in knowledge.

Another imperative half of this research is design briefing, which is crucial for any project as it contains the client's vision, needs, and desires, based on which the architectural team create their designs and the asset is built. A thorough review of literature related to design briefing was important as unlike BIM design briefing has been at the centre of all construction projects for years. It was necessary for the validity of this research to review every aspect of design briefing along with its weaknesses using traditional methods, to identify if there was a need to improve current methods of design briefing, to find out what past research had proposed for improvement and to identify if there were any potential for a BIM-based design briefing method.

Also, another issue crucial to this research was to understand the implementation process of BIM. Hence, various literature, particularly in the form of journals and white papers were reviewed in order to understand how BIM had been implemented in a new scenario, a new phase of design and construction and new projects. This has helped the researcher understand the challenges, requirements and benefits of implementing BIM.

3.3.2 Identify research problems and develop research questions.

One of the beginning stages of any research is concerned with the identification and selection of a research problem (Flick, 2015). A research problem can primarily be identified through the review of various literatures in order to find gaps in knowledge. Past research papers also provide solid ground for identifying research problems through their suggestions for further research (Creswell, 1998).

A research question is the heart of any research as it embodies the curiosity of the researcher as well as defines a guideline for the research. Answering this question is the central goal of any research project. During the development of research questions, the researcher was careful not to pose a question that was too vague or too broad, which would shift the focus of the research into unintended territory or become unmanageable.

After the identification of gap in knowledge through the review of literatures, the researcher sought to narrow down the gap into a research problem that could be used as a platform to develop a research question. The problem that was identified by the researcher was the lack of research in the field of design briefing (Kamara, Anumba & Evbuomwan, 2002; Ryd, 2004; Olatokun & Pathirage, 2015; Koutamanis, 2017). In this specific research, the process of design briefing had not been updated for years apart from it being digitised; BIM had played a major role in taking the construction industry to new heights, particularly in the field of architectural design and development. However, the design briefing phase was left behind. Hence, the problem that required research was clear: Design briefing based on the RIBA Plan of Works 2020 is a three-stage process however BIM does not play a role in its development and the implementation of a BIM-based design briefing method may have the potential for substantial improvement in capturing client requirements as well as the design and construction process.

Holliday (2016) explains that the initial research question steers research in a certain direction. But as the research develops, unforeseen discoveries are made that partially or entirely shift the focus of a study. The focus of this research from the beginning has been on improving the design briefing process through BIM implementation and this has remained true for the entirety of this research process. However, minor changes have been made to some of the research objectives, depending on the discovery of information through literature reviews and empirical data collected, but the original research focus has remained unchanged.

3.3.3 Develop research aim and objectives.

A research aim sets out what the researcher seeks to achieve by the end of the project and acts as a statement of intent. It provides the researcher with a target that can be used to answer the research question and informs the reader what the researcher will achieve. The research aim stems directly from the research problems. However, a researcher needs to bear in mind that the aim that he/she sets is realistic and achievable, particularly in PhD research, which has time limitations. And similar to the research question, the research aim also should not be too broad.

In order to achieve the aim of this research a number of objectives have been set. Research objectives are sequential steps that are taken in order to achieve the research aim which subsequently answers the research question. Five objectives have been set in order to achieve the aim of this research, which is to develop a framework to improve the quality and performance of building projects using innovative BIM based design-briefing methods.

3.3.4 Principles of software engineering

Software engineering is a process or a collection of methods using an array of tools to build a computer software (Pressman & Maxim, 2015). As with performing any other task, the process of building a software follows some basic principles and methods. As the aim of this research is to develop a software solution, it was crucial that the researcher understood the process behind developing a software. It should be noted that although this study does not use conventional programming language that requires knowledge of coding, but instead uses visual programming, where the process of development is similar and thus follows a conventional software development process.

This study partially applies the prototyping method, which can be seen in Figure 3.2, as the process to be followed for a few reasons. Firstly, it is an efficient paradigm for software engineering and one of the simplest yet effective process of software development (Pressman & Maxim, 2015). Secondly, the requirement to complete every step before moving on to the next allows any roadblocks to come forward and get resolved. Finally, with the use of a prototyping model, the end goal is known, and the work in each step is done in a timely manner to achieve that goal.

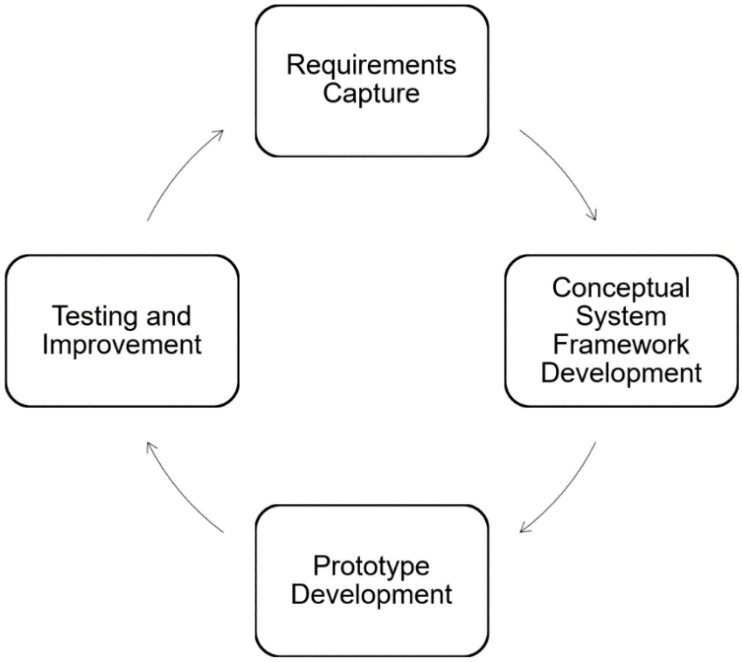


Figure 3.2: Prototyping model.

The reason for using a partial prototyping model was because in general the model consists of 6 steps. However, since the scope of this study is limited to developing and testing the software, there is no need for deployment and maintenance. Hence, this study will only follow 4 of the steps, i.e., user requirements capture, system framework development, prototype tool development, and system testing & improvement.

The user requirements for the proposed BIM-based design system are captured during the interviews with professionals and academics. They are experts in this field and through their experience and knowledge would be able to provide requirements that are or could be in demand. These would also include identifying functionality requirements and process of inputs and outputs.

The conceptual system framework development is then carried out in order to create an overall vision of a potential system that defines the major functional modules and databases of the system (Pressman & Maxim, 2015). The functional and non-functional modules and business requirements are also defined during this stage. This system framework development follows a 6-step process outlined by Sommerville (2016), which has been discussed in *Chapter 5: Conceptual System Framework & Prototype Development.*

The prototype tool development will be performed by using Dynamo, which is a visual programming language aimed at architectural and design professionals who may not be knowledgeable in using any programming languages. Several databases will also be required in order to store client requirements, which will be done through the use of MS Excel.

Throughout the development of the prototype tool, testing will be carried out in order to confirm that it is on the right track and the algorithm is working as intended. As the development will be carried out in stages it is important to constantly check for any issues that may arise (Sommerville, 2016).

3.3.5 Interviews

Data collection is the set of systematic steps taken in order to collect information from various relevant sources in the form of interviews, surveys, observations, documents, case studies etc. that can be analysed to fulfil research objectives (Creswell & Creswell, 2018). The steps in a typical data collection begin with setting boundaries for the study, collecting data/information through various methods and establishing protocols for recording and storage of information.

For this research, two types of data were collected, i.e. (i) Primary data; and (ii) Secondary data. Collection of data began from secondary sources first through a desktop study. It was crucial for the validity and reliability of this research that sources of secondary data were strong, credible, and accurate, as it would impact most of the research process as well as findings. Sources of secondary data were mainly published peer reviewed journals as they provide reliable and up-to-date information. Books were also consulted, however, due to the current interests in BIM in the AEC, the information contained in them sometimes were outdated. Other sources of data were websites and blogs dedicated to BIM and design briefing. Care was taken when sourcing online data so as to only use data from highly reputed agencies such as the National Building Specification (NBS), RIBA, BIM+, Designing Building Wiki which is supported by organisations such as Chartered Institute of Architectural Technologists (CIAT), Institution of Civil Engineers ICE, Building Research Establishment (BRE) etc. and the CIAT award-winning blog 'There's no BIM like home'. In terms of design briefing, journals, books as well as past research were excellent sources of information as they provided the researcher with years of information related to the problems, ideas, innovations, and failures related to the design briefing process.

Primary data for this research was collected in the form of semi-structured interviews with professionals from the industry. Generally, there are four methods of collecting data in a qualitative study, which are (i) observation, (ii) interview, (iii) focus groups and (iv) surveys (Creswell, 1998; Fink, 2014; Flick, 2015). For this study, semi-structured interview was selected as it is the most widely used form of interview and it can usually be the sole source of data in research projects (DiCicco-Bloom & Crabtree, 2006). It also lets the researcher to develop questions before the interview but also allows them to ask follow-up questions based on the interviewee's answers, resulting in a more wholesome capture of data.

The purpose of conducting semi-structured interviews for this study was to identify the user's demand and potential benefit of BIM-based design briefing tools and methods in addition to its potential impact on the overall process and productivity of a building project. Furthermore, conducting interviews will also help the researcher to explore and develop users' requirements in terms of functionalities and databases (inputs and outputs) of a BIM-based design briefing system.

Various architects, managers and academics were invited for an hour-long face-to-face interview in order to collect raw data, which was recorded for later transcription and analysis.

3.3.5.1 Semi-structured interview question design.

In order to conduct the semi-structured interviews, the suggestions provided by Flick (2015) were followed when developing interview questions. For example, leading and persuasive questions were avoided; questions were open-ended; and the first few questions were related to the interviewees' experience to help them feel at ease and reduce nervousness. A draft set of semi-structured questions were then prepared that covered the intended scopes of the interview. All of the questions were semi-structured to allow the interviewees to provide honest answers and avoid them from feeling pressured into agreeing or disagreeing with the interviewer. This would also allow the interviewees to ask follow-up questions based on the answers or probe further if the answers are vague.

Before finalising all the questions, a draft was prepared for review by the researcher's supervisor who has more knowledge and experience in this matter. After the review, it was suggested that since the study itself looks into two major factors, i.e., design briefing and BIM, it would be appropriate that questions for the interview were also divided into two sections. Hence the final set of questions were divided into two sections. Additionally, since the samples included professionals from the AEC industry as well as university academics, slight modifications were made to the questions to make them more relevant. In total 16 questions were developed for the interview.

The first section of questions dealt with the interviewees' experience with design briefing, the current issues in the briefing methods and process, innovative tools, and mechanisms that they may have come across or used. This set of questions were designed to understand their views regarding the design briefing process and to help them think about the issues that they may have faced (if any) in their working experience.

The second set of questions began with questions that sought to understand their views regarding BIM and its implementation in the early stages of the project. The questions then incorporated design briefing with BIM and sought their views regarding the possible implementation of BIM in the briefing process. In order to reduce biasness, the questions were designed to help them think about the implementation from both an advantageous and disadvantageous position. Questions regarding stakeholders' collaboration in the early stages of a BIM-based design briefing process were also included as this was identified as an issue during the literature review and was being considered as an important factor during the conceptual system development stage.

Upon finalising all the questions for the interview, a pilot interview was conducted in order to test the flow of the interview as well as to check if the interview could be covered in around 60 minutes. This also allowed the researcher to prepare for the interview, check the quality of recording devices, practice note taking and keeping the interview on track.

3.3.5.2 Selection of interviewees

Sample is a selected portion of a larger group of people (Fink, 2014), and sampling is the process of selecting the people of interest in a research study. As the participation of an entire group of population is not feasible in majority of studies, a small group of people are selected to provide data based on which analysis can be carried out. Sampling is more practical as it allows data to be collected faster and economically rather than accumulating data from every single member of the target population (Turner, 2019).

During the review of sampling techniques for this study, the researcher came across two sampling methods: (i) Probability sampling & (ii) Non-probability sampling, each of which has four techniques in general. The first of the two methods - probability sampling is where every member of the population has an equal chance of being selected. This method of sampling is useful when a study seeks to produce results that represent the entire population. The second method - non-probability sampling is where samples are selected based on a list of criteria set by the researcher. This method of sampling is used in qualitative research in order to understand the views of a selected population sample (McCombes, 2019).

Probability sampling has four techniques of sampling which are: *simple random sampling, systematic sampling, stratified sampling, and cluster sampling*. As this method of sampling is based on randomly selecting participants, each one of these techniques also uses one or another type of randomisation when selecting samples. For example, simple random sampling may use tools such as a playing dice or a random number generator on MS Excel to select random samples from a group of population, while cluster sampling requires dividing the population into subgroups with similar characteristics, and rather than selecting individuals, entire subgroups are randomly selected (Fink, 2014; McCombes, 2019). Due to the randomness of probability sampling, it was decided that this would not be the most ideal sampling method as the samples would need to possess a certain level of understanding and experience in design briefing and BIM.

As this study utilizes qualitative method, it was decided that a non-probability sampling method would be more appropriate in understanding the views of the professionals in the industry. However, this method of sampling also has at least 4 techniques of sampling, namely: *convenience sampling, voluntary sampling, purposive sampling & snowball sampling*. Convenience sampling utilizes those people who are most accessible to the researcher, while voluntary sampling includes those who volunteer to become participants. And snowball sampling is where participants are enrolled though contact with other participants (McCombes, 2019).

After eliminating rest of the techniques, purposive sampling was chosen as the most appropriate technique for this study. This type of sampling requires the researchers to use their expertise to select samples that can be of most help in the research. Purposive sampling is mostly used in order to select samples who meet certain criteria to gain detailed knowledge about specific topics with the research topic and also in cases where the population is small (McCombes, 2019).

The reason for the selection of this type of sampling was the need for participants who could fulfil the criteria of possessing knowledge in both design briefing and BIM, who had at least 7 years of practical experience in either design briefing or BIM, were practicing in the UK and were willing to be interviewed. As BIM is a relatively new process in the field of AEC and still has not been adopted by many practitioners, it was imperative that the participants were well aware of the details of BIM. This also meant that the samples had to possess knowledge and experience in carrying out design briefing in order to be able to visualise the likelihood or unlikelihood of implementation of BIM in the briefing process.

In addition to working professionals within the AEC, academics with interest in design briefing and BIM were also included in the population size. While professionals are able to provide their input regarding current industry requirements, trends and suitability of BIM implementation, academics are able to provide a different perspective, provide input regarding upcoming technologies related to briefing and BIM and highlight issues that may arise from the same.

3.3.5.3 Methods of capturing interviews

The main purpose of conducting interviews was to gather answers from experts in the field and carry out in-depth analysis to understand issues, answer research questions and fulfil objectives. In order to achieve this, the interview had to be recorded and transcribed.

As part of the research ethics, potential interviewees were provided with a consent form which required them to agree to their voice to be recorded during the interview so that it could be transcribed later. For this purpose, a Sony voice recorder was used with a microphone attached. In addition to this a laptop was also used to operate Google Docs' voice typing feature that can automatically type words spoken by the interviewee. This feature was moderately effective but still required the researcher to listen back to the recorded audio and correct any inconsistencies.

There were instances when an interviewee was not available for face-to-face interview, and it had to be done through Skype. In these instances, Skype's call recording feature was used during the interview portion of the call, after notifying the interviewee when the recording was about to begin and after it had stopped. These types of recording were fully transcribed by the researcher manually.

Some notes were also taken by hand, mostly to quickly note the interviewee's response and ask any follow-up questions based on their answers. Notes were also taken to make observations of the interviewee's body language and tone of voice (to the best of the researcher's ability) when answering certain questions as suggested by Flick (2015).

3.3.5.4 Methods of analysing interview

In the previous section, it was established that interview of professionals was the chosen method of data collection. Audio data from these interviews were then transcribed and analysed on a software program called NVivo. Analysis without the use of a computer software may have been possible but at the same time the amount of paperwork would have been overwhelming and time consuming and the level of analysis may not have been of the same quality.

For this study, a thematic analysis approach was selected, which is a method used in qualitative study for identifying, analysing, organising, describing, and reporting themes found within a data set (Braun & Clarke, 2006). This is an excellent approach to structure data, examine the perspectives of the interviewees, where their differences or similarities can be highlighted which can help produce a clear understanding (King, 2004).

The analysis was carried out in a total of 6 phases as outlined by Nowell *et al.* (2017), which are:

1. Data familiarisation: The first step in analysing data was to get familiar with the data. Although the interview questions were structured in a similar pattern for all interviewees, the process in which the interviewees provide their answers were not structured. Hence, it was imperative that the researcher went through the transcripts to find

some initial patterns that can be used in order to begin generating codes for the next stage. The management of data was also a crucial step in this stage which included naming the transcripts correctly and storing audio and transcribed data in an encrypted drive with a cloud backup.

2. Code generation: The raw data generated via interviews are vast and unsystematic. Hence, coding was carried out in order to simplify and structure, identify reoccurring themes within the data set and develop ideas (Morse & Richards, 2002). Coding was done with the use of NVivo that helps in structuring and sorting data. The process of coding began by importing the transcribed document into NVivo. Then the interviewee's thoughts, ideas and views were coded into various themes such as "[Interviewee] Believes BIM-based design briefing methods can improve the process: Yes or No." The 'Yes' node then contained the interviewee's reasons for a BIM-based design briefing method and the 'No' node contained their views against the same. A more detailed process of coding has been provided in *Chapter 4*.
3. Searching for themes: Once sufficient numbers of codes were identified, various themes were searched for, which involved sorting and collating relevant codes based on themes. Firstly, themes which would seek to answer research questions were identified and then further sub themes were sought after.
4. Reviewing themes: This phase involved going over the identified themes as well as codes in order to identify any inaccuracies. King (2004) suggests reviewing themes as inadequacies in the initial

coding and the themes may be revealed that might need to be changed. It was also identified that even though a number of themes were identified during phase 3, not all of them had enough data to support them. Hence, these were eliminated or where possible, merged with other sub-themes to develop new themes.

5. Naming and defining themes: In this phase, the researcher writes a detailed analysis of each individual theme, identifying what is of interest about each theme. King (2004) suggests that it is necessary to decide when to stop refining and changing themes. Hence, after sufficient themes were identified, the research questions were answered, and all the data had been read through, it was concluded that it was time to stop any further reviews.
6. Writing up report: Finally, a report was written up based on the analysis carried out in phase 5, which has been presented in *Chapter 4*.

3.3.6 Conceptual system framework development

Upon completion of the interview analysis, the next step was to develop a conceptual system framework that forms the base for the prototype development. A conceptual system framework's aim is to define the functionality and data structure of a system. In this research study, these are based on the requirements captured from the interviews. The conceptual system framework includes major functional modules, as well as input and output databases. The development of this framework is an essential stage that is required in the software engineering process in order toto convert the user's requirements into feasible conceptual functions which can be materialised via computer programs.

The development of a conceptual system framework plays a vital role in this research as it acts as a bridge between empirical analysis and the development of the prototype. Data gathered through interviews and literature review provides ideas and concepts as well as the needs and requirements from the new system. However, this conceptual system should not be confused with a full conceptual model used in computer software development as this is more abstract than those used in computer system architecture. The conceptual framework for this research will be limited to developing a schematic system that shows the relationship between a client's requirement capture, the process of derivation of these requirements through add-in software the technical and functional requirements of the system and the output of a conceptual BIM model.

The outcomes of the interview analysis play a key role in the development of the framework, as the interviews were also used as a method of capturing requirements from the interviewees. The initial requirements captured from the interviews demonstrate some types of demands for a BIM-based solution to design briefing and any solutions the interviewees had come across in the past. This helped the researcher understand if the proposed solution was feasible or not and if continuing with this development would be useful for the study.

Upon confirming that the proposed solution was feasible through literature reviews and analysis of interviews, an initial conceptual framework was developed. This framework was based on the researcher's findings from the literature review and only included some key BIM functions to begin with. The development began by outlining the traditional process of design briefing as well as BIM-related activities based on the RIBA Plan of Works (PoW) 2020. This helped the researcher identify areas of design briefing that could be improved with the implementation of a BIM-based design briefing solution.

Then the functional requirements extracted from interviewees were analysed and implemented in the framework. The addition of Post Occupancy Evaluation (POE) data and the inclusion of other stakeholders were also mentioned by the interviewees and were also identified during the review of literature, which were then added to the framework.

Next, the sources of data for the system were added. It was recognised during the literature review as well during the interview process that MS Excel is widely used as a form of collating and structuring client requirements data. Since the development was being done on Revit and Dynamo, which allows importing of data via MS Excel, it was decided that this would be the best source of data. This meant that the proposed design briefing prototype would be able to extract information such as space data from MS Excel files and produce solutions.

Based on all this information the final conceptual system framework was developed. Further information and discussion regarding this can be found in *Chapter 5: Conceptual System Framework & Prototype Development.*

3.3.7 BIM-based prototype tools development

This section describes the process used in the development of the proposed BIM-based design briefing prototype. Based on the principles of software engineering, prototyping is the process of implementing ideas into a preliminary working model, known as a prototype, which is generally developed for demonstration purposes or as a part of a wider system development (Pressman & Maxim, 2015). Around 70% of systems development uses prototyping (Hardgrave, 1995) and should be used for all object-oriented projects (Coad and Yourdon, 1991). A prototype plays several roles in the system development process, which can include the following points identified by Chua, Leong & Lim (2017):

i. Experimentation and learning
ii. Testing and proofing
iii. Communication and interaction
iv. Synthesis and integration
v. Scheduling and markers

During the course of this study, prototyping has helped the researcher learn new methods of software development using Dynamo, experiment with different ideas and methods as well as test the prototype for further refinement. Due to time constraints, an evolutionary method of prototyping was used, where only one prototype is developed and is built incrementally (Pressman & Maxim, 2015) rather than developing each prototype from the beginning.

Multiple advantages of prototyping were also identified, which helped the researcher choose an evolutionary method (Pressman & Maxim, 2015), some of which are listed below:

i. As the development is carried out in small increments, progress can be seen early in the development phase.
ii. Additional requirements can be added if needed.
iii. Errors in programming can be detected early which helps reduce time and cost.
iv. The prototype can be refined further to develop wider programs.

3.3.7.1 BIM-based platform development tools and methods

It was mentioned earlier that the BIM-based design briefing software development would not mainly use traditional programming languages such as C++ or Python. Instead, a visual programming language called Dynamo will be used that is aimed for use by architectural and design professionals who do not possess programming skills. Dynamo provides the user with the ability to visually script behaviour in real-time and define pieces of logic and script with the use of traditional programming languages (Dynamo, 2018).

As described earlier, the major functions are defined in the system framework/architecture based on the user's requirements, which have been derived from the interviews. The design of the prototype will be conducted with the help of Dynamo, which is a Revit add-on program. Client requirements, building regulations, local council requirements etc. are stored on an MS Excel file, and imported into Dynamo, which will then be used to analyse the data and generate multiple 3D models of the building. Dynamo does not require the researcher to know object-oriented programming languages such as C# or Python, which requires knowing and typing the codes in order to create programs. Rather, Dynamo utilises a Visual Programming Language (VPL). A VPL is a type of programming language that is specifically designed to cater for the needs of architects and designers. It enables the creation of programs by manipulating graphical elements, or nodes, providing a more suitable approach for these professionals, as seen in figure 3.3 (Kilkelly, 2018).

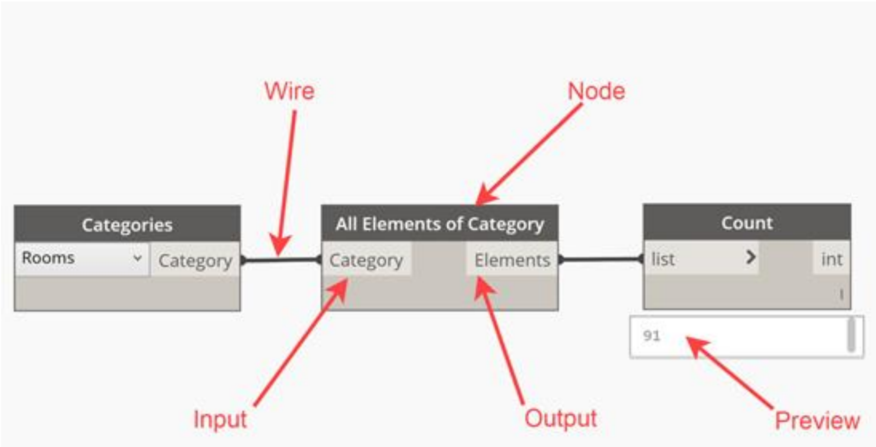


Figure 3.3 Basic flow of dynamo interface

(Source: Kilkelly, 2018)

Revit is a very powerful program on its own, but Dynamo allows the user to access Revit's Application Programming Interface (API), allowing higher levels of manipulation to what the program can accomplish as well as develop custom commands and programs. As seen in Figure 3.3, a Dynamo interface is composed of 'nodes' and 'wires'. Nodes are objects that are programmed to perform a specific operation, which may simply be that of storing a single numerical digit or placing a geometric shape on a particular point. These usually contain one or multiple inputs and outputs. A wire connects one node to another and establishes the flow of the program. Through the development of a complex series of nodes and wires one or multiple designs can be generated.

Testing of the developed prototype will then be carried out upon the development of the prototype and any necessary changes will be made. Testing will be conducted with an aim to “break” the system as typically done in computer programming in order to locate every possible problem and test it to its limits. (Pressman & Maxim, 2015).

3.3.7.2 Database for BIM-Based design briefing

As mentioned earlier, the chosen format for the management of client requirements database was MS Excel. This is a format that has been used for design briefing purposes and is available easily and is a program that the researcher is familiar with. This format is also compatible with Dynamo which allows the user to import data from MS Excel directly.

For the development of the prototype, a simple data sheet for a hypothetical school was used. This data sheet was developed based on the output of the schedule of accommodation developed by the DfE (2015), which allowed the researcher to use accurate area sizes. The MS Excel file consisted of names of spaces, area size and adjacencies to other rooms. This simple data allowed the researcher to develop a program on Dynamo that would generate multiple floorplans, where the spaces were located on either side of the hallway.

3.3.8 Testing of prototype

Testing the prototype is necessary in order to confirm that the program is functioning as intended as well as to identify any bugs in the system that may hinder the functionality of the software (Pressman & Maxim, 2015). There are various methods of testing a prototype where each method consists of advantages and disadvantages. Vliet (2008) discusses two different types of tests in that can be used to test software during its development, i.e., (i) Unit testing & (ii) Integration testing.

i. Unit testing: This is a software testing technique in which units or components of a software application are tested in isolation from the rest of the application. This type of testing is done during the software development process, which helps in validating that each unit of the software are performing as expected.

ii. Integration testing: With this technique, the composition of multiple components is tested, where the focus is on testing the interaction between different units. The purpose of this type of testing is to verify that the various units work together as expected and that the script produces the desired outcome.

Generally, these types of tests are performed automatically by writing a test code, setting-up a test environment and running the tests independently. However, these tests can also be carried out manually, while replicating similar results as that of an automatic test. A manual approach is more time consuming, but this does not require the researcher to possess knowledge in coding in Python and develop multiple scripts solely for testing. Additionally, since this study utilises Dynamo as the scripting tool in order to develop the prototype, unit testing would not be the most appropriate form of testing. This is because Dynamo is a VPL, which uses nodes and wires instead of written scripts, and testing each node individually as a unit would not be useful as nodes as nodes would have already been tested to provide a specific output with the correct input. Hence, this study has been tested using manual integration testing method. In addition to this, a demonstration was also provided to a group of professionals and academics, followed by a discussion in order to gain feedback on the prototype developed for this study.

3.4 Research method justification

As mentioned earlier, this research mainly takes a qualitative approach, and this section of the chapter provides the reasons behind the selection of the approach. It also provides reasons as to why a quantitative approach was believed to not be as suitable to achieve the outlined aim and objectives.

Creswell (1998, p. 15) defines qualitative research as,

"…an inquiry process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem. The researcher builds a complex, holistic picture, analyses words, reports detailed views of informants, and conducts the study in a natural setting."

A qualitative method of research and data collection was chosen keeping the aim and objectives of this research in mind. Quantitative method of research is more suited towards presenting contrasts between groups (e.g., Is group A better at performing a task than Group B?) or showing a relationship between variables (e.g., Did Variable A explain what happened in Variable B?) (Creswell, 1998). Hence, a quantitative method for this research would not have been suitable as the researcher is not attempting to quantify the results or identify simple trends in the industry. If the motive behind this research was to simply identify, for example, if professionals believed BIM would be useful in improving the design briefing process, then a questionnaire could have been developed, emailed and the results could have been quantified to provide a yes or no answer.

However, the motive behind this research is not just to understand the feasibility of a BIM-based briefing method but also to understand the issues they face in their everyday practice, how they believe BIM can contribute to the improvement of the briefing process, what functionalities they believe would be useful, if they have come across similar methods in their practice etc.

Qualitative methods of data collection, particularly interviews, are most useful for analysing the meaning behind interviewees' words. It can provide researchers with deep and detailed information that can be used to analyse and find matching trends with other interviewees. It would also allow researchers to design questions in such a manner that would extract as much information as possible from an interviewee.

Few benefits were identified before the interview process even began. For example, an interview also allows the researcher to add a human dimension to the research where two people can sit down and have a conversation. Flick (2015) states that interviewees are more likely to be honest and share their experiences in this manner than through questionnaires or written answers. It also provides them with a comfortable and confidential space to relay their thoughts on an issue than they probably would in a focus group for example. A semi-structured interview would also allow the researcher to follow-up the interviewee’s answers to get more information, or clear-up misunderstandings making it more reliable.

An added benefit of conducting face-to-face interviews is that the researcher will be able to observe the interviewee for any discomfort or hesitation in providing answers which could prove to be useful during the analysis of the data. However, observation on its own would not have been suitable as the researcher would not have been able to achieve detailed answers from the participants. In an observation scenario, the conversations they would have with other people may have provided the researcher with some form of answer to a few research questions. For, example if there was a problem with a brief document and the participant had a conversation with one of their colleagues regarding this issue, the researcher might have been able to pick up on this. But there would have been a separate issue regarding ethics, participation of the other person in the conversation and the researcher being present at that moment in time when the conversation took place.

When selecting interview as the preferred method of collecting data, the researcher was also aware of the issue that this method would entail. For example, Adams (2015) warns that semi-structured interviews as time-consuming and laborious. The researcher needs to be sophisticated and should know the subject area very well before conducting the interview. He further states that setting up an interview can also prove to be extremely difficult, particularly when the area of study is niche, and the number of potential samples are small.

Once the interview is completed, the process of analysing the vast amount of data can also be extremely time-consuming and frustrating. Although some software can assist the researcher in organising the data, the researcher still needs to complete the difficult task of sorting the data into various themes and analysing the data.

3.5 Research ethics and ethical considerations

Research ethics in simple terms refers to the researcher's moral judgement, their commitment towards the interviewee's/participant's rights and honest publication and dissemination of their research. ESRC (2015) defines it as *"…the* moral *principles guiding research, from its inception through to completion and publication of results and beyond."* ESRC (2015). It can sometimes be easy to estimate that a researcher's ethical responsibilities begin with seeking an informed consent from the interviewee and ends with the keeping their identity anonymous. However, ethical decisions need to be made as early as during the research design phase and depending on the type of research can last long after publication of the results.

Ethical dilemma transpires in every research project, and with ethical issues mixed with social media it is more important than ever before to solve these dilemmas with uttermost care. In the eyes of majority of the general population, research is a well-educated, accurate, reliable and unbiased source of new information that can be trusted and relied upon. Depending on how the data was collected for research, the interviewees, participants, and subjects also expect their right to privacy be respected and their views to be presented accurately. Similarly, for this paper ethical considerations had to be made at almost every stage of the research with the help of ethical norms, guides, frameworks, and moral judgement. This section provides a general overview of some of the ethical decisions made during the development of this paper.

3.5.1 Privacy

Privacy of the interviewees was a major ethical concern for this research. As with majority of research, the researcher provided the interviewees with all information required for them to make an informed decision regarding their participation. They were made aware regarding methods of data collection, storage, management, usage, accessibility, and eventual deletion. Once the participants were satisfied, 2 copies of a consent form were signed by both the interviewer and interviewee, and each received a copy for their records. For interviews carried out over Skype or the phone, a digitally signed copy was provided to the interviewee and a copy was retained by the researcher.

3.5.2 Incentives

An ethical issue, unrealised until just before the first interview was that of payment or incentives. Oliver (2010) provides an argument that it can be deemed reasonable for the interviewee to expect to be paid or reimbursed for giving up a portion of their time for an interview rather doing their own work. He further states that this could engender a professional approach to their contribution. However, from the researcher's point of view this had the possibility of increasing biasness from the interviewee as they may feel inclined to provide answers different from their belief simply to please the researcher. Hence, it was decided that it was best if the interviewee were not paid, reimbursed, or compensated in any way.

3.5.3 Safety

Face-to-face interviews were all conducted in the interviewee's place of work, hence there was little to no concern for the safety of either of the participants. The research also did not require any physical contact, testing or personal details from the interviewees, hence approval from the concerned organisation were not required. Since the interview was only related to a small part of their professional life, the researcher did not find any risk towards the interviewee's emotions or mental wellbeing.

However, Wiles (2013) identifies that despite anonymisation, interviewees may be upset at the portrayal of their ideas during publication and dissemination of the research. Hence, care will be taken by the researcher as to not bend the interviewee's words or take them out of context to give a different meaning than intended.

3.6 Summary

This chapter provided a thorough description of the process of literature review, research design methods used in this study. Through the review of literature gaps in knowledge were identified and the research aim, objectives and questions were developed.

In order to collect empirical data and capture requirements from professionals in the industry, semi-structured interviews were conducted. The interviewees were selected based the criteria of possessing knowledge in both design briefing and BIM, who had been practicing BIM for at least 7 years, were practicing in the UK and were willing to be interviewed. A total of 11 interviews were conducted each lasting around 60 minutes. The interviews were audio recorded (with the interviewees' written consent) and then transcribed for thematic analysis using NVivo.

Based on the literature review and requirements captured from the analysis of the interviews, a conceptual system framework was developed for a BIM-based design briefing system which illustrates the relationship between different variables and the flow of information between them. Multiple iterations of the framework were developed until a final version was chosen.

The development of a prototype tool was carried out using an evolutionary prototyping method of software engineering, where the conceptual system framework was used as a base during the development. This method of software development allowed the researcher to carry out the development in stages while working on a single iteration of the prototype.

A Revit based visual programming tool called Dynamo was used for the development. An MS Excel file was used as the database for the tool which was derived from the schedule of accommodation for school buildings developed by the Department of Education.

Chapter 4: User requirement interview and analysis

4.1 Introduction

The previous chapter discussed the research methods and methodology used in this research study as well as described process used to develop the conceptual system framework and the BIM-based prototype tool development. This chapter presents the process of capturing user requirements via interviews and thematic analysis of the data. It explains in detail the process of selecting interviewees, data collection processes & methods as well as the interview analysis. This was done in order to understand the shortcomings of current briefing practices in the UK construction industry. This included the feasibility of implementing a BIM-based design briefing method, issues that may arise with the implementation and identify the functional requirements of a BIM-based briefing method. The chapter begins with the preparation of this semi-structured interview by developing questions for the interviews, with a brief explanation of each question. This is followed by a section which explains the process of selecting interviewees, the process of interview and the process of thematic analysis used in this study. The chapter also presents the key interview outcomes with the results of the thematic analysis. Finally, the findings from the interview are addressed before providing a summary to the chapter.

4.2 Interview questions development

Questions for the interview were set by the researcher with the research questions and objectives in mind. The review of literature provided the researcher with knowledge regarding the current state of design briefing and BIM. This also helped the researcher in identifying gaps in knowledge that this study could fill. Based on the information acquired through the literature review a set of questions were developed for the interview.

The decision to opt for a thematic analysis was made early in the research process, which helped in organising questions for the interview in the same manner. This also meant that when analysing data, it could be divided into similar categories and themes. Organising questions in this manner would also improve the flow of the interview process, and keep similar questions together, which would help minimise the time it would take to organise and code data during the analysis phase.

Additionally, the researcher felt that by taking the interview through these themes, the interviewee would get a chance to think about all aspects of briefing and BIM while providing the answers. For example, it would not have been appropriate for the researcher to ask the interviewees about the method of briefing they use in practice and then immediately ask about the implementation of BIM in the briefing process. This type of questioning may not compel the interviewees to systematically think about the possibilities of a BIM-based briefing process and probably may not have been able to provide very detailed answers. However, the researcher’s intention was not to create biases and understood that some answers provided by the interviewees may not support the researcher’s objectives.

A preliminary set of questions were first developed by the researcher for a pilot interview. Based on this, minor changes to the wordings were made that would give the questions more clarity. Some questions were combined together to keep the interview within the timeframe while some questions were added or omitted to suit the research objective. Overall, 2 sets of questions were finalised for the interview as there were 2 types of professionals that were being interviewed, i.e., industry professionals and academics. However, the 2 sets of questions were similar in themes and were only developed to suite their working background and experiences, hence providing the researcher with the ability to analyse them together.

The questions for the interview have been provided in Table 4.1 below with explanations for choosing to ask these questions.

Table 4.1: Interview questions

Questions	Rationale
1. What is the traditional method of briefing used/ that you use?	This question would help the researcher understand the method of briefing that they use or have used in the past and identify common methods between other interviewees that may potentially be linked to issues with the traditional process.
2. What tools or mechanisms have you used for design briefing?	Through the literature review, it was concluded that majority of the briefing involves the use of simple pen and paper that can later be digitised through a word processor software. This question sought to verify

	this finding and also learn of any new and innovative method that professionals might be using in the industry or the academics may have developed or seen in development.
3. What are the key issues that needs to be covered in the design briefing process? Do you have standard templates?	The purpose of this question was to identify key issues that needs to be addressed during the design briefing, which can then be analysed and used during the development of the conceptual system framework. This would help assure that important phases were not being left out in the development of the framework.
4. Have you come across any poor briefs or issues with the current method of design briefing?	Through the literature review, it was identified that design brief documents may consist of errors that later lead to issues in the design or even the construction phase or are lengthy that lead to confusions among various stakeholders. Hence, this question sought to identify the kinds of briefs that could cause issues as well as any issues faced by professionals with the process of briefing itself.

5. Is design briefings a dynamic process or static that ends before design begins?	This question would help the researcher understand the rationale behind the use of the two processes of briefing, which can later be analysed along with the issues they face during briefing to identify any correlation. A BIM based briefing method is also prone to be more dynamic in nature hence identifying the preferred process of briefing of majority of the interviewees would allow for the development of the conceptual framework in a similar manner.
6. Are there any innovative methods of design briefing that you have come across?	This question was asked in order to identify any innovative methods of briefing that the interviewees had come across that may have helped in resolving issues. It would also allow the researcher to identify if any new methods of briefing were being used in the industry.
7. Who are the stakeholders involved during design briefings? Who should be involved?	This question was specifically asked to identify the stakeholders present during the briefing process and to understand the interviewees' views regarding the inclusion of non-design-related stakeholders. During the literature review, it was concluded that non-design-related stakeholders such as project managers, and facility and operation managers are not usually present during the briefing stages.

8. What kind of dispute or misunderstanding can occur in the briefing stage?	As mentioned earlier, one of the issues identified in the briefing process was that it was prone to errors and misunderstandings. This question sought to understand the reason behind these issues and analyse how a BIM-based briefing method could help reduce these issues.
9. At what stage of the RIBA PoW should BIM be implemented?	Based on the RIBA PoW 2020, BIM implementation begins at stage 2, apart from the preparation for the implementation that takes place during stage 0 & 1. However, this is just a guidance and practices are free to develop their own guidelines for implementation of BIM. This question seeks to understand if any of the interviewees have implemented BIM in stage 0 or 1, and if so, why? This would help the researcher analyse the feasibility of implementing BIM in the pre-design stages and set a base for this research as well.
10. Do you believe BIM can have an impact on the design briefing process?	The purpose of this question was to allow the interviewee to think about the implementation of BIM in the briefing process and the impact (positive or negative) that this may have on the briefing process. If the interviewee did not mention stage 0 or 1 in the previous question, then this question would allow them to think about the implementation of BIM in the

	pre-design stages and allow the researcher to further analyse the feasibility of the proposed implementation of BIM.
11. What do you think about other stakeholder collaboration if BIM is implemented at the design briefing stage?	This was a follow-up for question 7, where the interviewee was asked about their view regarding the inclusion of other stakeholders in the briefing process. The purpose of this question was to analyse if the interviewees saw any benefit in the inclusion of other stakeholders as BIM, by nature, takes a collaborative approach. This was also used as an opportunity to reframe the question to check for biasness from the interviewees.
12. Why do you think BIM has not been implemented in the briefing process so far?	Findings from the literature review concluded that BIM as a process is not implemented in the briefing stages of the RIBA PoW 2020. This question sought to understand if the interviewees agreed with this approach and if they have their own approach to BIM.

14. What impacts (negative or positive) can BIM implementation have in the briefing process?	The purpose of this question was to remove any biasness from the interview and capture the interviewees' honest point of view on the implementation of BIM in the briefing process. The analysis of this question would contribute to the feasibility of the implementation and allow the researcher to learn of any issue that may have been overlooked.
15. Do you think BIM implementation in the briefing stage can help reduce conflicts?	It was evident from the review of literature that the briefing process and the design brief can cause conflicts and errors due to confusion between various stakeholders. Hence, this question sought to analyse if and how the implementation of BIM in the briefing process can resolve such issues. This idea stems from the fact that through the use of BIM, projects have seen a reduction in errors, particularly in larger projects (Love *et al.*, 2011; Lee *et al.*, 2015; Wong, Zhou & Chan, 2018).
16. What barriers/challenges do you see with BIM implementation in the briefing stage?	BIM has had issues with implementation in the design stages in the early days, hence this question sought to identify potential issues that may hinder the implementation of BIM in the design briefing stage. As this is a novel study there were no literature found that were related to this issue and

	would rely on the analysis of empirical data from these interviews.

Questions were set systematically based on their respective areas. The questions were reduced to cover three areas:

i. Issues with current briefing process
ii. Implementation of BIM-based design briefing methods
iii. Required functionalities & datasets for a BIM-based design briefing method.

Further explanation for dividing the interview questions into three areas has been provided below.

i. **Issues with current briefing process:** First of the three areas of the interview were related to design briefing and its issues. This section of the questions was developed to understand the interviewee's/organisation's process of design briefing, the format they utilized, their expectations from the client and their response to the client's brief.

   Through the review of various literature, it was found that the briefing process had remained the same over the past couple of decades and was prone to errors and problems. In order to further understand if these or any other issues existed in practice, a few questions related to the interviewee's experience with briefing were developed. This would assist the researcher in further understanding how briefing issues materialised and what countermeasures had been taken by the interviewee or their organisation.

Along with understanding the issues with briefing problems in the real world, the researcher would also get an idea if any organisation or any academic has tried to implement BIM in their briefing process or not. This part of the interview would also establish the feasibility of this research by answering if there were any major issues in the briefing process that needed addressing and the role BIM would play in improving this.

ii. **Implementation of BIM-based design briefing methods:** This section of the interview was concerned with understanding the possibility of implementing BIM for briefing purposes. The questions were related to the interviewee's experience of using BIM as well as briefing. Because BIM is a relatively new process which gained popularity through the government's 2016 deadline for implementation on all public projects, it was expected that most of the interviewees would have some experience in its implementation process as well. Hence, some questions related to the implementation were also included.

Furthermore, every potential interviewee would have gone through a different route of BIM implementation in their practice. These set of questions sought to extract their experience and ideas related to the implementation of BIM and their interpretation of what BIM should and could be able to accomplish in the briefing process.

iii. **Required functionalities for a BIM-based design briefing method:** This part of the interview question sought to understand the interviewee’s functional requirements in a possible BIM-based design briefing method. The inclusion of questions related to the functionalities was of high importance as it would provide the researcher with answers that would not have been available through the review of literature. Through years of experience, an interviewee would have gathered enough knowledge and idea as to what kind of improvements could be made to the briefing process, even though these may not particularly be BIM based. The ideas could simply be software-based or a method of systematic organisation of data. It would then be up to the researcher to analyse their answers and develop a functional BIM-based method.

4.3 Interviewees selection

This section of the chapter explains the process that went into selecting the most appropriate interviewees for capturing requirements and data. Next, it provides detailed information regarding the interviewees while maintaining their and their organisation’s anonymity, followed by an explanation of the method of data collection.

The samples targeted for this research stems from the research questions, objectives and the researchers aim. For example, one of the research problems identified for this study is the lack of involvement of stakeholders such as facility and operations managers, suppliers, engineers etc. in the briefing process. The corresponding objective for this problem is to extract and examine knowledge from the design team for their lack of involvement in order to understand what contributions they could have made to the briefing process. This objective could be best achieved by interviewing a high-profile professional with authority to make such decisions from an architectural firm as they would have first-hand knowledge regarding this issue. A random selection of interviewees from any architectural firm would not have been appropriate as not all architects may be involved in the briefing process or knowledgeable in the process of BIM. Hence, a purposive method of sampling was approached (as explained in *Chapter 3),* where only those samples best suited for this research were considered and approached.

Age, gender or race of the interviewee were not criteria for selection of an interviewee. However, it was decided that a sample with at least 7 years of experience would possess adequate knowledge and experience. The interviewee's knowledge regarding both the briefing process and BIM was an important factor. But because BIM is a relatively new process in the AEC, the researcher understood that there would be a limited number of professionals that were experts in both fields.

The interviewee's geographical location was not considered as a factor affecting their selection as the interviews could be conducted over the internet. However, since this research is based in the UK and considers the RIBA PoW 2020 to be a basis for this research, it was decided that only practices and practitioners based in the UK would be approached.

A total of 51 formal emails were sent to various professionals in architectural firms, particularly aimed at senior members as they would possess more experience. Where possible their direct email address was sought after and sent a request email. In cases where a direct email was not found, an email to their organisation was sent with ‘for attention of Mr/MS ABC’ added to the subject line. As a backup, these particular set of professionals whose direct emails were not available, an email was sent to their LinkedIn account, which in fact produced results and a couple of professionals wrote back and agreed to be interviewed. Of these 51 emails sent, 36 responses were received with a response rate of 70.6%. Of these 36 responses, 11 professionals were interviewed, which is a response rate of 30.5%. Some of the professionals who had agreed to be interviewed requested a copy of the questions in order to prepare themselves, which was provided to them.

Of the 11 interviewees, 7 were architects who had been working in the industry for over 7 years, 1 was a BIM-manager with a background in BIM communications. 4 academics were all professors with at least 14 years of experience within the field of architecture/built environment, with involvement in various research projects funded by EPSRC and other funding bodies.

During the early stages of this research, an architectural firm based in London agreed to provide assistance in the form of interviews and briefing materials. This early opportunity was utilised as a pilot study in order to formulate and develop the interview questions.

4.4 Interview process

The interview process began with the arrangement of a time and place for the interview. All face-to-face interviews took place in the interviewees place of work, hence there was little to no concern for the safety of the interviewer or the interviewee. Upon meeting the interviewee and exchanging pleasantries, the first task at hand was to invite the interviewee to initial, sign and date the ethics consent form, of which they were informed in the invitation e-mail. This form provided a brief description of the research and their right to withdraw from the research at any point up to the point of submission. The form was then signed, dated and retained by the researcher. In order to remove any biasness, they were once again reminded before the interview, that the conversation was strictly confidential and subsequent transcript of this interview was only accessible to the researcher and the principal supervisor.

Once the consent form was signed the interviewee was once again informed that the interview would be audio recorded for the purposes of transcription at a later period. The audio was recorded on an audio recording device and as a backup it was also recorded on the researcher’s smartphone, which also acted as a timekeeping device. In order to assist in the transcription process, Google Doc’s voice typing feature was also used to automatically type the transcript that the researcher went over for any corrections.

The semi-structured interviews took place for around 60 minutes on average and the researcher also sought to observe the interviewee's body language and level of comfort when providing answers. The researcher is not an expert in kinesics but some natural human behaviour such as discomfort or hesitation can be observed in everyday life. Based on this the researcher made simple notes, where necessary, along with the time when the observation was made in the interview process. This would help the researcher in interpret and analyse the message the interviewee was trying to convey.

Instances where a face-to-face interview was not viable, due to the interviewee’s availability or due to their geographic location in the country, interviews took place over the phone or skype depending on the interviewee’s preference. In these cases, the respondents were emailed a copy of the consent form before the interview took place and were requested to either physically or digitally sign and email back the form to the researcher.

The face-to-face semi-structured interviews took place at each individual interviewees place of work, which was usually in a meeting room. Recordings of the audio was made using a Sony audio recorder as well as the researcher’s smartphone’s in-built audio recorder as a backup. Interview conducted via Skype were recorded using Skype’s native conversation recorder on the researcher’s encrypted laptop.

By the end of the allocated time for the collection of data, a total of 11 interviews had taken place, which had lasted for an average of 61 minutes. Creswell (2013) argues that in a phenomenological study an average sample size of 10 interviewees is acceptable where a long form of the interview takes place. Based on this information, it was decided that the sample size was acceptable. Hence, it was determined that the amount of data collected would be adequate for the study.

Table 4.1 provides a list of interviewees occupation, location, and years of experience. To protect the interviewees and their organisation's identity as well as to abide by the university's ethical code of conduct an alphabetic code has been assigned to each interviewee to be able to recognise their part of the contribution.

Table 4.2 List of interviewees

Alpha Code	Profession	Location	Years of Experience at time of interview
A	Architect	London	21
B	Architect	London	15
C	Architect	London	16
D	Architect	London	8
E	Architect	London	17
F	Architect	London	12
G	BIM Manager	Cardiff	7
H	Uni. Professor	Withheld	19
J	Uni. Professor	Withheld	16
K	Uni. Professor	Withheld	16
L	Uni. Professor	Withheld	14

Table 4. 1 Interviewee Information

4.5 Thematic analysis process

The following sections discuss the process of thematic analysis implemented in this research (as outlined in *Chapter 3*), followed by the researcher's analysis of the data collected through interviews. Thematic analysis is one of the most common methods of analysing qualitative data, where the researcher picks out similar themes and patterns in the data and organises them under a certain heading or code for further analysis (Flick, 2015; Holliday, 2016). In order to efficiently manage and analyse the data, a computer software called NVivo was used which is purpose-built for qualitative data analysis. It helps the researcher store, organise, identify trends, categorise and code data for effective analysis.

i. Data familiarisation: The first step in carrying out the analysis was familiarisation with the data that had been transcribed. This basically involved importing all transcripts to NVivo, adding alpha codes to each transcript to maintain anonymity, reading through the transcript, making any minor corrections such as spellings, removing filler words such as 'umm', 'err', 'ahh' etc, highlighting portions of interest and generally getting familiar with the written texts.

ii. Code generation: Code generation or coding is the process of labelling the data based on the gist of the sentence or paragraph. The idea behind coding is to break down the vast amount of data into smaller pieces of information and filter out any unnecessary information in order to better understand what the data is really trying to convey. NVivo played a major role in assisting the researcher with this process. By using these codes, the aim was to break down a large amount of information into smaller, more manageable parts, remove unnecessary details and view just the necessary and relevant parts from the data. For example, some of the codes were labelled as ‘not satisfied with the way briefing was carried out’, ‘difficult to capture all requirements’, ‘design brief defined too early’, ‘client was not sure’ etc. The researcher then identified these as having a common theme of ‘issues in the design briefing process’ and was labelled accordingly at a later stage. This process helped understand the main message in the data. The generated codes were then grouped together with similar ones from other datasets to develop themes that formed the basis of the analysis and helped answer the research questions. Since there was a lot of data to code, the codes were organized into categories, grouping similar codes together. These categories represented different groups of codes.

iii. Searching for themes: Upon the completion of coding and then categorising data, the search for themes began. The process was similar to the previous step of categorising codes into sub-themes. However, in this step, the priority was to search for themes that would help answer research questions, which have been re-iterated below for reference.

1. What is the current sentiment towards the traditional process of design briefing?

2. Can the design briefing process be improved with the implementation of BIM, and if so, how?

3. What kind of advantages could a BIM-based design briefing method present?

4. What kind of functions and outputs would a BIM-based design briefing tool require?

Searching for themes was a more rigorous process than that of coding and categorising as this involved reading the text numerous times in order to correctly identify what message a word or sentence or paragraph was trying to convey. There were also times when the researcher had to re-read transcripts multiple times to check if there were any data that had been missed and would be valuable to the research.

iv. Reviewing themes: The review of themes was an essential step in the analysis process as it involved checking for any inaccuracies and mistakes made during the previous step and rectifying them. This step was also used to go through the themes and decide if they were relevant and within the scope of the research or not. It also helped the researcher streamline the themes where possible to develop a clearer understanding of the data and eliminate or merge various codes together in order to stay within the scope of this study. For example, before the review of themes, there were a total of 7 themes that had been developed. However, the researcher felt that some of the themes such as 'BIM experience', 'design briefing demands' and 'system requirements' could be merged with other themes. This process involved either eliminating codes that did not fit the new theme or simply migrating codes over to the new theme.

v. Naming and defining themes: The final step of the analysis process before the report write-up was to define or finalise the themes. This process involved grouping the themes that were reviewed in the previous process under one name that captured the essence of the grouped themes. It was crucial that this step was executed correctly as the report in the next step would be entirely based on the themes identified here.

vi. Report write-up: The final step of carrying out a thematic analysis is the report write-up, which can be found in the next section. The report will seek to define each of the themes and provide evidence in the form of direct quotations from the interviewees. Followed by the analysis section, the findings section will report on what the researched was able to find through the analysis of data and how relevant research questions have been answered.

4.6 Key interviews outcomes

This section of the chapter presents the key interim outcomes of the interview before an in-depth analysis was conducted. While the focus of this research is to answer the research questions, this section provides a general interpretation of the data that was collected, in order to help the researcher, understand the data a little more. This section has been structured based on a part of the key questions of the interview with an attempt to understand the overall view of the interviewees on that particular question. This section forms part of the familiarisation with data, which is the first step in carrying out thematic analysis.

a. Process of design briefing: The first question in the interview was related to the interviewee’s process of or experience in design briefing. The majority of the interviewees mentioned that they follow the guidance in the RIBA Plan of Works (PoW) as much as possible, but some choose to apply their own process of briefing. *"I don't think that has ever really changed, but people might be doing it in different ways."*, he commented. However, not a lot of variation was found in their responses as most interviewees simply stated that they attend meetings with client(s) and capture their requirements to provide some sketching or simple line drawings.

b. Use of tools or mechanisms in briefing: Next, they were asked about any tools or mechanisms that they use during the design briefing process. Majority of the interviewees responded that their tools of preference is a pen and paper that they use to gather requirements and communicate with sketches with the client. *"We would be capturing all of our information face-to-face with pen and paper. Only digitally into a word document."*, one interviewee stated. While another stated that, *"Pen and paper mostly. I think it's important always as architects that we express are able to express our ideas to people who don't understand architecture and we've got to find the right means to do that."* There seemed to be a trend with the briefing process where every professional follows the same style. The fact that briefing has not changed in over a decade seemed to be true at this point early in the interview.

   However, one interviewee claimed to use a digital model early in the briefing process stating that: "So nothing special that we use, just pen and paper. We use the digital model very early on... the client can actually comment back on and express whether they like or not." This suggested that even though majority of the professionals followed similar trend of briefing, there are few that attempt to do things differently, even though a digital model at this stage is deemed no necessary by many.

c. Issues to be covered during the design briefing process: The third question was related to the kinds of issues that needs to be covered through the design briefing process. The interviewees provided various answers such as, *“understanding constraints and opportunities”, “understand who the stakeholders are”, “what the general approach would be” and “ambition of the project.”* Some provided more specific answers such as, “*in hospital projects, how many beds, operating rooms....in a hospital a benefit might be actually the reduction of cross infection between patients...so how can the built environment help?”*

d. Poor briefs: The interviewees were also asked about the kinds of poor briefs that they had come across during their time in the industry. The outcome of the responses suggests that many of the initial briefs that they receive are inaccurate or too ambitious to a level that it would be impractical to build but they had to rely on the brief they had at hand and work with it. For example, interviewee A, an architect, expressed his frustration stating that, *“I think some of the worst examples is where we have been briefed by somebody and we’re given a brief and we don’t feel the brief is good enough. But because of time constraints and the lack of understanding from the client we have to just muddle through it.”*

Another architect mentioned difficulty in managing a client's expectation through the briefing process stating that, "So, a lot of clients don't expect or realise is that to go to planning you need to actually appoint a lot of other consultants and do a lot of engagement. So, the thing is managing expectations."

e. Static vs dynamic process of briefing: The choice between static briefing, where the brief is completed and locked before the design commences and dynamic briefing where details of the brief are decided as the project carries on was somewhat divided. Interviewees stated that it can be *"tricky and possibly quite rare to get a full brief from day one."* While others commented on how they prefer for a brief to be *"done from the offset because it's a lot easier for us to be creative."* However, most understood that *"the reality is that the brief changes all the time"* and they simply had to adjust to any change that the client may request.

   The overall preference of the interviewees was static brief as it would mean that there would be minimal or no change in client requirements in the future. However, *every* interviewee agreed that changes in brief at some points in the project process were inevitable. It can also be understood from the responses that even with advancements in 3D modelling and BIM, changes to client requirements often happen. Hence, the target of any potential tools should be to help clients understand their requirements as well as the design solutions from the early stages in order to reduce changes rather than trying to eliminate any changes at all.

f. Stakeholder inclusion: When asked if other non-design related stakeholders such as engineers, project managers, facilities managers, contractors etc are usually included in the briefing process, majority of the interviewees stated that they were not. Some of the reasons provided by the architects were that they did not want them to *"dictate"* and *"dominate"* the briefing process and *"influence the design"* solution. As architects, it is their responsibility to develop the design and they believed that involvement of non-design related stakeholders would cause unnecessary hinderance to their work. They also wanted to provide the *"right information at the right time"* as the stakeholders may feel burdened with too much unnecessary information at the early stages.

   Majority of them agreed that *"inclusion of other stakeholders in the briefing process for their knowledge may be beneficial"* for the project. However, the decision lies with clients as well the method of project procurement. For example, if a client is looking to develop a project with the sole aim of selling, then they may not be inclined to include other stakeholders and bear the additional cost.

g. Disputes and misunderstandings: The interviewees were asked about any misunderstandings or disputes that can occur during the design briefing process in order to understand the issues better and find solutions through the development of the BIM-based design briefing tool. One of the major issues that were realised was the *"unrealistic views on the programme (design brief) and process"* by the client highlighted by two of the interviewees. Comments were also made regarding a client's lack of understanding of *"how spaces work together", "additional cost" and "constant requirement changes."*

One of the reasons for rise in issues was miscommunication between the client and the design team, hence, it is crucial that *"all communications received from the client are documented."* This also helps the design team in clearing out misconceptions if the client representative changes over the period of the project.

The general consensus here seems to be that most of the misunderstandings occur from the client's end. However, it should be noted that not all clients are well versed in the process of briefing, and it is up to the design team to communicate the design solutions with the client in an effective method.

h. Impact of BIM implementation on design briefing: The majority of the interviewees agreed that the design briefing process will have a positive impact if BIM were to be implemented. An interviewee claimed to have "implemented aspects" of BIM in the briefing stages through "early 3D modelling and use of the BIM Execution Plan (BEP)" in order to "align their system with the British Standards (BS)." While another claimed that they use BIM in the briefing process "to be able to manage both the clients and their expectations" through the use of "3D massing to be able to visualise" the potential building. A comment was also made regarding the use of BIM in the early stages as a "method of validating the brief" and "to check what is feasible."

   There, however, was an interviewee who could not see *"how relevant BIM was to the briefing process"* and thus could not see how impactful the implementation of BIM would be in the briefing process. The reason behind this statement was the lack of designs during the briefing stages that BIM is reliant upon.

4.7 Thematic analysis

This section of the chapter presents the thematic analysis carried out in order to identify patterns in the interview transcripts. Four themes pertaining to the research questions were identified which have been listed and explained below.

4.7.1 The issues in existing design briefing process and outcomes

One of the core subjects for this research was the identification of issues in the design briefing process. Although various issues were found through the review of literature, identification of similar issues through analysis of empirical data confirmed that the data captured was valid. Moreover, the data also highlighted some of the lesser-known issues with the design briefing process that individual professionals have experienced during their careers.

a. Unrealistic expectations

Interviewee B, an architect, expressed his frustration with a client's unrealistic expectations with regard to project schedule during the briefing process, saying that:

> "*I think there can sometimes be an unrealistic view on briefing. That's one thing. So, for instance, a client may want a job to be done in three months*

when the rest of the design team knows it's going to take 4-5 months for particular reasons. Might have to do with the convoluted engagement process or a particular planning process. That's probably the biggest challenge and managing that expectation. And you are in sometimes in a difficult place because you can be very honest with a client and tell him it's going to take 5 months and he may say I'm going to go with someone else who can do it in three months. And what sometimes happens is he takes on that other person and 3 months later they're still working on that project. And it still gets done in 5 months."

The interviewee also delved into the issues clients might face during the briefing process, explaining that:

"And I think sometimes it can lead to frustration on the client's side and so if you've got to make sure that they understand why these things take so long. So, they don't start being critical and you got to make sure that you take them on the journey with you at all times."

The interviewee was able to explain the journey of a client during the design briefing process that begins with the fuzziness of their requirements. If the clients are not experienced in the design and construction process, then this contributes to them having unrealistic expectations regarding the time it takes to go through the briefing process and develop a design brief. These issues are worsened when an architect or designer, knowingly or unknowingly, agrees to complete the process within the unrealistic time period and ends up taking longer. This eventually leads to frustration for the client and criticism of the design team creating a negative relationship between the two stakeholders.

b. Inaccuracy

Interviewee C, an architect, commented on the inaccuracies in design briefs as well as the misinterpretations by those writing the brief by saying that:

> *"I think it's always tricky and possibly quite rare to get a full brief from day one. There's usually a brief that we develop with the client and know their requirements. I've been involved in projects where there is a strategic brief which is set out at the very start, but it's never really true to what the client actually wants. And sometimes it can be written by a third party who try to interpret what the client wants, and from our experience, the agreement doesn't quiet hit the mark. So, it is quiet disappointing."*

Design briefs are often written for the client by a professional such as an architect. The architect developing the brief needs to interpret the client's needs and requirements that may have been verbally communicated over one or several meetings. However, there may be times when either the architect misinterprets what the client has communicated, or the client may communicate their needs in a manner that is not completely clear to the architect, both of which may lead to the development of an incorrect brief. This error may go unnoticed for various reasons and may only be clear when a design is developed or even after the construction is underway, causing disputes, re-works, and extension of project timelines. Inaccurate briefs were also identified, through the review of literature, as one of the leading issues in the design briefing process.

c. Misunderstanding

Interviewee D, an architect, commented on the issue of misunderstanding that can arise during the briefing process by stating that:

> *"We obviously have misunderstandings and I believe whilst it is our clients, I believe this is quite reflective of what goes on in this industry. but then you do have to be very careful with clients if you do note everything and if do record everything with them. If they do give you change order over the phone, then you should at least e-mail them back to confirm that because a lot of clients will work on the presumption that they have already briefed you to do that, or you should have known that anyway."*

Misunderstanding between two or more parties can occur in any project due to various reasons. The interviewee quoted above points towards one of those instances where the client may ask for a change in their brief over the phone. Failure to note down this change in the brief may cause issues during the design stages leading to disputes, as the client may believe that they have communicated their requirement once they have provided verbal instructions to the design team. This also points towards the need to promptly update the design brief as soon as new instructions are received from the client. This may be in the form of an e-mail to the client confirming the receipt of instruction or a note in the design brief documenting the change.

Interviewee E, an architect, also shared an experience of misunderstanding that may occur if the person representing the client organisation is replaced, saying that:

"Although a lot of our clients are larger bodies and we would have somebody who would come on behalf of the client, who would be working on this particular project. What we tend to find in the industry is that if that person changes jobs or moves on and somebody else comes into replace them. We need to make sure that everything is clearly noted and documented, because they don't pass on information. So, we have to work with them, and we have to expect client changes all the time or our client representative changes all the time. And making sure that we are watertight on our briefing process and any change that has been instructed."

One of the issues of working on large projects such as hospitals or schools is that these are multi-year projects and there usually is a person who provides the brief for the project and is the main point of contact for the design team. However, there may be times where that person may move on to work for another company or retire and may or may not have briefed the new person regarding all the matters of the project. The new person may also request changes to be made to the brief based on their beliefs. If changes are not noted and documented correctly, then there again may be disputes hindering the timeline of the project.

4.7.2 Issues in current methods of design briefing

a. Lack of use of technologies

One of the interesting findings from the literature review was that even with all the technical advancements of the 21st century, there were still architects and designers that carried out design briefing meeting with clients with the use of a pen and paper. Similarly, during the interview process it was noticed that majority of the architects still prefer to only use pen and paper to gather and convey ideas to the clients. Interviewee A, an architect, mentioned that:

> *"We can sit there with pen and paper, we can run workshops, where we use white boards, and we write things down, separate into small groups. But yeah, pen and paper, and communication is the best thing."*

While interviewee D, another architect, conveyed a similar idea elaborating that:

> *"I still think that pen and paper is a great way of communicating with people. That might be slightly old-fashioned, but we use the screen, we use interactive means of doing things as well. We take people to places and try things out. I'm sure technology has its part in all that as well."*

While the researcher agrees that pen and paper is an excellent medium of communication with clients, there are demands for a more robust tool that can be used during the design briefing process to help convey design solutions. For example, interviewee, B an architect, commented on the availability of tools that can be used for briefing purposes saying:

> *"They have tools that allow them to capture and there is this new start-up called Scenario Lamps. It's not the only one, there are a few others that help capture things like energy analysis and things like that on existing developments so then helping the briefing process for the next one to see where cost savings and things can be taken. So, there are tools out there, but I don't think many people are using them as much as they possibly*

> *could, because it's all very new. Software in the construction industry is very new to a lot of people."*

However, he ended the statement by mentioning the lack of enthusiasm in professionals to learn new software, even though they are freely available. This points toward the fact that learning to use new software can be a barrier to adoption of technologies, much like the delay in the adoption of 3-D BIM which was a step-up but a move away from the traditional CAD system. It also shows that if a new software solution was to be developed, it needs to be something that does not deviate too far from the kind of system that professionals already use and has a simple user interface. Based on this knowledge, this research project aims to develop a BIM-based design briefing tool as a Revit add-in seems to be an appropriate solution. This solution may not appeal to every professional in the industry as not everyone uses Revit, however, to those who do use Revit and are familiar with its functionalities, this solution needs to feel like their everyday work and not something they may have to spend hours or days learning.

As a result of generally using only pen and paper during the briefing stages, most of the interviewees stated that they only produce 2D sketches for their clients to communicate their design solutions. Interviewee C, an architect stated that:

> *"What we tend to find is that it's easier to get the client around the table and even in this digital age you can get a pencil out and start sketching. this is our preferred method."*

However, interviewee D, another architect, mentioned that they make use of 3D mass modelling as well in addition to 2D Sketches.

> *"Sketching is probably the key part to briefing. We are working with quiet a lot of numbers as it is about occupancy densities. So, we work with quiet a lot of sketching. We use everything from massing within Revit or SketchUp. Just simple line drawings."*

There is certainly no issue with the use of pen and paper to convey ideas to clients. But with the use of technological tools, there is an opportunity for the design team to better communicate the ideas in the early stages of a project. And this has been evident with a couple of respondents who use simple 3D massing in addition to the sketching to convey ideas during the briefing stage.

b. Lack of stakeholder involvement

Generally, during the briefing process, the only stakeholders involved are architects and a design team and clients and their team. There is usually a lack of involvement from non-design related stakeholders such as the project managers, operations and facility managers, contractors, suppliers etc. And the general reason behind this is that a project is in its very early phase during the briefing stage, and conventionally there is no need to the involvement of these stakeholders. The analysis of interviews showed that although these stakeholders are not involved during the briefing stages, professionals are, to an extent, open to the idea of including them for their inputs.

For example, interviewee A, first stated that:

“I think partly with the briefing stage is about identifying who the stakeholders are. But I think everyone is gonna have their say and its important you give people the forum to have their say.”

However, later in the interview when asked if contractors and operations managers could contribute to the design brief, he stated that:

“I think contractors do have a lot to offer. But I think it’s important that they don’t dominate... And I think contractors have a very strong say in all that and should have a strong say in all that. But they shouldn’t be dictatorial either. I think operations manager should do as well because I think buildings ultimately have to be able to work both on a technical sense and operational sense."

The notion that can be derived from the interviewee’s comments above is that architectural professionals see the design as solely their part of the project and they prefer that other stakeholders do not begin to govern the design process. They are happy to receive inputs and suggestions as long as they do not dictate the architect and the design team on how designs should be carried out.

Interviewee B, an architect, shared a similar sentiment and also provided reasons for the same.

So, in terms of briefing, it’s not that all your briefing is done in the first stage, in fact, it can be incremental as you bring in more people into the project. If you have the residents asking at this stage, you’ll get nothing done. Because you’ve had approval from the local authorities in terms of massing to this. You can go back to the residents and say quite *confidently, we've spoke to the planners. We are quite happy that this is going to be allowed. So yes, stakeholders are important at the beginning as long as the right stakeholders at the right time.*

c. Lack of POE integration

One of the final issues identified with the method of design briefing was the lack of integration of POE data. Interviewee G, a BIM manager, first commented saying that,

"Also, POE, that's Post Occupancy Evaluation data, there is a vast amount of knowledge hidden within POE data. Hardly anyone uses it before any design work is done, but that is something you could look into. A lot of progress can be made early in the project if we can learn from old projects and know how targets can be achieved and work towards that."

Through the review of literature, it was known that although POE has been around for a few decades, it has not been widely adopted. The interviewee quoted above added an interesting point regarding the integration of POE data in the briefing process and how this can help in decision making. Learning from previous projects that are similar in nature or even small aspects of it can be extremely valuable, particularly for newer clients, who are pursuing a project for the first time.

Another mention of using data from older projects was mentioned by interviewee H, an academic. She commented by saying that:

"I think knowledge from past projects really need to be incorporated at the early stages because the BIM process as a whole can bring all this information together that can be used to build a holistic brief."

Although POE was not implicitly mentioned by the interviewee, the meaning behind the statement refers to the incorporation of POE in the briefing stages. Similar to various regulations and principles, POE data can also be used to guide the briefing and design process in the correct direction. Although this might be an issue if the client has not developed any projects in the past and the design team are not able to source POE data from past projects.

4.7.3 Functionalities of BIM based design briefing tools.

The previous sub-sections outlined key outcomes of the interview with various professional in the industry that were related to the process and methods of design briefing. This sub-section delves into the BIM-based briefing side of the study. Identification of functionalities for a BIM-based design briefing tool was one of the important factors for this research study as it not only involves understanding the functional requirements of the tool but also helps the researcher understand what the professionals in the industry really want to achieve through an improved process of carrying out design briefing.

i. Automation

Unsurprisingly, one of the most demanded functions of a BIM-based design briefing tool was for a level of automation. Interviewee, B, an architect, stated that:

> *"So, say if you take this site where we are now. If the client bought this or the site next door, and they wanted to build residential, they would come to us and brief us to do that. But if they can just take the site, put it into a*

software, just say we want to build residential, the software could just come back and say X zone for industrial or you could get some other result. So, they can do the initial process but, they would come to use saying, we've done our research on the site next door, I know we can get around 100 units on it, because we've run it through the software. My brief to you now is I want you to design 100 units on the scheme or more."

Automation and generative design are the latest developments in the field of the AEC industry, although, it has not been widely adopted in the industry yet (Davis, 2020; Wintour, 2021). This lack of adoption can be due to a lack of training, overall implementation in the workplace or even fear and resentment of a technology that has been seen as a replacement for actual human inputs. However, through the interviews conducted with professionals in the industry, it was identified that a certain level of automation is in demand even in the early design briefing stages. Whilst this demand may not exactly be to develop a design solution, it may be extremely useful in helping the client and the design team make decisions related to spaces, orientation, occupancy levels etc.

Interviewee C, an architect shared a similar comment stating that:

"I guess we always try to be more efficient in the briefing process. We are trying to evolve the way we work so that we can do actions quicker. And more intelligently based work informed through useful data. We are at the moment trying to develop a lot of workflows that link, particularly BIM workflows. We are trying to enable ourselves to be able to do lots of options in a fraction of the time."

Efficiency has always been one of the most crucial factors in any project's success, impacting time, cost and quality. Professionals in both the design and construction side of projects are looking into ways of carrying out tasks efficiently, which has led to the development of various kinds of software, equipment and tools. The interviewee quoted above talks about developing workflows in-house that will enable them to develop multiple design options, albeit conceptual designs, in a fraction of the time it would take to design manually. This shows that there is a demand for automation, at least at the outset, where decisions are not final, and both the client and the designers are trying to visualise what is possible and what might be challenging. As this is simply a momentary process and major decisions regarding the spaces will be made at a later stage, a certain level of automation of such tasks seems agreeable.

This comment made by an architect also shows that not every professional believes that automation and robotics will replace the human elements in projects. As most of the designs are still done by human designers and automation plays a small role in only carrying out repetitive tasks, developing small programs that can aid in improving efficiency of a project seems logical.

Interviewee G, a BIM manager, shared a similar experience, where they tried to develop a tool using spreadsheet that can be used in the early stages of a project. He commented saying:

> *"We have developed a couple of tools in the last 2 years particularly to make BIM really valuable in stages 0 & 1. More in the master planning*

scale, we are using linking data from massing to excel spreadsheet that have a lot of formulas relating to apartment mixes."

This quote again shows that demands for some types of tools that can be used in the pre-design stages still exists. A few design briefing tools that can be used to structure and manage design briefs were discussed in the literature review. However, the demand is not for a tool that can only manage but also provide value in the form of automation and concept or massing design. The interviewee discusses using spreadsheet, which is a highly powerful tool on its own and can perform multiple mathematical functions and calculations, in order to perform tasks. It has been noted, through the review of literature, that spreadsheets have been used in the briefing process, particularly in large-scale projects to calculate occupancy rates, spatial requirements and other regulatory requirements based on various guidelines and documents. Spreadsheet, coupled with programming tools such as Dynamo or Grasshopper, would be able to rapidly produce multiple floor plans and massing drawings, which could improve efficiency in the early stages. Surprisingly, a couple of architects that were interviewed also discussed using spreadsheet and dynamo as part of their workflow, which will be discussed in the next section.

However, as far as automation is concerned, there is certainly a high level of demand for its development and there even are professionals that trying to develop their own tool that can automate certain tasks in the pre-design stages. Their goals are actually not to simply develop an automation tool but to improve efficiency in their workflows, which can be achieved by automating tasks that are repetitive and are not final versions of a design.

ii. Spreadsheet and dynamo integration

The use of spreadsheet for design briefing purposes was partially discussed in the previous section regarding automation. This section delves further into the use of spreadsheet along with dynamo to develop scripts that can generate floor plans, massing studies and spaces with BIM authoring tools such as Revit.

When asked about any innovative method of carrying out design briefing interviewee C, an architect, discussed how they have developed a Dynamo script that interacts with spreadsheets allowing them to input colours in floorplans. He mentioned that:

> *"So, any quick changes we make through Dynamo script, any changes that we make to an excel spreadsheet will influence the colours in the plan and allow us to then produce the drawings quite quickly."*

Coloured floor plans are usually used in order to define and visualise different rooms or materials. These are particularly helpful when conveying ideas to clients who may find it easier to visualise the space in this format rather than the traditional black and white format of floor plans. However, in order to achieve this version of the floor plan the architect or designer needs to add colours manually to every space and material, which in larger projects such as schools and hospitals may take a considerable amount of time. Hence, in order to automate this task, the architect quoted above developed a script in Dynamo linked to a spreadsheet. This shows that minor tasks such as this, which may be carried out only to help with communicating with the client, is best if automated as it does not directly contribute to the design and construction of the project.

An example of the use of a MS Excel-based briefing tool can be seen in Figure 4.1. As previously discussed in Chapter 2: Literature Review, this tool has been developed by the Department for Education that can provide spatial requirements calculations based on the number of students that the user can input. However, professionals can use this as a tool for briefing purposes to not only carry out calculations but also integrate with programming tools such as Dynamo to visualise spatial requirements.

	Non-net Area									
KIT01	kitchen prep, servery & wash-up		53	1	53			50 m² min recom'd for full service	53	1
KIT11	kitchen office/ admin area		2	1	2				2	1
KIT20	kitchen dry store		3	1	3				3	1
KIT25	kitchen cold store		2	1	2				2	1
KIT25	kitchen freezer store		1.5	1	1.5				1.5	1
KIT40	kitchen toilet/ changing area	3	5	1	5			66 m² min recom'd for total kitchen area	5	1
	toilets (and personal care)							*(pupil toilets: 23 recom'd 24 provided)*		
TOC01	pupil changing and showers	23	27	2	54			54 m² for 45 incl shower cubicle	27	2
TOC02	accessible/ staff changing	1	6	2	12			6 m² minimum including shower	6	2
-	-									
TOC04	large hygiene room	1	12	1	12			12 m² minimum if ceiling-mounted hoist	12	1
TOC10	pupil toilet suite(s)	6	19.5	3	59				19.5	3
TOC10	other pupil toilet suite(s)	2	6	3	18			2 in PE changing area	6	3
TOC15	individual toilet (pupil)		2	1	2			in admin suite for sick room	2	1
TOC10	staff toilet suite(s)	2	6	2	12			including lobby with coat hooks	6	2
TOC21	accessible/ staff toilet		3.5	2	7			also for visitors and staff	3.5	2
	plant indicative area, as %age of net area: for new:		2.3%	incl ICT hubs and risers						2.3%
PLA01	central plant room		43	1	43			43 m² minimum recom'd in new build	43	1
PLA02	ventilation and other plant							Contractor to add area if provided		
PLA05	distribution boards		1	7	7				1	7
PLA06	risers, flues and vertical ducts		1	4	4			Contractor to add vent ducts if provided	1	4
PLA10	server room (2 cabinets)		9.5	1	9.5				9.5	1
PLA10	ICT hub(s)		6.8						6.8	0
	circulation as percentage of net area: for new:		25.0%	incl circ noted abov	**(12)**				(12)	25.0%
CIR12	stairwell(s) area per floor		27	6	162			25.0% of net min circulation for 3 storeys	27	6
CIR13	lift area per floor, incl space to wait		4	3	12			25.0% of new build net area recommended	4	3
-	-									
-	-									
-	-									
CIR00	main circulation remaining		508		508			incl.corridors and horizontal circulation	508	
	partitions %age of net area for new build		4.4%		122				122	4.4%
	TOTAL AREA BB103 range **1110** to **1249**				**1121.5**			OK: area within recommended range	1121.5	
	Total Gross Area min **3885** max **4465**				3896.5		-	**12 m2 over minimum gross area**	3896.5	
	Total Gross Area (including supplementary area)				**3897**	of which		retained, so: **gross area to be built**	**3897**	m2
	Gross area as proportion of net				140%					

Figure 4.1 Spreadsheet tool for school buildings

Interviewee E, an architect talked about the use of tools in the design briefing process, which was again in the form of a spreadsheet. He commented by saying that:

> *"Their briefing tool is actually an MS Excel spreadsheet which is very clever. How many classrooms do you want, what do you have at the moment. Its schedule of areas analysis of the existing accommodation plus what is the additional that you are asking for. So, there's no ambiguity in terms of that briefing from the school's point of view. Cause it's either you are allowed to have the area or not. And it equates to what the funding allows you to have 1000sq m development, what can you get in that? So, it's actually quite an interesting thing where it's very scientific in many ways. There are no emotional things that are attached to it to a large degree. If the computer says that you are allowed to have that, you are allowed to have it."*

Through the quotation above, it can be seen that they, just like many other architectural and design firms, use spreadsheet for organising and managing the design brief. However, they also use spreadsheets as a design briefing tool that can analyse area requirements based on the number of occupiers. The Department for Education also provides a similar tool that can be used to calculate the spatial requirements of school buildings, which was discussed in *Chapter 2: Literature review.*

The interviewee also talks about the removal of any ambiguity when using such tools. Decision making, particularly based on regulations and principles can be time consuming, and one party may disagree with the interpretation of other parties. This can not only be time consuming, but also a reason for dispute later down the line. Hence, the development of tools that can carry out complex analysis in seconds and provide a definite answer to questions regarding not only area requirements and occupancy levels, but also materials, components, fire safety, access, egress etc in the pre-design stages can remove emotions from decision making process. Furthermore, these data acquired in the briefing stages may also be attached to the BIM data in the design phase.

iii. Early simulations

Interviewee H, an academic, pointed out that the implementation of BIM in the design briefing process could benefit from early simulations of performance. She commented that:

> *"I'd say one thing that is important is about actually providing very early simulations of performance so you could use it to start having simulations of energy efficiency for instance...obviously it should be used for cost purposes and the idea is that instead of actually doing the whole design to the cost, you do costing as you move on as you develop the project and then you keep the project to the costs you want to achieve."*

One of the most important aspects of a BIM authoring tool is the provision of simulations that show the designers how the building may perform in terms of energy, lighting, circulation, cost etc. The interviewee quoted above anticipates the implementation of BIM in the briefing process to be able to carry out similar simulation functions that can be used for analysis as well as costing purposes. However, since there is no design prepared during this stage of a project, traditional simulations using tools like Revit would not be possible. Hence, this points towards the need to develop a tool that develop early conceptual designs and can carry out early simulations based on it.

4.7.4 The impact to the overall project performance and process

One of the key aspects of this research project is to understand the impact of BIM in the design briefing process, identify any barriers that would possibly hinder the implementation of BIM and develop solutions to overcome these barriers. The implementation of BIM in the briefing process is a novel subject, hence, literature related to the implementation of BIM in general and other stages of projects were reviewed in order to identify the kinds of issues that can be expected. Overall, the consensus was that the implementation of BIM in the briefing stages would bring about a much-needed update. However, some issues might arise in the beginning when the concept is first implemented. Interviewee C, an architect, highlighted his thoughts on this matter by saying:

> *"I think everybody when they first start on this journey* [of BIM-based briefing] *might see a loss because they are learning, and when you're learning, you make mistakes. But once everybody is there, I don't see how it could negatively impact at all. Because we are looking at more of the long term, and generally we would probably see a loss when implementing BIM across the practice over the last 3-5 years. But do you look at that as a loss or do you look at that as a development? So, we see that as an investment in research going forward. But I can see that this is just a more exciting and more efficient way of working."*

The interviewee quoted above implied that when it comes to adopting new technology or software, it takes time, especially if it's complex. The more complicated it is, the longer it takes for people to get used to it. Introducing BIM-based design briefing methods and tools may seem difficult or counterproductive at first, especially if someone is not familiar with BIM. However, once a majority of people have adopted and used the new system for a while, it becomes the new normal.

Interviewee E, another architect pointed towards a similar issue that he saw with the adoption of a BIM-based design briefing and commented that:

> *"Maybe the only hinderance is that sometimes if you show something like this then they might get that in their head and be scared by it. So, if you show them a tall tower, then they might think they might not be able to achieve this. So, you kind of got to understand the maturity of the client in terms of being able to take the info we showed and not make massive assumptions about it."*

The two architects quoted above share similar views regarding the implementation of BIM in the design briefing process, where they both agree that professionals may be hesitant to adopt newer technologies. Moreover, designers also need to be cautious in the way they approach clients when using generative or automated technologies such as this because the clients may think that the design solution has already been developed when they are still trying to develop a vision or idea.

As far as the impact of a BIM-based design briefing method is concerned, majority of the interviewees had a positive response. Interviewee B, one of the architects commented that:

> *"I think we can use it from the beginning to be able to manage both the client and our expectations of what can and cannot be achieved on these particular sites. So yes, BIM from the 3D point of view and the numbers and all the suite of documents. The whole preamble that you had to do in order to develop the EIR for the client. That's way before you even start looking at a project anyway. So, this is all going to happen before you even know what the sites are. There's definitely more work that can be done with that."*

The idea behind the BIM-based design briefing tool is to allow the designer to be able to rapidly develop a conceptual design or a plan that can help them and the clients in making decisions early in the project. Additionally, this will also allow them to identify a wider range of options and see the types of ideas that are viable early in the project lifecycle. The architect quoted above was able to identify this and add that this would also help in managing client expectations as they can visualise the possibilities early in the project.

However, there were also a response from interviewee A, an architect who suggested that implementation of BIM in the briefing stage would not have much of an impact on the project. He commented saying that:

> *"I can't see the reason for introducing it* [BIM] *at the briefing stage. I can see there are loads of reasons for bringing it in once you start actually doing something physical. I'd say the only thing is getting prepared for it. If you know that actually you are going to do BIM. And say for instance that you are actually providing information for the FM guys at the end of the job is actually really important. Actually, you want to make sure you get*

everything set up at the early stage and get the libraries in place and get your process and protocol. Equally, you can do that in stage 1, after the briefing when you do the feasibility. So, I can't quite see it yet."

The architect quoted above makes a valid point when he says that BIM can be implemented after the briefing process is completed, which is the current process used in the industry today. However, with the rest of the industries evolving and embracing technologies as part of their workflow, it is crucial that the AEC industry strives to develop its systems and technologies to keep up with the rest of the industry. As identified from the literature review, the AEC is already behind most other industries such as manufacturing due to the lack of development in the way design and construction are carried out. Hence, the development of more efficient methods of carrying out tasks will be highly beneficial.

Furthermore, BIM has already proven to be one of the biggest leaps the AEC industry has taken in recent years and although it is currently one of the most heavily researched topics in this area, there are still numerous factors that are yet to be considered such as the one this research study aims to tackle. Currently, BIM is only implemented at stage 2 of the RIBA PoW 2020, however, through the data collected through interviews, this study has begun to show that majority of the interviewees believe that BIM can be bought forward to stage 1 or may be even 0 by implementing aspects of BIM that are necessary at the early stages of design.

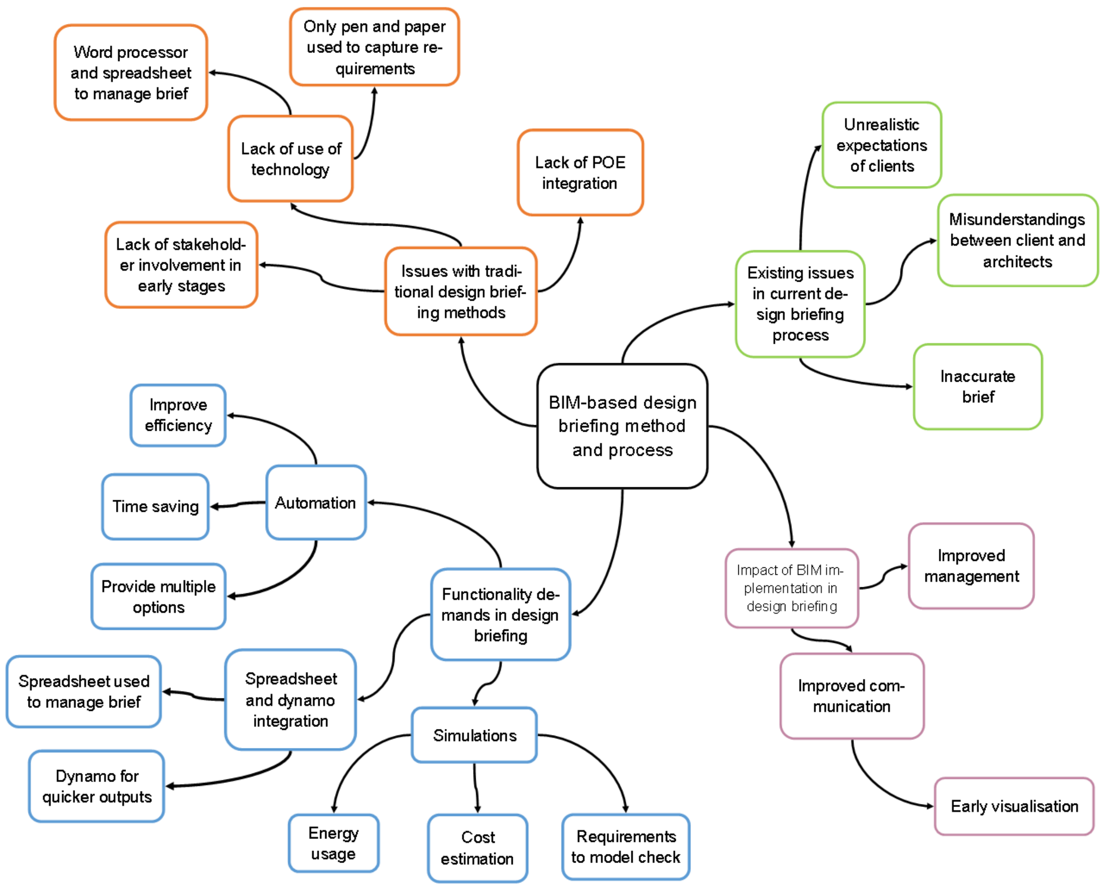


Figure 4.2 Brainstorm diagram based on interview analysis.

4.8 Findings and discussions

This section of the chapter presents the findings from the analysis of the transcripts and the researcher's interpretation in the form of a discussion. It begins with the discussions related to the prevalent issues of the design briefing methods and process, which helps verify that the issues in the briefing process are still ongoing. Due to these existing issues, it is evident that there is a need for a solution that can help eradicate or at least minimise some or all of the issues. Next, a discussion regarding the implementation of BIM in the design briefing process is presented including the benefits identified through analysis of the interviews. Finally, an argument regarding the functionalities of a BIM-based design briefing tool is presented, which discusses the functionalities demanded by the interviewees are discussed.

i. Problems in the process and methods of design briefing

It was evident through the review of literature that the design briefing process and the resulting design brief have numerous issues. However, since some of those literatures were over a decade old, the researcher believed that the findings may be outdated particularly due to the advancement of BIM. Hence, empirical data were gathered in order to assess the prevailing issues and the kinds of advancements that may have been made in the design briefing process. The results of the data analysis were, however, surprising in the sense that the researcher had expected to identify some advancements in the briefing process and find some newer issues that could require a solution. However the analysis suggested that the design briefing process was still facing similar issues from the early 2000s and 2010s.

Some of the most common issues were misunderstanding between clients and design teams due to the communication being limited to verbal interface. A client may sometimes provide instructions for changes verbally and may believe that they have done their part in briefing designers. However, there may be mistakes on the design team’s side if this change is not immediately recorded and the client sent a written confirmation via e-mail.

Issues related to unrealistic and inaccurate briefs were also identified through the analysis. Unrealistic expectations may be related to the amount of time required to complete a project or the number of spaces that can be designed onto a site or the materials to be used for the construction. These issues can be solved by the architect simply by explaining to the client why the brief they have provided is not achievable or would not be feasible. It would be rather difficult to develop a software that would be able to reason with human emotions. Another issue of inaccurate brief is caused by human error, which can happen while interpreting the client's verbal brief into written words or simply misunderstanding what the client actually wants. There may be some sketches involved at this stage, however, this method is also known to fail at times due to miscommunication between the two parties.

This brings up the issue with the method of carrying out design briefing. Majority of the professionals interviewed confirmed that their preferred method of carrying out a design briefing session with a client is with the use of a pen and paper. The issue here is not with the use of a pen and paper as this has been the preferred method of communication in various industries for many years. The real issue here is that this is the only method of communication used by majority of the professionals during briefing sessions. With the advancement of technology, the assumption was that the use of digital tools for briefing would be common. However, it was surprising to find out that apart from the digitisation of the design brief onto a word processing software, most professionals did not use any other tool. Moreover, not a single interviewee mentioned the use of any design briefing tools such as the ones identified through the review of literature. Instead, most of them opted for the use of spreadsheet.

It was also noticed that when asked directly about issues in their current methods of briefing, majority of respondents believed that there were almost no issues, but almost all wanted to make the process more efficient and intelligent. However, the analysis of data revealed some issues during the briefing process that they mentioned when answering other questions. One of the issues pointed out was that the individuals (client, company or consultant) briefing the design team are usually the issue, as sometimes they are not sure what they really want or even what a brief is. Or sometimes there can be more than one individual carrying out the brief and their requirements can vary from one another. This also causes issues.

Another issue identified was a brief that was not up to a certain standard, but due to time constraints and lack of understanding from clients. A design team had to work with it. The response acknowledged that this was wrong, would cause confusion and cost the client time and money. However, this was just how some of their projects had to work. Time has always been a major factor in the design and construction industry and is one of the corners of the golden triangle. It has a negative effect on both cost and quality, but it very high importance to all stakeholders. The solution, at least for this particular issue of time, could come in the form of a BIM tool, which this paper seeks to achieve.

Efficient capturing of client requirements, particularly those that are vague in nature, such as a big room or a bright office and then developing an automated concept design can greatly reduce the time it requires a designer to achieve this manually. This process can prove to be more efficient if, in the future, this can be achieved in real time in front of the client. Dynamo to an extent can create concept designs in its native application Revit. However, this requires input of a large amount of accurate data, again requiring a lot of time, depending on the size of a project.

Sun and Meng (2009) argue that poor brief development due to misunderstanding a client's requirements and making incorrect assumptions are one of the causes of changes, leading to damaging design revisions. A tool that can generate real-time design and layouts, while checking for errors based on various regulations and standards in the briefing stage, would help avoid mistakes at the very beginning of the project and persuade clients to change some of their requirements that do not meet required standards. The development of this type of tools would help reduce errors, re-works, cost overruns and provide clients and designers with multiple design solutions that would comply with all the concerned standards and regulations.

According to the interviewees, their current briefing practices have been working fine, but a change in the way that briefing is carried out has been welcomed by all. In a day and age where the construction industry, which has argued that "they have always been doing things this way", is going through a BIM revolution, briefing is one of the last few aspects of the design and construction process that has not yet received any BIM attention yet. This can change with the development of a briefing tool that can, to an extent, standardise the way briefing is done in the industry and take one more step towards BIM level 3

The implementation of BIM in the briefing process also has the potential to influence future updates of the RIBA PoW. The latest version of the PoW has BIM requirements added to it amongst other updates. However, the document does not explicitly require users to introduce BIM into the project until stage 2. The implementation of BIM into the design briefing stage has the potential to change as well as improve not only stage 1 but the entire design, construction, and management stages of the RIBA PoW.

Design briefing can basically be carried out in two formats. First the process, as outlined in the PoW, can be carried out in stage 0-1, resulting in a final brief that is then used by the design team to create one or many design options for the client. Second, the briefing process can continue through Stage 2: Concept Design, Stage 3: Developed Design and Stage 4: Technical Design (Blyth & Worthington 2010). However, in practice, the latter seems more practical as clients are prone to make changes, which results in updating the brief as well. Similarly, with implementation of BIM, the design briefing process can be extended in the RIBA PoW to accommodate the practicalities of real-life projects as well as to improve upon the existing design process.

Post occupancy evaluation (POE) can also play an important role in a BIM based design briefing. POE evaluates how successfully a project was delivered, how successful the completed project is, reasons behind the success or failure of a completed building project as well as lessons that can be learned for future projects (Designing Building 2015). Implementation of BIM in the design briefing process can help implement POE results from a client's previous projects or the design team's POE experience in the design briefing stages that can be used as an added level of verification of the design brief as well as verification of the competed project against the briefing.

ii. Limited technological advancements in briefing but high demand for tools.

During the literature review a lot of briefing methods, problems and solutions were identified. It was also realised that although the design and construction industry is one of the fastest advancing industries in the UK, the process of briefing has more or less remained the same over the past few decades. A similar trend was identified during the analysis of interview transcripts as well. Majority of respondents stated that their method of briefing has remained the same over the years. The only major advancement in briefing has come in the form of digitisation of information, but pen and paper are still the preferred format for capturing client requirements. There are some tools that help in structuring and managing the design brief. However, most of the interviewees mentioned using spreadsheet more than any other tool to manage briefing. This could be due to every organisation having their own methods of structuring data, unlike in a commercial tool that would require them to adhere to whatever structure the software allowed them to.

It was also evident through the analysis of interviews that there actually is a demand for tools that can be used during the design briefing process. Organisations have been developing their own native tools using spreadsheet that can not only structure data but also integrate with design and BIM authoring software like Revit and its native programming tool, Dynamo to write scripts. The overall goal behind the development of these tools and scripts was more than simply structuring requirements, it was to improve efficiency of the design briefing process as well as the entire project process.

It should be noted at this point that there are some commercial tools available for briefing. These tools come in the form of native tools that can be installed on a PC or online tools that can be accessed anywhere via cloud servers. However, there was no evidence of any of the professionals actually using any such tools for briefing. A reason for this, as mentioned by one of the interviewees, may be the process of adoption, which includes learning to use new program. The architecture industry is already a highly overworked field and learning to use a new software that can merely structure data and provide minimal level of interoperability may not be worth their time. Instead, they continue using simple yet effective programs such as Excel that are known by most professionals.

Through this evidence, it can be concluded that the demand for a tool that can be used in the briefing process is there. The requirement at this stage is that the tool needs to be simple to use; possibly something that can be used with authoring tools such as Revit; it does not need to develop design solutions but be of assistance in optimising and making decisions related to design; and it needs to improve efficiency of the project. There are also signs that professionals prefer if this can be achieved with the use of Dynamo along with spreadsheet that contain requirements.

iii. Can BIM implementation in the briefing stages resolve issues and fulfil demands?

BIM has taken the industry by storm and is probably the most important commodity in the field of architecture today. From the UK government to big and small practices and to universities, everyone is in a race to learn, adopt and implement BIM. However, BIM is yet to be established in the field of briefing. The 2020 version of the RIBA Plan of Work (PoW), which sets out a framework for both designers and contractors and offers a process map and management tool, includes requirements for implementation of BIM at stage 2. However, BIM activities in stage 0 and 1 are limited to introducing the client to BIM and preparing for the implementation of BIM in stage 2. This could mean that BIM has not yet been seen as a measure that can be used for design briefing purposes.

Before discussing reasons as to how a BIM-based design briefing can help resolve some of the prevalent issues within the design briefing process, it is necessary to address doubts, that interviewee A expressed regarding the usefulness of BIM in the pre-design stages. He stated that:

> "*I can't see the reason for introducing it* [BIM] *at the briefing stage. I can see there are loads of reasons for bringing it in once you start actually doing something physical.*"

Here, the interviewee suggests that since briefing falls under the pre-design stages where the designing process has not yet commenced, BIM may not be very useful and sees no reason for its implementation. By definition, BIM is the combination of graphical information and addition of non-graphical information, hosted in a Common Data Environment (CDE). Hence, the implementation of BIM in the pre-design stage, where there is no graphical information yet, may not seem fruitful. However, in projects that do utilise the process of BIM, models and information do not always go together. Usually, the modelling is done first, and information is later added to comply with BIM requirements. Similarly, in a BIM-based design briefing process, information may be available before the development of any graphical information, which can be added at a later stage. There can be conceptual plans and designs generated through BIM-based design briefing tools, such as the one this research proposes to which the non-graphical information can be added and carried over to the future stages if useful and necessary.

Moving onto how BIM-based design briefing can help resolve issues in the briefing process. The analysis of the interviews revealed a number of benefits that a BIM-based briefing process may offer which have been listed below:

a. Improving project efficiency: One of the major ideas behind BIM is that it is a process of extensive planning for the upcoming project, and not just the current state, to minimise as much issues as possible in the future. Hence, the implementation of BIM in the design briefing process also may not immediately provide any improvements in efficiency as the project will still be in its initial stages. However, if implemented early through a BIM-based briefing tool, then the non-graphical information collected with the help of stakeholders and conceptual drawings generated before the actual design stage can help streamline the project and improve the overall efficiency.

b. Improving communication with clients: With the current process of design briefing, communication with clients is mostly carried out verbally and with the help of sketched on paper. However, with the implementation of BIM, conceptual plans can be generated based on design principles and regulations. Hence, the client can be informed of what is and is not feasible in the project, based on which the client can make a more educated decision. A simple example of this is a large-scale project where a client wants X number of spaces. However, with the help of the BIM-based briefing tool, a conceptual plan can be generated relatively quickly, and the client can be informed if their aspiration is feasible or not.

c. Error reduction: BIM has played a major role in reducing errors in designs by enabling designers to detect clashes in their models. Similarly, the implementation of BIM in the briefing process may be able to help reduce certain types of errors present in the brief. This may be achievable through a BIM-based design briefing tool that can import the requirements into a BIM-authoring tool such as Revit and visually represent errors in layout and adjacencies, spatial co-ordination, fixture requirements, use of materials and components etc.

iv. Involvement of non-design related stakeholders is crucial.

One of the crucial parts of this research is to analyse the contribution of non-design-related stakeholders, such as project managers, contractors, facility managers, etc, can make in a BIM-based design briefing process. They possess a vast amount of knowledge and experience that can help clients and design teams develop a more detailed design brief as well as help them make more informed decisions early rather than leaving it for later stages.

A design brief that was too detailed was identified as an issue both through the review of literature and analysis of interview data. However, the detailed brief that can be developed with the help of stakeholders would be rich in details that the design team can use during the design process but would not limit their designing boundaries.

One of the questions asked during the interviews was regarding the involvement of these stakeholders in the briefing process. The analysis of the interviews showed that the majority of interviewees believed that more stakeholders should be involved in the briefing process. This not only helps the process with contributions from these stakeholders but also helps the stakeholders, such as facility managers, understand the BIM process early on and support them on their BIM journey.

However, some of the interviewees did suggest that although their input would be beneficial to the briefing process and the overall project, that should not dictate the design solutions and processes or at least should not have too much of an influence over the design. This showed that architects and design professionals, to an extent, feel that involving too many stakeholders early in the project may somehow influence client's decisions too much and limit the designers' ability to freely design the structure in the later stages.

v. Inclusion of POE information can be beneficial.

Designs and projects are usually guided by various factors such as client's brief, various local and government regulations, design principles and other guidelines. Similarly, POE carried out after a new development has been occupied produces valuable data that can also provide guidance for future reference. Hence, an argument can be made for the integration of POE data in the design briefing process.

It should be noted that none of the interviewees mentioned that they use POE data in the design briefing stages and no evidence was found in literatures that professionals were continually making use of POE data in the pre-design stages. It can be argued that professionals such as architects possess ample experience that their knowledge may be regarded as incorporating POE into the project. But a single professional cannot be expected to retain and implement every single piece of information learnt from past projects.

However, the integration of POE data may provide benefits to the briefing process and help the involved partied make informed decision. For example, in a school project, the decisions may be related to use of certain materials, or layout of spaces or even the use of an innovative design or method of construction. Integration of these information in the design briefing process via a BIM-based design briefing tool can result in a more efficient project and reduction in errors from the beginning.

4.9 Current applications of BIM in briefing process

The main focus of this study is to identify how BIM can be used in the design briefing stages, particularly between RIBA PoW stages 1 & 2. The current PoW only requires BIM to be introduced at the end of stage 2 and then used from stage 3 and onwards. The findings from the interview analysis also showed similar usage of BIM in practice. Majority of interviewees agreed that they only started using BIM in their projects towards the end of stage 2. However, a couple of respondents claimed to use BIM from stage 1 for briefing purposes for a few of their projects as an internal strategy. In case of the first respondent, the client, at this stage, were not notified of the use of BIM, so as to not *“...give them a false perception of what they are getting.”* When questioned further regarding their use of BIM for design briefing purposes, it was understood that their idea of briefing in stage 1 was the development of Employers Information Requirements (EIRs) in parallel with concept design. The EIRs here, are developed in order to identify and plan for the rest of the stages. There however, is no connection between the EIRs and design at this stage as design has not started. Also, this process is not automatic, and requires the same input from the designers as in any normal BIM based project.

The second respondent who believed that they used BIM in the briefing stage also talked about developing EIRs particularly with housing associations which have multiple sites, who can benefit more than an individual client who will only develop one residential project. The idea revolves around the fact that after a few years of developing multiple sites, a general framework can be developed through feedback from those projects, that can help in writing EIRs for future projects. However, it is not very clear how well this will work with multiple clients as everyone has their own requirements, but it does fulfil one of BIM’s main agenda, which is to structure data for future use.

The result from the analysis of the interview transcripts shows that currently BIM and design briefing has been considered but not yet used to support one another. However, those respondents who claimed to be using BIM for design briefing purposes have both talked about the development of EIRs which is different from a design brief.

EIR is one of the starting points of BIM just as design briefing is a starting point of a building project. IT can sometimes be confused regarding the two as they can seem interchangeable. However, as Barnes and Davies (2015) explains, a design brief defines the nature of a built asset whereas an EIR defines information about the built asset that the client requires in order to ensure that the design is developed according to their requirements and are able to operate the asset effectively and efficiently. This document is also used by suppliers during the tender process to bid for projects by developing a pre-contract BIM execution plan (BEP), which demonstrates how they will deliver and manage digital information throughout the project (Pringle 2015, Designing Building Wiki 2019). The focus of design briefing process is on client's design, spatial and esthetical requirements which is completely different from the three areas that EIR covers, i.e., technical, management and commercial. Hence, the respondent's argument that the development of EIR was part of their BIM enabled design briefing process is not accurate.

Having established that there are differences between a design brief and an EIR document, it should be noted that the process of capturing data for the two documents are quite similar. Both use a similar question and answer technique to capture requirements and data are recorded in written format. But EIR is stored in a Common Data Environment (CDE) which forms part of the BIM process. This technique can also be implemented in the design briefing process which can take it one step closer to the process being BIM enabled.

4.10 Issues with implementation of a BIM-based briefing method

Implementing BIM in a workplace can be a challenge, particularly in small and medium sized enterprises (SME) where the cost of training and tools are major barriers in BIM adoption. Various research has been carried out (e.g., Navendren *et al* 2014, NBS 2014, Criminale & Langar 2017) in order to identify why organisations are struggling to adopt BIM in their projects. These research conclude that time, cost and client needs are the mains reasons why SMEs as well as larger organisations are not very keen on implementing BIM process.

Keeping these barriers in mind the interviewees were questioned on potential problems with implementing BIM in the design briefing stages. Identifying potential problems will provide experts' opinions on the feasibility of this research; issues with design briefing that can be resolved with BIM; potential barriers to implementation and measures to overcome these barriers.

The analysis of interview transcripts identified a few barriers in BIM implementation. However, these barriers did not deviate too far from those barriers, presented earlier, that affected general BIM implementation. Most of the barriers were not concerned with the actual process of implementing BIM in design briefing, but rather with the users, i.e., clients and designers. One of the interviewees did not see any hinderance in the process itself but believed that clients might *"be scared"* when presented with this type of idea as it might become a case of providing too much information before it is necessary. He further stated that it was important to understand the overall maturity of a client, including experience with BIM. A client who does not have much experience in construction and is presented with the idea of using BIM from the very beginning of the project might have massive assumptions about the design outcome of it. Also, if a client is presented with a 3D design of the asset, then they might presume that they were not fully involved in the designing process and that their requirements were not considered.

Another respondent also stated that the main barrier could be understanding of what could be on both sides. Clients and designers might have very different understanding of BIM, which might lead to confusion and misunderstanding. A solution was also proposed by the respondent, which was to educate, so that everyone could have a universal concept of BIM. While BIM is not exactly a new concept, it has gained popularity in the past few years. This problem of implementation and adoption is similar to the problem in the early days of CAD adoption, when the industry was more used to hand drawing and drafting. However, there is a lot of confusion as to what BIM really is and what it can and is supposed to do. The development of a BIM based briefing method may add to this confusion, hence it needs to be as user friendly as possible and produced in real time in front of the clients which will help them understand the process from the beginning.

Another interviewee believed that BIM implementation or briefing purposes could be restrictive on a software level. It is quite well known that Revit is capable of handling large projects, however its power can be limited by the hardware being used to run the software. Even though this seems like a minor barrier, it can prove to be frustrating to new users who might be using other BIM authoring software such as SketchUp or ArchiCAD, with lower system requirements. This, more than a barrier, could prove to be a deterrent, that could affect the use of BIM in design briefing.

Autodesk's Revit, which also developed the acclaimed AutoCAD, is considered as one of the leading BIM authoring tools, so much so that Revit is commonly used synonymously with BIM. Revit was chosen for this research due to its ability to simulate, visualize, collaborate, and share design, as well as the numerous plug-ins available such as Dynamo, a visual programming extension for Revit, that helps manipulate data, explore design options, automate process and create links between applications (Dynamo BIM, 2016).

After analysing all the responses from the interviewees, the barriers to implementing BIM in design briefing has been the implementors and the users than the actual implementation process itself. Implementation and adoption of a new technology such as BIM has always been affected by the time and cost it takes to train, understand, implement and adopt successfully. And due to most practices in construction being SMEs, its usefulness has been outweighed by the feeling of unnecessity and high cost. Hence, the implementation of BIM in design briefing will almost certainly face similar barriers, due to the fact that for users it will judge its usefulness based on their necessity and willingness to invest time and cost. However, for organisations that have already adopted BIM, implementation in may not face barriers that cannot be overcome.

4.11 Adoption of BIM in the design briefing stage

Upon analysing the interview transcripts, and identifying some of the issues when it comes to adopting new technologies in a practice, the question now is ‘what can be done to encourage the adoption of BIM in the design briefing process?’ Although this question was not asked during the interview, few clues can be deduced from answers provided by the interviewees as well as the review of literature related to adoption of BIM.

One of the common issues that was identified through the analysis of the interview transcripts was that professionals can be hesitant to adopt newer technologies in their everyday practice as it requires time, effort, and money. They also prefer to use programs that they are familiar with, even if it's not traditional tool for a certain task. For example, interviewees have mentioned the use of spreadsheet to structure some of the quantifiable design brief requirements and also develop small programs on Dynamo to automate tasks. This shows that they are open to using a different technology, particularly those that require little to no new learning or those that utilise programs that they use every day. Hence, one of the requirements for the successful adoption of a BIM-based design briefing tool is for the program to be built upon a program that most professionals are familiar with. It also needs to be simple enough to use with little training and it should not give the feeling that it is too big of a change in their daily tasks. Additionally, the cost of implementing a BIM-based design briefing tool needs to be minimal, it needs to provide value to both the architectural team and the clients and most important of all, the program should not be packaged in a way that would make professionals feel that it seeks to replace them from their job.

The tool needs to be one that simply assists them in making decisions early in the pre-design stages and communicate ideas with the client.

4.12 What can BIM achieve in the briefing stage?

As mentioned earlier, BIM has proven to be highly effective in improving the design, construction, and management of building projects in terms of time, cost and quality. However, there are aspects of the design process, such as design briefing where BIM does not yet play an active role. This research, through its review of literature and analysis of empirical data, has shown that BIM in design briefing is indeed a possibility and a step forward in the overall BIM process.

Identifying the exact capabilities of BIM in design briefing will require development and testing of a framework and prototype project. However, through analysis of interview transcripts, a general idea can be drawn to see what BIM can achieve if it is implemented in the design briefing stages, which can then be used to develop a framework.

Most of the interviewees had positive views regarding the implementation, while one did not see how BIM could possibly be used in the briefing process. Even though the practice was BIM ready, BIM implementation took place from RIBA PoW Stage 4: Technical design. The respondent argued that a BIM tool *"…should support design, it shouldn't be the design"*. It has been argued many times that a brief should inform the architect of the client's needs and not what the design should be. The architects and the design team need to have the freedom to produce their own design based on the client's requirements and then seek approval from the clients. However, improving methods of requirement capture in a briefing process and storage of information in a pre-design BIM mass model only assists the architect and the design team to perform faster and more efficient checks against regulations and standards, input building properties such as area, volume, function and specification of material services and structure in the briefing stage. From a client's perspective, this allows them to visualize and interact with spaces in their potential asset and make required changes in the briefing stage and get a more accurate cost for the project based on the concept area of the building and potential materials being used.

Those interviewees who agreed that implementation of BIM in design briefing would indeed help the design as well as construction process provided reasons such as an increase in efficiency, an intelligent connection of the brief and design, conflict management, ability to better meet client expectations availability of more options and cost savings. Even though organisations are already reaping some of these benefits through the use of BIM, implementation in the briefing stage can increase efficiency and further improve output time and quality.

The 'I' in BIM which stands for Information has always been regarded as its greatest strength. BIM is the process of building a model full of useful information that can improve the design, construction and most importantly management of buildings. Implementation of BIM in design briefing will carry on this trend and improve the pre-design stages by injecting valuable information generated through collaboration of design and non-design related stakeholders such as clients, architects, project managers, structure and service engineers, contractors, operations and facilities managers.

Currently, briefing is carried out using pen and paper to make notes of client requirements which is then digitised in a word processing software and a concept design is developed, properties and materials are specified, and changes are made until a final design is developed without any connection with a BIM process. Implementation of BIM, as one of the respondents mentioned, will add an intelligent connection between the briefing process and design, which will enable all stakeholders to make early decisions which in turn will assist the client to make an educated decision ultimately saving time, money and improving the overall quality of the project.

4.13 Summary

This chapter has discussed the process of data collection through interviews, the process used in carrying out a thematic analysis, presented the results of the thematic analysis and discussed the findings.

The process of collecting data began with the development of questions for semi-structured interviews. A set of questions were first developed keeping current architectural professionals in mind and then the questions were slightly modified to suit academics. The interviewees were selected based on a few criteria including at least 7 years of professional experience as they would possess adequate experience and knowledge in the field of BIM and design briefing. A total of 11 architectural professionals and academics in the field of AEC were interviewed. The average length of interviews was 61 minutes.

The thematic analysis was carried out in NVivo and followed a 5-step process that involved getting familiar with the data; generating codes;

searching for themes; reviewing those themes; naming and defining the themes; and writing up the report.

The analysis of the interviews identified various issues that still exist in the design briefing process as well as methods used to carry out briefings. Some of the issues identified were inaccuracies in the briefing process, misunderstanding due to various reasons and unrealistic client expectations. The biggest issue identified with the method of design briefing was the lack of use of any technology apart from pen and paper. This was true with majority of the interviewees. However, some did claim to use some digital tools during this process.

It was also identified that BIM-tools were not implemented in the design briefing process, although some interviewees claimed that the development of the BEP and EIR was part of implementing BIM in the briefing process. However, these are document-based preparation, rather than BIM implementation. Secondly, it lacks involvement of other professionals at such an early stage, whose professional knowledge and experience will be valuable contributions to a design brief. Further issues identified included a lack of use of POE data in the briefing process as well as lack of stakeholder involvement in these early stages. This study seeks to develop a BIM-based tool that will be used as a vehicle aiming to improve these issues.

Some functional requirements were also identified through the analysis. The most demanded function was automation of tasks that can improve the efficiency of the briefing process by providing them the ability to complete tasks in a fraction of time. Another functionality identified was the integration of data through spreadsheet and Dynamo which is a Revit based visual programming tool. Some professionals claim to be using this system to make changes to their drawings such as changing colours of spaces automatically based on a set of criteria.

It was also identified that there was limited technological advancement in the field of design briefing but there is a high demand for briefing tools that can do more than just structure and manage briefing data. However, the tool needs to be simple to use and possibly integrated with a tool that the professionals are already familiar with, such as Revit. The tool should also not make decisions for the design team but guide them into the right direction while improving the efficiency of the overall project.

Overall, the analysis has shown that the implementation of BIM in the pre-design stages can be useful and is also in demand in the industry. Although some doubt was cast towards the usefulness and appropriateness of implementing BIM in the design briefing process due to the lack of a model during this stage. The researcher understands that in the briefing stages, there are no drawings involved apart from some sketches that the design team can use to communicate ideas with the client. However, with the implementation of BIM the design team could generate a conceptual drawing or a model that could enable them to develop an initial concept based on design principles and regulations. This would provide the client with a sense of the feasibility of the project and enable the design team to communicate with the client more effectively.

Chapter 5: Conceptual system framework & Prototype development

5.1 Introduction

This chapter focuses on the development process of a conceptual system framework for a BIM-based design briefing tool and the development of the prototype tool. It builds upon the findings from the analysis of data collected through interviews as well as learnings from the review of literature. The development of the system framework is a crucial part of the prototype development process as it acts as a template based on which the system can be designed.

In chapter 2: literature review, it was established that the process of design briefing was fragmented, sometimes incomplete, overwhelming due to the vast amount of information and this more or less has remained unchanged from the last couple of decades. These iterative issues can lead to severe problems in the design and construction phase of a project resulting in cost overruns, delays and failure to meet client expectations. These issues were verified during the interview process where most of the interviewees repeated similar issues in the briefing stage, while stating other issues realised during their own practice.

Conducting a BIM-based design briefing is relatively a new concept in the AEC with only a handful of research being conducted in the past. However, there is no known literature that suggested the development of a BIM-based design briefing framework and prototype. Hence, empirical research was conducted in the form of interviews to collect first-hand data. The analysis of those data has shown that most professionals believe that there is a need for improvement in the processes and methods of design briefing. They also envision BIM as a potential way forward for the development of an improved design briefing process. This also concurs with findings in the literature review where some authors and researchers believed that the adoption of BIM in a project should happen as early as possible to improve the project performance and quality, such as Koutamanis (2017) and Meel and Størdal, (2017).

Through the collection of empirical data, the researcher has also been able to collect valuable information regarding the potential requirements for BIM-based design briefing. These include the development of partial automation in the early stages of the project, integration of MS Excel data with programming software such as Dynamo and the ability to carry out early simulations that can help in decision-making. These are data that would have not been available to the researcher through a simple study of literature, case studies or observations.

Having gathered and analysed all the necessary data and carried out an extensive review of literature, the next phase of this research involves the development of a conceptual system framework and prototype. Firstly, a comparison with a traditional method of the briefing process has also been carried out to demonstrate the potential effect of a briefing based on BIM. Then, the process of this development has been explained in detail in this chapter along with the programme that will be used during the prototype development.

5.2 Stages of conventional design briefing

Currently, the design briefing process is carried out as a separate task, independent from the BIM umbrella. The briefing process has always been overlooked on the grand scale of design and construction, so much so that it is barely thought about when it comes to implementing BIM into a project. However, it should be remembered that the briefing process and ultimately the brief are the foundation upon which the design and the entire project is developed. Hence, it is crucial that the briefing process is updated in order to match the advances in other project stages.

A typical process of briefing illustrated in Figure 5.1 was developed based on the RIBA PoW 2020, which also shows the BIM-related activities carried out in each stage. During Stage 0 the client has a vision for the asset that they want to develop along with a primary list of requirements that the architectural team uses to begin the development of a Strategic brief. However, activities related to BIM are limited to only advising the client of using BIM in their projects, including the explanation of purposes, advantages and related costs. The RIBA Job Book does advise the development of a design responsibility matrix in this stage; but this is optional and can also be developed in the next stage (Ostime, 2020).

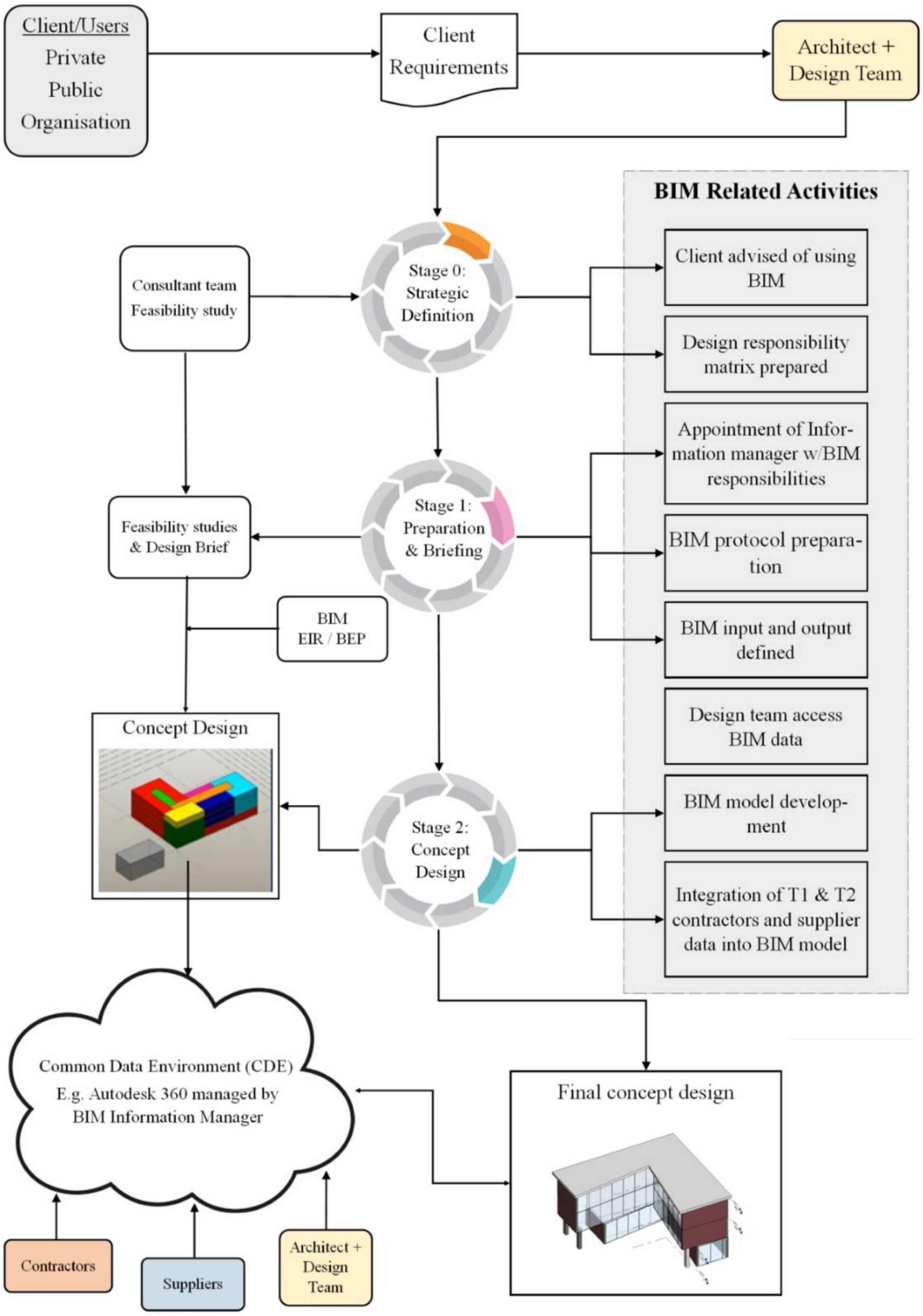


Figure 5.1 Traditional method of design briefing and BIM activities.

Upon the development of the Strategic brief, the client can appoint consultants, who, at this stage, can advise the client in matters of setting up and defining the project (Designing Building Wiki, 2019a). With the input from consultants, a brief can then be developed to include information necessary for feasibility studies and to be carried out and further developed into an initial brief in Stage 1.

BIM activities in Stage 1 is more prominent than in the previous stage. It involves appointing an Information Manager who is responsible for majority of BIM related activities such as determining the roles and responsibilities of every member of the project team with regards to the BIM process and model; leading other consultants in preparing BIM execution plan; defining and communicating BIM inputs and outputs; issuing data from model at appropriate times etc. Other BIM related activities include preparation of BIM protocol in order to define, produce and use building information models and define deliverables for data drops at every stage of the building project (Ostime, 2020; RIBA, 2020b).

From the requirements set out in the initial project brief, a concept design is produced by the design team in Stage 2 including an outline of structural and mechanical services designs. This is the design that will provide a visual representation and allow the client to understand, comment and make changes or approve the proposed concepts and designs (RIBA, 2020). With the appointment of an information manager in the previous stage a Common Data Environment (CDE) will have been set up where the designers can share their concept designs with the rest of the project team. BIM activities in Stage 2 include organising a BIM pre-start meeting, organising initial model sharing with the design team for strategic analysis and options appraisal, enabling the design team o access BIM data, ensuring data sharing protocols are followed, integrating T1 and T2 contractors and supplier's data into BIM model etc.

From this illustration in Figure 5.1, it is clear that BIM plays a minor role during the briefing stage and does not actually play any role in the briefing process. The analysis of interviews has also shown that BIM is usually implemented at the end of stage 2 in practice and does not contribute to the briefing process. Contractors, suppliers and managers are also not usually part of the briefing meetings and process, hence, have a limited or no input in the brief or in providing suggestions. Furthermore, the interviewees revealed that although they would value inputs from these non-design related stakeholders, they would not want them to over-step their boundary and dominate the design process.

5.3 Stages of Design briefing in a BIM-based method

Figure 5.2 illustrates the process of a potential BIM-based design briefing, which is based on the RIBA POW 2020 (RIBA, 2020) stages but also utilizes BIM from Stage 0. Unlike with traditional design briefing process, this BIM integrated process will fall under the BIM umbrella and will utilise the functionalities of BIM from the very beginning of the process. The main goal behind implementing BIM in the briefing process is to improve the briefing process, improve communication with clients through the aid of a visual model, generate early data to minimise errors from the initial stages leading to saving of time and cost for both the client and stakeholders. This also helps improve risk management, streamline the briefing and ultimately the design process.

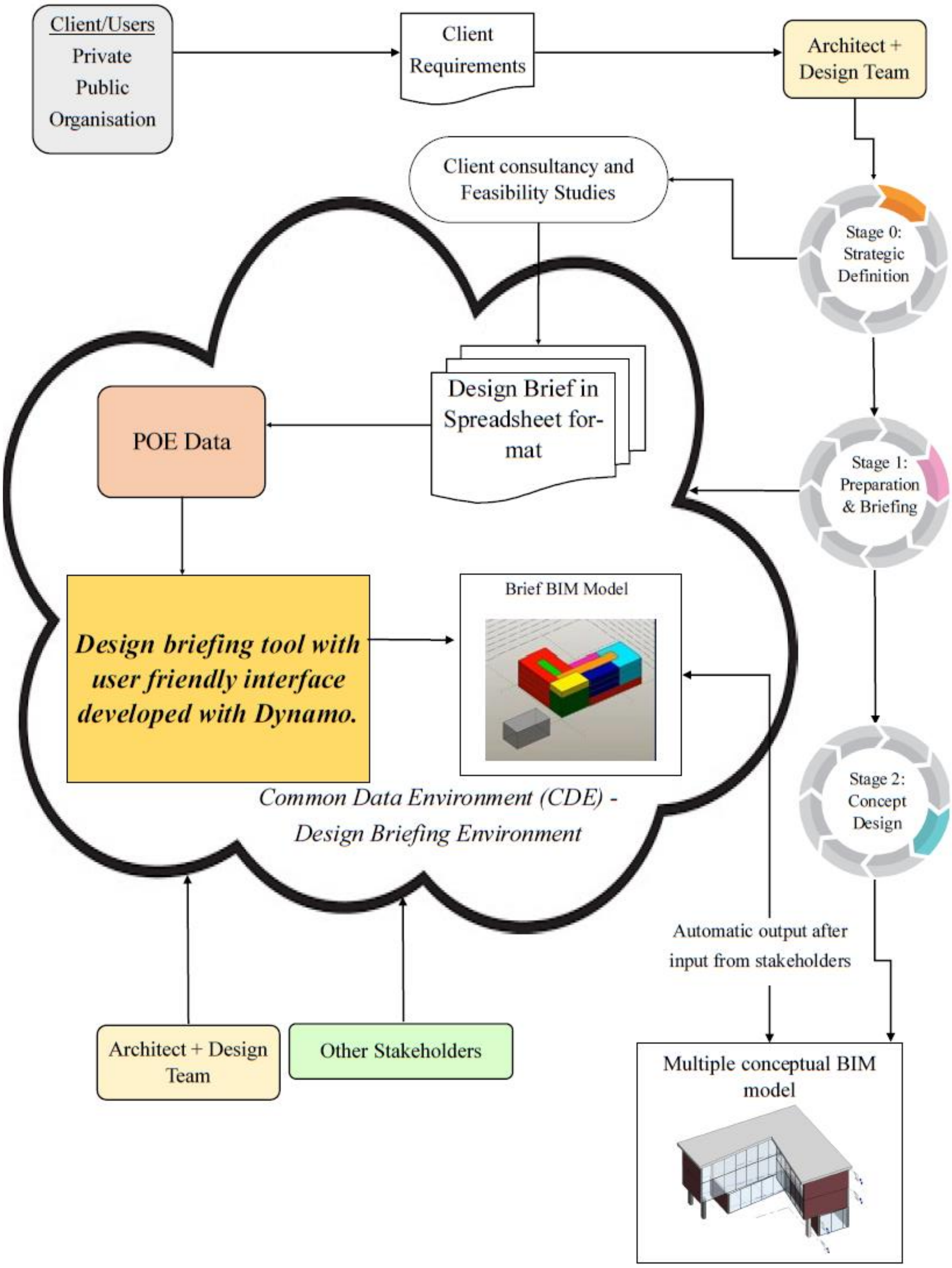


Figure 5.2 Stages of briefing and conceptual model development with BIM-based briefing

Figure 5.2 illustrates the process of a potential BIM-based design briefing, which is based on the RIBA POW 2020 stages but also utilizes BIM from Stage 0. Unlike with traditional design briefing process, this BIM integrated process will fall under the BIM umbrella and will utilise the functionalities of BIM from the very beginning of the process. The main goal behind implementing BIM in the briefing process is to improve the briefing process, improve communication with clients through the aid of a visual model, generate early data to minimise errors from the initial stages leading to saving of time and cost for both the client and stakeholders. This also helps improve risk management, streamline the briefing and ultimately the design process.

The ideas proposed in this study follow the BIM ideology of sharing information, improving collaboration, integration, visualisation and analysis to reform and streamline the briefing process. This process is supported by early appointment and collaboration of various professionals and teams in a building project who share their skills and knowledge from the early stages of design briefing. The benefit of this early collaboration is twofold. First, this will help the client make a more educated decision regarding various aspects of the building based on the knowledge of various stakeholders. Second, early collaboration allows early gathering of data that can be incorporated into developing a better BEP (BIM Execution Plan) in addition to adding the information into the BIM model itself. Utilizing the automatic designing and verifying capabilities of Revit and its add-ons such as Dynamo, the proposed design briefing process seeks to improve the output duration and quality of concept designs, which can also help in keeping costs low. Additionally, POE outcomes can also be attached to the general space or building elements/components through a POE library. This can be delivered into next design projects that utilise similar space types or building elements.

The process begins as any traditional method does, where the client provides the architectural team with their requirements. These requirements are then structured in MS Excel and is then processed through the prototype developed with Dynamo, which can quickly produce multiple spatial designs with 3D masses. This conceptual design will begin with a BIM mass model in this process of design briefing. It should be noted that this design is only intended to serve as an initial concept that can assist designers in decision-making and provide a visual reference to clients. Designers would still need to verify the suitability of designs.

Next, similar to a traditional method, consultants need to be appointed including an information manager, in order to further develop the brief, carry out feasibility studies and set up a CDE for the initial concept model. However, this process of briefing greatly relies on the appointment of stakeholders such as project managers, engineers, facilities and operations managers, suppliers etc. in order to gain valuable inputs to develop the client's requirements represented in the concept mass model. However, this is dependent on the type of procurement route that the project is using. For example, under a design and build procurement route, a main contractor is appointed to design and construct the building (Designing Buildings, 2022). In this case the involvement of other stakeholders may be higher than in other route such as a traditional design-bid-build procurement route, where the design is developed by a design team and a contractor is appointed at a later date (Designing Buildings, 2022).

Input from stakeholders plays a vital role in implementing BIM in the design briefing process. Unlike a traditional briefing process, stakeholders other than the design team need to be part of the briefing meetings where they can provide their input towards the concept design. This will help further develop the parametric concept design at Stage 1; along with the development of an initial brief. This will provide the project with a more accurate cost, improve sustainability and assist the client in making informed decisions from the beginning of the project.

The use of BIM-based design briefing may also change the processes and procurement of a project as in general, such stakeholders would not be employed or formally involved in a building project in the briefing stages. However, it has been evident from the interview analysis that early involvement of these stakeholders will benefit the performance of any building projects.

After further development of the conceptual mass model that has been developed with Dynamo in Stage 1, it can be used to consult with clients and to check for the compliances of relevant basic design principles and Building Regulations with the aid of Revit add-ons such as Xinaps. And the ability to check a design against building regulation compliance at the early stages will provide all stakeholders with an added benefit. As the brief is further developed, the concept design can be constantly monitored against regulations, improving the entire briefing process.

5.4 Process of prototype development

As discussed in *Chapter 3: Research methods*, the software development process for this research project utilizes a partial prototyping method, which is cyclical in nature. The deployment and maintenance stages of software development were outside the scope of this research. Figure 5.3 illustrates the same process in a linear format that also depicts the structure of this section. The first step in prototype development is *requirements capture*, which was done via interviews. The second step is the development of a *conceptual system framework*, which is based on the learnings from the literature review as well as the outcomes of the interview. This step consists of 6 sages of its own. The third step is the *development of the prototype* itself with the use of Revit and Dynamo. The final step is the *testing and improvement* of the developed prototype.

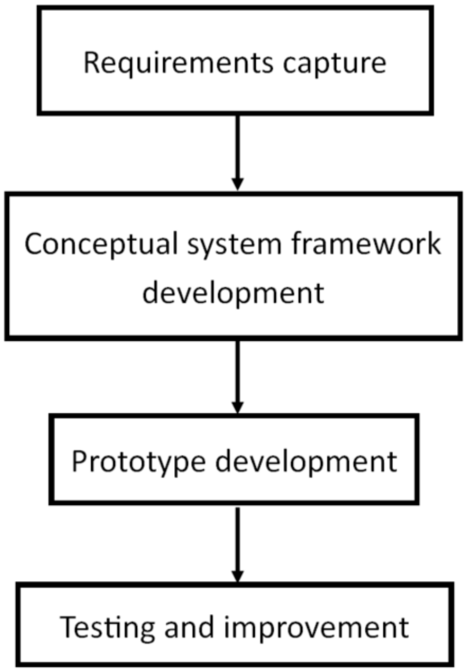


Figure 5.3 Process of prototype development

5.4.1 Major functionalities of BIM-based design briefing tools

Functionalities for the proposed BIM-based design briefing tool were identified through the requirements capture, which is a process of eliciting requirements from potential users of a system or tool. This is the first step in the prototype development process. For this research study, the requirements were extracted via interviews with professionals in the industry. The analysis of the interviews showed three fundamental functional requirements d from a BIM-based design briefing system. Each of the requirements contains some further sub-requirements that explain what functionalities are in demand. These requirements have been re-iterated below. These requirements will form the base during the development of the conceptual system framework and the functionalities will contribute towards the prototype development.

Table 5.1 Requirements from a BIM-based design briefing tool.

Requirements	Functionality
1. Integrate/input initial design briefing outcomes into a BIM platform (Autodesk Revit)	• Loading initial design briefing outcomes stored in MS Excel file into Revit. • integration with Revit Dynamo • Management of brief via spreadsheet • Dynamo for quicker outputs
2. Automation	• Automatically generate a mass model with the constrains of Building Regulations and design principles. • It may also be able to optimise floor plans based on more detailed schemas/constrains. • Generate multi options

3. Early simulations to promote the performance of a building	• Energy efficiency • Cost efficiency • Check model based on requirements

5.4.2 Conceptual system framework development

The interdisciplinary approach of this research (built environment and computing) requires the development of a conceptual system framework which is a steppingstone towards the development of a BIM-based design briefing prototype. A system framework is a visual representation of a programme to be developed, depicting the flow of information, their interrelation, storage, users/contributors and the overall process of development (Avison & Fitzgerald, 2008; Pressman & Maxim, 2015; Sommerville, 2016). In other words, a conceptual system framework is what a design is to the construction of a building. It acts as a blueprint before the actual programme is to be developed.

The objective behind the development of this framework is primarily to make decision support regarding the requirements for the prototype, the actors that would be involved, and the directions of flow of information. With this information in hand, the researcher can then move on to develop the prototype using Dynamo a Visual Programming Language (VPL) available as an add-on software in Revit.

Conceptual system design is one of the first tasks that need to be carried out in the systems development process. In this stage, the feasibility of the initial ideas is investigated and developed to create an overall vision of a potential system, whilst defining the purpose of the system. Functional and non-functional systems and business requirements are also defined during this stage. Conceptual system framework design can also sometimes overlap with the requirements engineering process during this system development, as it involves discussions with potential users about how the system is to be used and some of the functionalities that they may wish to see in the system. There are a number of activities that need to be carried out during in the conceptual design process, which has been followed in this project as well (Sommerville, 2016). These activities help ensure that the framework being developed fulfils all the needs of the system.

a. Identification of problems

In a dynamic process such as the development of conceptual design and even system design, problems appear on almost every step. When a problem is identified, there usually is a clear lack of definition of the problem. In order to solve the problems at hand, the information needs of the system has to be identified and prioritised based on the final target of the system. Some of the initial problems that can arise is identifying the need of the system, defining a specific goal and the kinds of issues the system needs to solve.

For this research, problems with the current process and method of design briefing were identified through interview with professionals which were discussed in the previous chapter. A reiteration of the issues with the current (traditional) process of design briefing have been outlined in table 5.2.

Table 5.2: Issues with the process and methods of traditional design briefing

Issues with process of briefing	Issues with method of briefing
i. Unrealistic expectation of clients ii. Misunderstanding between clients and architects iii. Inaccuracies in the brief iv. Difficulty in managing larger brief. v. Lack of clarity towards client requirements vi. Short timeline for briefing vii. Minimal support for inexperienced clients	i. Ineffective use of technology for briefing ii. Lack of stakeholder involvement in briefing iii. Lack of POE integration iv. Lack of a structured format and methodology

b. Setting objectives

Once the problems are identified, the next step was to set objective of the system. Sommerville (2016) understands that it can be quite difficult to set objectives for a system to cover all functional requirements, hence, these must be set based on the importance and demand of each function. Keeping this in mind, a set of objectives were developed for the conceptual framework that aimed to reduce the effects of the issues in the design briefing process, which are:

i. To allow stakeholders to contribute and develop a holistic model.
ii. To attach and utilise POE data into the model.
iii. To improve efficiency through automation of iterative tasks.
iv. To develop early conceptual plans to analyse the possibilities of a site.

These objectives were primarily derived by analysing the issues as well as the functional demands and matching issues with functions that could potentially reduce or eliminate that particular issue. For example, it was identified that there were misunderstandings in the early stages of briefing when ideas are still fuzzy and the only method of communication is verbal, written and sketches. However, one of the functional requirements in demand was of a tool that could generate multiple options, which should provide an early conceptual plan for a project. Although this may not eliminate the possibility of misunderstandings between a client and a design team, it would however, provide a quicker and additional method of communication between the two parties. Moreover, this can help with the issue of short timelines in the briefing process by improving efficiency.

c. Establish constraints.

Establishing constraints is a major step in conceptual design as allows the system to be designed with certain restrictions or boundaries. These constraints can be internal or external or both. Internal constraints imposed by the management or system designer helps the system design to stay realistic and achievable within a certain timeframe. These can also come from final users if the system is being designed and developed in-house.

Limitations also come in the form of cost and resources, which need to be kept in mind during the conceptual design.

External constraints may come from sources such as the client commissioning the system design who may or may not require certain functionalities. Depending on the kind of system that is being designed, local councils and other organisations may also impose restriction in forms of data processing or copyright.

As this was a single-person research all the limitations were set by the researcher. Decisions related to limitations were made based on learnings from the literature review as well as the outcomes of the interviews. Additionally, the limited timeframe and achievable functions as a lone developer also played a role in determining limitations. The various limitations set for the prototype development have been listed in the table below.

Table 5.3 Limitations set for prototype development.

Criteria	Constraint	Reason
Data source	Spreadsheet with MS Excel	- User friendly - Easy to structure - Design briefing data - Readable by Dynamo
Development tools	Autodesk Revit & Dynamo	- Researcher familiar with the software

		- For use by design professionals who are not programmers - Natively available - Used by some practices already
Checking	Autodesk Revit	- Useful tool for checking against clashes - Available to the researcher
Spatial layout	UK Building Regulations & Design Principles	-Allows the researcher to develop accurate and acceptable layouts

Imposing these constraints may have a negative tone to it and may give the impression that the design is somehow negatively impacted, or its potential is limited. However, a lack of constraint has a greater possibility of causing the design to diverge, lose track of its initial objectives or even get tangled on external issues. Remaining within the limitations has allowed the researcher to focus on the demands that were identified from the interviews and develop related functionalities. This has also helped the researcher see what is achievable and what may be too ambitious and out of the scope for this particular study.

d. Alternative designs

Conceptual framework design is a creative process, which is iterative in nature, that requires synthesizing and constant modifications to achieve the desired outcome from the system. The design needs to take into account the sources of information, the pattern in which information will flow efficiently, the roles of various stakeholders and decision points. Due to these various factors, there will come a point in time where two or more conceptual designs are developed. These designs may have major or minor differences in terms of how the system will function and what kind of output is achieved. In order to select the optimum design, all designs should be compared and the one which meets majority of the requirements and is cost effective (if cost is a factor) should be selected.

During the development of a conceptual system framework for this study, a few iterations were developed before selecting a final framework. One of the early iterations of the framework can be seen in Figure 5.4 below. The issue with this framework was that while this framework covered the basic flow of information and actors involved in the process, it was not detailed enough for the development of the prototype. For example, this model does not make clear how the information would be added/imported into the software or at what type of output would be generated at which stage. Moreover, the flow of information here is mostly one-directional, which does not allow for the inclusion of POE information to be added.

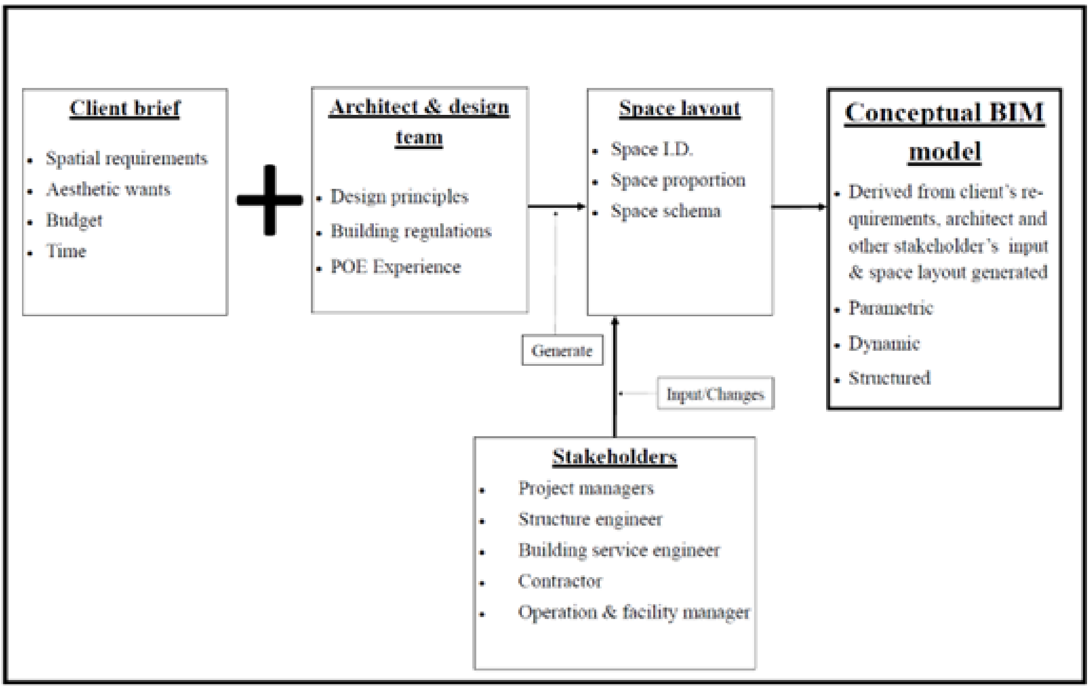


Figure 5.4 Initial conceptual system framework development

The initial design was not very different from a traditional process of briefing. It depicted clients with their requirements and design teams with their design principles and knowledge. Then a space layout would have been generated using Dynamo in Revit. Next, stakeholders such as the facility managers, surveyors and project managers would have been able to provide their inputs, which would then generate a conceptual BIM model.

There were multiple issues with this initial framework design. For example, it did not clearly identify the formats of clients' requirements, it did not mention the RIBA PoW stages at which each task would be carried out and ignored the testing and verification of the developed conceptual design. Hence, after revising this framework design, another iteration was developed, as illustrated in Figure 5.5.

The final step in the development of a conceptual system framework is the selection of the best design. This iteration, seen in Figure 5.5, was a modification to the framework shown in Figure 5.4, providing a more detailed concept of how a BIM-based briefing prototype might work. It begins with the client's requirements in a spreadsheet format, which makes it compatible with Dynamo leading to automatic that is converted into a spreadsheet. This format of a client's requirements makes it compatible with Dynamo leading to faster processing of information and the automatic development of a conceptual briefing model.

Although this version of the framework (Figure 5.5) was selected as the best iteration at the time, it still required verification as this was developed by the researcher with feedback coming only from the researcher's supervisor. The next section discusses the steps taken to verify the framework including the outcome.

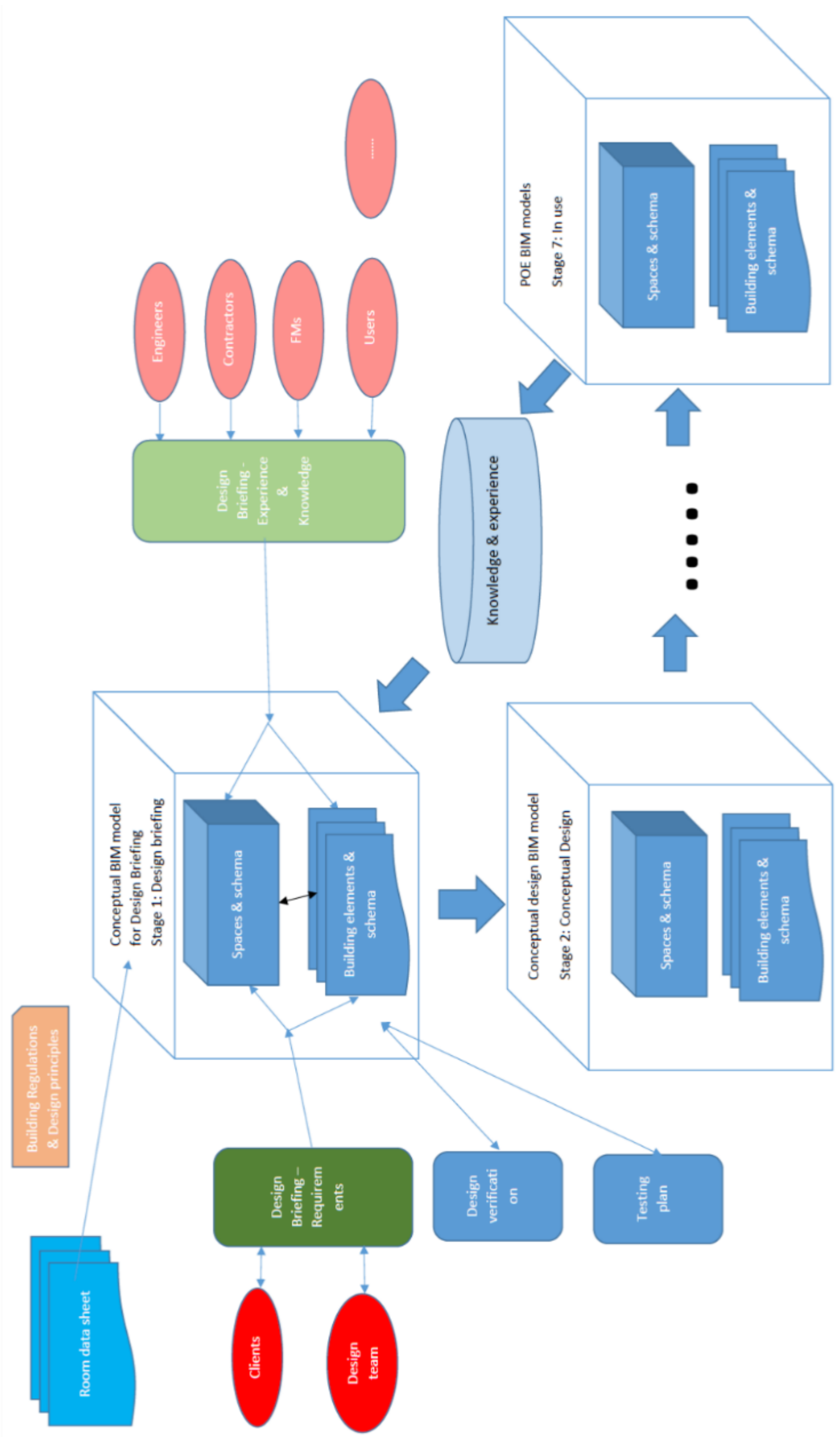


Figure 5.5 One of the finalised versions of the conceptual system framework.

5.4.3 Verification of the conceptual systems framework.

One of the crucial steps that needed to be taken after finalising a conceptual systems framework, was to verify that the framework was developed well enough to be used for the development of a prototype. As a framework is still a work-in-progress towards building a prototype, it was not possible to simply test is this on a computer and determine if it was appropriate or not. According to Morse (2018) one of the strategies of verification is through peer reviews. This is not a method of validation for the correctness of the proposed framework but a means for the researcher to identify flaws and to further develop and polish the framework in order to create a better version, based on feedback of other experts in this field.

Hence, this research including the conceptual system framework was presented in a seminar at the university in order to gain feedback from the attending peers and academics from the field of Architectural Technology, Built Environment and Engineering. Some feedbacks were received after the presentation and two of those were related to the conceptual system framework. The first feedback received stated that *"The framework must show what kind of information would be handled and how the information would be processed in BIM during the design briefing."* While another feedback recommended, *"...to develop an information framework that can be incorporated into BIM with uniqueness and creativity from the early stage of a project life cycle."*

Based on these comments, improvements were made to the conceptual framework and a newer version was developed as seen in Figure 5.6. This version of the framework shows a more robust flow of information, including different types of information that would be handled at different stages and the outputs in more detail. A new addition of testing and verification of the developed models in the early stages was also added to the framework. The idea behind this was to test a design or model at every interval to keep the process dynamic and improve efficiency. The research including this conceptual system framework was then published.

Furthermore, this final version of the framework was also presented to peers in two separate seminars organised by the university. Some feedback was received during these presentations, however, they were not substantial enough to make further changes to the framework and this version was finalised before moving on to the next stage which was the development of the prototype.

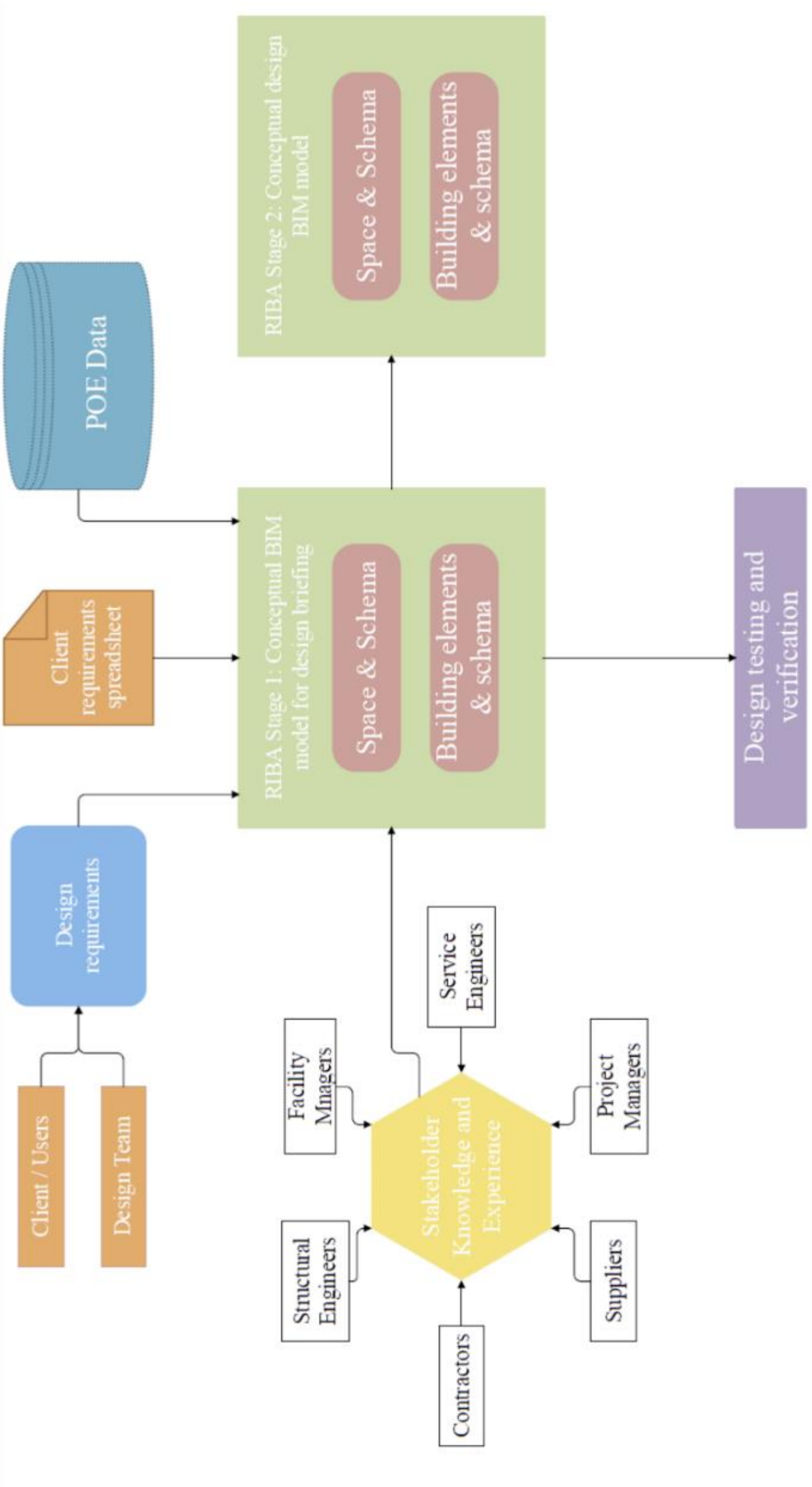


Figure 5.6 Final version of the conceptual system framework.

5.4.4 Prototype development

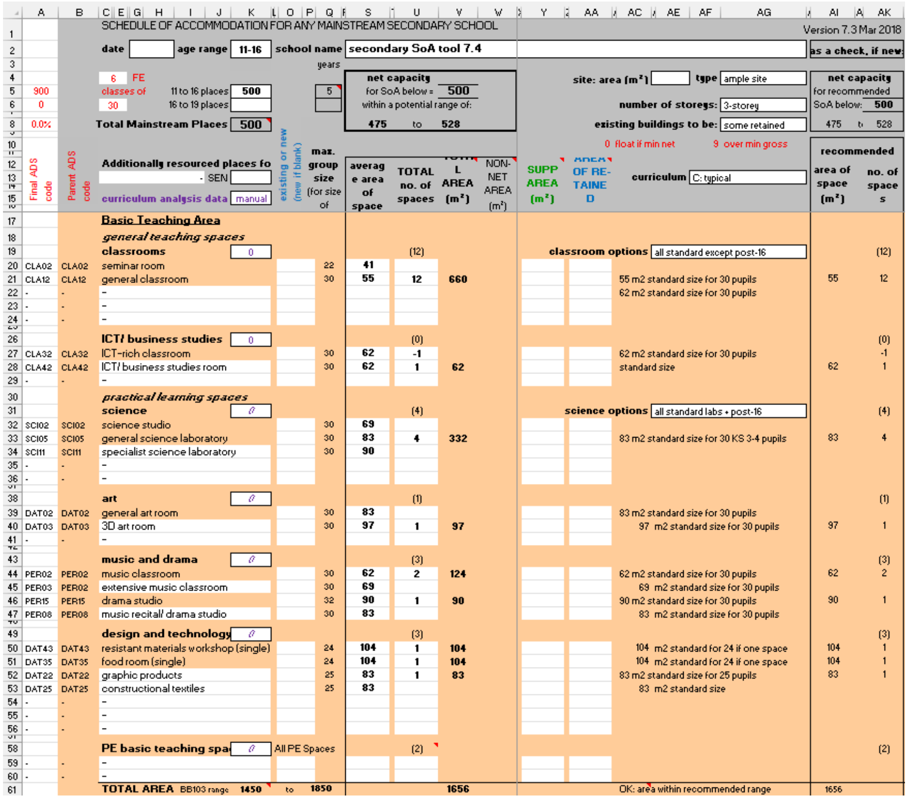
Upon developing and verifying the conceptual system framework, the final step in this research study is the development of a BIM-based design briefing tool. As previously mentioned, the primary program that will be used for the development of the prototype software is Dynamo, which is a visual scripting program that uses Visual Programming Language (VPL). This program is a Revit add-in and is designed for use by non-programmers such as architects and designers and is able to access Revit's Application Programming Interface (API). Though the API and Dynamo, commands can be executed programmatically, and custom commands and programs can be developed. It also allows the user to create custom algorithms in order to process data and generate geometry. This section explains in detail the process used to develop the BIM-based design briefing prototype.

5.4.4.1 Data repository

Data repository here refers to the data extracted from the initial design brief, that can be input into a BIM platform, namely Revit in this study in a graphical format that is easily understandable and readable and processable. Design brief is usually descriptive and uses more words than numbers to describe the user's requirements. For example, a client might ask for a certain room to be 'spacious that allow plenty of natural light as well as fresh air.' Words such as 'spacious' and 'plenty' cannot be translated by software and even if it were able to translate these words, the requirement may be different from one client to another.

In order to avoid too many uncertainties, an educational building was selected to develop and test the prototype. The reasons for choosing this type of building were because the shape and spaces of the building is simpler than that of a house or an office building, i.e., a simple rectangular or and L-shaped building, where the corridor can run between two sides of rooms. This simplifies the process for the researcher to develop the prototype within the limited time. Another reason for this choice is that architects and designers use an MS Excel based Schedule of Accommodation (SoA) tool document developed by the Department for Education as a briefing template, which was discussed in *Chapter 2: Literature Review* and also identified during the interviews. Through the use of this tool, which can be seen in Figure 5.7, the researcher can input the number of students and the tool will provide minimum size requirements of various spaces within the school building. These space requirements can be extracted and imported into the BIM-based tool and imported firstly to Dynamo and later the prototype software. This also helps the researcher avoid guesswork or make-up spaces that may not be accurate or compatible. For this study, a total of 500 students was used as the input in the SoA sheet and the results were used as the minimum spaces in the prototype development.

Testing on other types of buildings such as houses was not carried out during this research as the prototype development was carried out to demonstrate the possible uses of a BIM-based design briefing tool, which this test was able to verify. Secondly, this research was conducted within a set time frame which restricted the amount of time the research could spend on each aspect of this study.



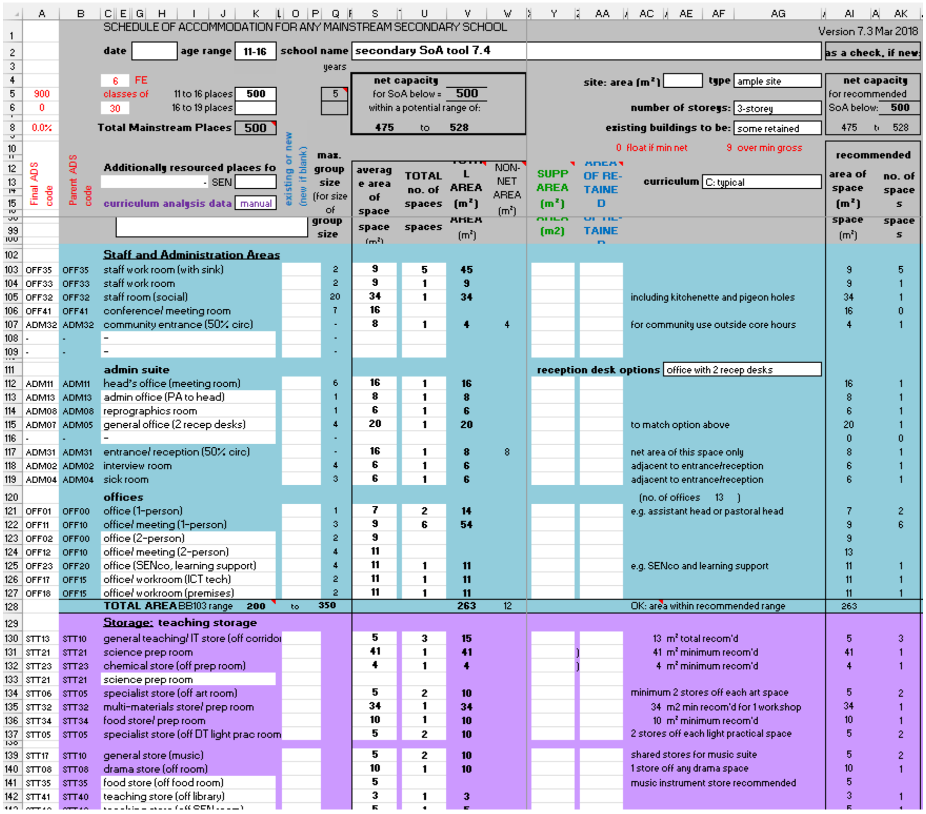


Figure 5.7 Schedule of Accommodation (SoA) spreadsheet

iii. Structuring data

The first issue that needs to be tackled is the structuring of data from the SoA as the data is scattered in various cells within the spreadsheet. In order to achieve this, a simple cell reference can be performed from this main sheet onto another sheet created by the researcher. An example of this can be seen in Figure 5.8 below. When the total number of students is entered as 500 the total number of general classrooms is 12 and general laboratory is 4. These 2 cells are then referenced onto the new sheet named ‘Spaces’ using the formula “='Secondary SoA'!(*Cell Number*).” This means that every time the value changes on the main SoA page, the values change in the new ‘Spaces’ sheet as well, hence structuring the data together which is easily readable by Dynamo. Creating this new sheet in Excel saves time than creating numerous nodes in Dynamo to read from various independent cells in the SoA sheet.

SPACE ID	SPACE NAME	AREA	COLOUR	ADJACENT SPACES	WIDTH	LENGTH
0	Corridor	321	102,244,255	General Classroom, Art Room, Music Room, Sports Hall, Library, PA to Headmaster, Staff Room, Meeting Room, Interview Room, IT Storage, Science Prep-room, General Storage, Cleaner's Storage, Kitchen	54	6
1	General Classroom	55	0,255,255	Corridor	9	6
2	General Classroom	55	0,255,255	Corridor	9	6
3	General Classroom	55	0,255,255	Corridor	9	6
4	General Classroom	55	0,255,255	Corridor	9	6
5	General Classroom	55	0,255,255	Corridor	9	6
6	General Classroom	55	0,255,255	Corridor	9	6
7	General Classroom	55	0,255,255	Corridor	9	6
8	General Classroom	55	0,255,255	Corridor	9	6
9	General Classroom	55	0,255,255	Corridor	9	6
10	General Classroom	55	0,255,255	Corridor	9	6
11	General Classroom	55	0,255,255	Corridor	9	6
12	General Classroom	55	0,255,255	Corridor	9	6
13	PA to Headmaster	8	255,175,175	Corridor, Headmaster's Office	3	3
14	Interview Room	6	125,125,125	Corridor	2	3
15	IT Storage	10	195,255,65	Corridor	4	3
16	Chemical Storage	4	255,255,100	Science Prep-room	2	3
17	Headmaster's Office	16	195,165,255	PA to Headmaster	3	6
18	Library	69	255,185,255	Corridor	12	6
19	Art Room	97	0,255,0	Corridor	16	6
20	Music Room	62	255,204,204	Corridor	10	6
21	Music Room	62	102,255,103	Corridor	10	6
22	Staff Room	45	140,140,255	Corridor, Staff Social Room	8	6
23	Staff Social Room	34	128,0,128	Staff Room	6	6
24	Meeting Room	16	255,0,125	Corridor	3	6
25	Meeting Room	16	255,0,125	Corridor	3	6
26	Science Prep-room	34	255,205,100	Corridor, Chemical Storage	6	6
27	Kitchen	57	100,100,255	Corridor, Kitchen Dry Storage, Kitchen Freezer Storage	10	6
28	Music Storage	10	210,180,210	Music Room	4	3
29	General Storage	8	245,130,130	Corridor, Sports Hall	3	3
30	Cleaner's Storage	6	140,245,190	Corridor	2	3
31	Kitchen Dry Storage	3	255,155,0	Kitchen, Kitchen Freezer Storage	3	3
32	Kitchen Freezer Storage	2	255,185,155	Kitchen, Kitchen Dry Storage	2	3

Figure 5.8 Structuring data from SoA sheet

ii. Adding schema.

The next step after structuring the data is to create a schema for the prototype to follow. In a database, a schema defines the relationships between various fields of the database (IBM, 2018). The algorithm in Dynamo will still be able to produce outputs without these schemas however, some or most of them may not be practical and useful for the user in making decisions.

The first schema added to the spreadsheet, as seen in Figure 5.8, was ‘adjacency.’ This basically refers to spaces that needs to be adjacent to one another, such as a classroom needs to be adjacent to the corridor, or a door needs to be placed on a wall adjacent to the corridor and not another classroom. Using this schema assures that the software only provides outputs of those conceptual floorplans that adhere to the adjacency rules set by the user.

Another schema added was the colours for various rooms. This will allow the user to visualise the space more easily and will also enable them to identify if any of the outputs are not ideal. For example, it will be easier to spot an improper placement of a kitchen space coloured orange between a row of classrooms coloured green, and lunch area coloured purple at the end of the corridor.

The final data spreadsheet consists of information that the tool would require to generate a conceptual floor plan. This includes a name for the space such as classrooms, staff rooms, W/C etc. The area of these spaces which are derived from the SoA spreadsheet, although the user has the ability to change this is necessary. The next cell consists of a particular colour for various types of spaces. These colours are defined using the Red-Green-Blue (RGB) spectrum codes as this is readable by Dynamo and will also simplify the process of defining colours within the algorithm. These codes can be found in the custom colour pallet in Excel or any other office tools. The final cell consists of adjacent spaces, where the user can add any spaces that require to be next to one another and the program will be able to produce outputs based on this.

It could be possible to add these schemas within the algorithm in Dynamo. However, as explained in the ‘structuring data’ section above, this would require developing a more complex string of nodes to execute this schema, which may result in the program slowing down and even crashing. Furthermore, this would also slow the development process of the program as a whole as more time would need to be allocated just to develop the schema and test it.

Further schemas may also be added to the prototype that are based on various building regulations such as Fire Safety: Approved Document B Volume 2. This can be used to generate designs that comply with regulations from the briefing stages and assist the user in developing compliant designs from the beginning. For example, schemas that can place fire doors at required distances or generate designs with minimum travel distances can be added.

5.4.4.2 Input Data

Once the data repository has been developed, the next step is to import those data into Dynamo. An example of the nodes used to import the spreadsheet can be seen in Figure 5.9. The input consists of importing the spreadsheet file and pointing to the sheet within the document for Dynamo to read. Once the file is correctly loaded the script can begin processing the data and create an output.

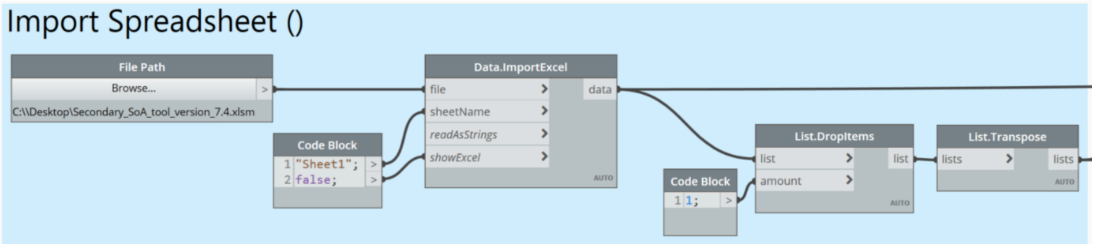


Figure 5.9 Nodes used to import spreadsheet data.

5.4.4.3 Data processing

After successfully importing the spreadsheet, the software begins processing the data. The amount of processing time depends on various factors such as the size of the data and the processing power of the device being used. For example, a 34 row and 4-column data took about 4 minutes to process on the researcher’s laptop which consists of a 2GHz Ryzen 7 processor with Radeon Graphics and 8 GB of RAM. Whereas a 5-row and 4-column data took only a few seconds to process.

The algorithm processes the data through a series of steps in order to generate a geometry. The first step is to isolate the corridor as it is adjacent to almost all the spaces and has a high length-to-width ratio. Due to the shape of the corridor an option to adjust the width needs to be added. In this instance, the width of the corridor was set at 3m. The length of the corridor can be adjusted using $Int\left(\frac{\sum WIDTH}{2}\right)$ formula. Here, the width of all spaces is added and divided by 2 in order to generate them on either side of the corridor. These nodes can be seen in Figure 5.10 below.

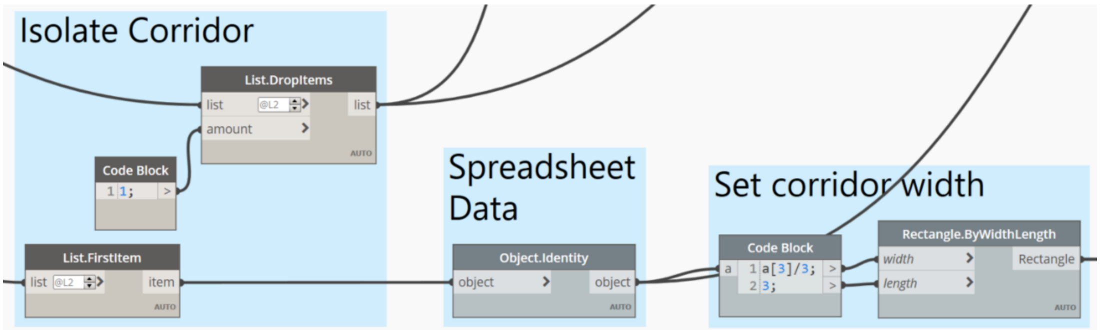


Figure 5.10 Corridor isolation and width adjustment

Next, the shape for the remaining spaces is generated based on the area specified on the data spreadsheet using the set of nodes seen in Figure 5.11. In order to generate spaces, a node that calculates the square root was used. The input was the list of areas from the spreadsheet and the output were the two numbers that were assigned to form the length and the width of the spaces. The resulting spaces will only generate square-shaped spaces; however, this was done in order to keep the program simple and functional as the script was already generating large number of spatial layouts. Additionally, since the output is conceptual and will need refining later in the design stage it was considered suitable for this early pre-design stage.

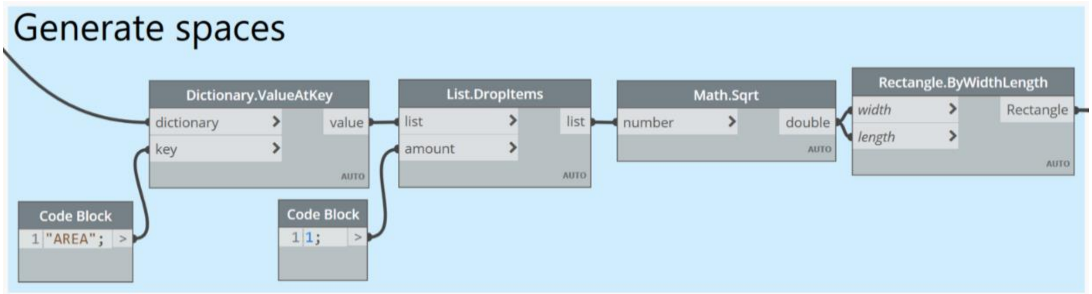
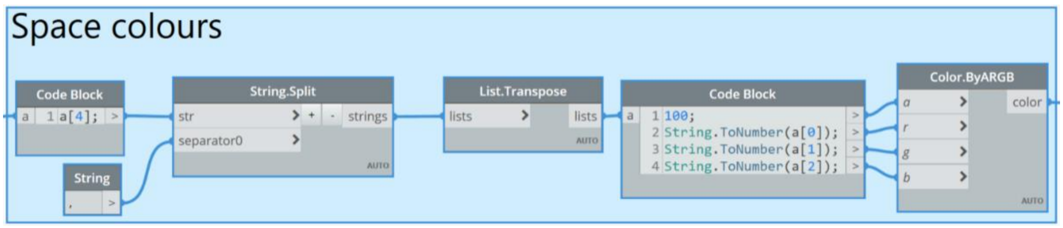


Figure 5.11 Set of nodes used to generate spaces.

Next, the colours of various spaces are added from the data spreadsheet as seen in Figure 5.12. The colour codes used in the spreadsheet is translated by the 'Color.ByARGB' node and added to the final output. The letter 'A' stands for Alpha, which in this node is used to control the translucency of the colours. Colours in this instance is used as a medium of visualising the spaces and helping the client better understand how the layout works. This feature can be turned off if the user feels that it is unnecessary.



5.12 Adding space colours from data MS Excel file.

After this the spaces get divided into two using the set of nodes seen in Figure 5.13. This is done to ensure that the spaces can be added along the two sides of the corridor and not just one. If there are multiple corridors, then the spaces can be divided accordingly.

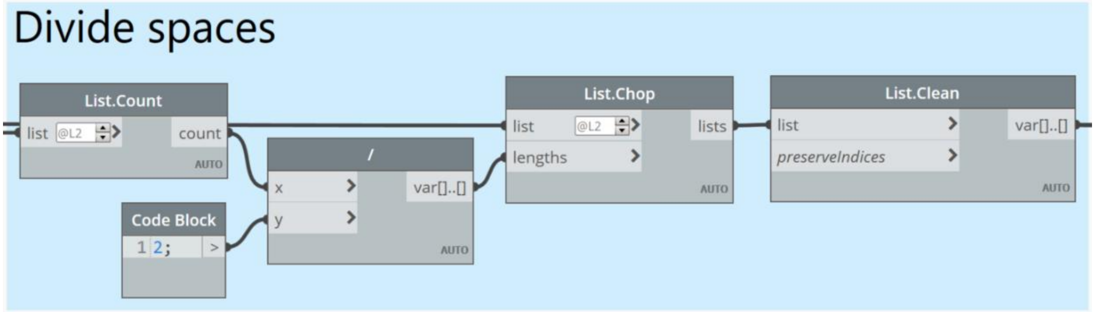


Figure 5.13 Division of spaces

Next, a set of nodes are added, as seen in Figure 5.14, which will align the spaces along the corridor as well as with the spaces next to it. Without this, the centre of all spaces would snap to the origin, i.e., ‘0, 0’ on the x & y coordinate. In order to align the spaces horizontally along the x-axis, the width of the spaces was divided by 2 and then moved over by the resulting number. To align the spaces vertically along the y-axis, a manual code was added where the spaces were first divided by 2. Then 1.5m was added to each side, as the width of the corridor was set at 3m, which aligns the spaces along the corridor.

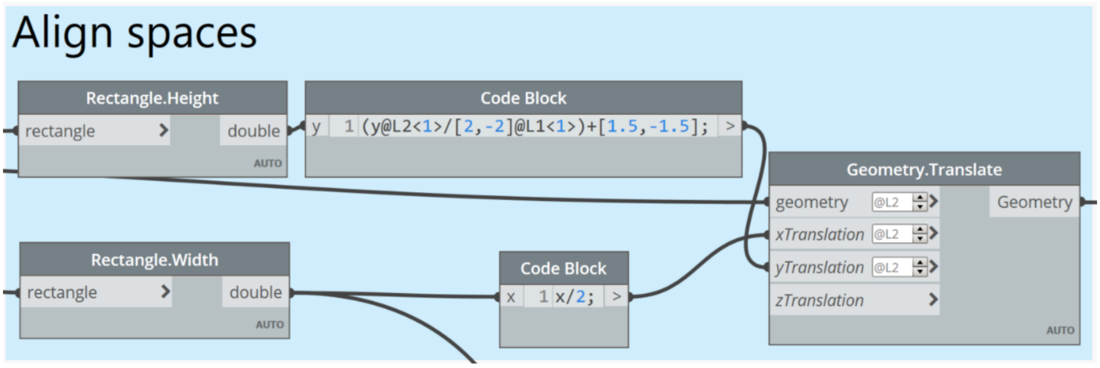
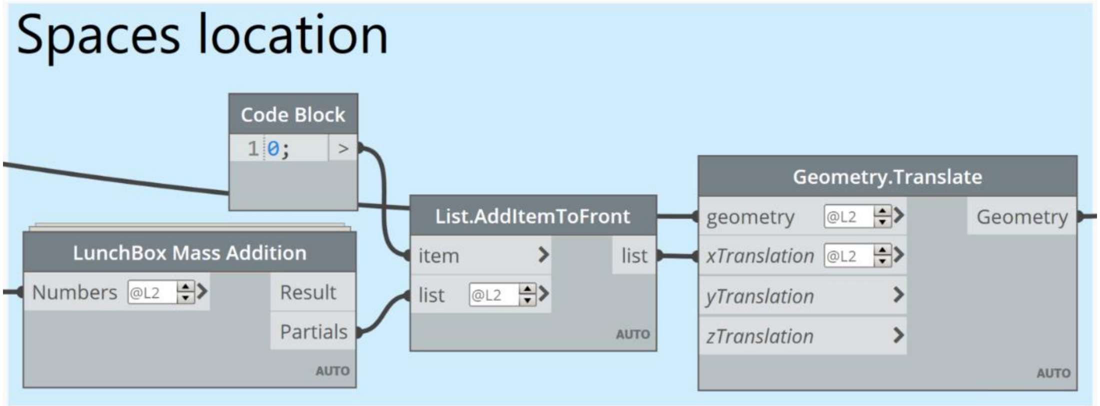


Figure 5.14 Space alignment.

After aligning the spaces, a script that sets the locations of the spaces needs to be developed. This was done with the set of nodes seen in Figure 5.15. In order to carry out this function the coordinate of the first point was set at ‘0’ on the x-axis, by adding it to the beginning of the list of widths, as the spaces only needs to move horizontally in this instance. Then a mass addition node was used to add the width of the spaces one after another, that would plot the spaces on the x-axis.



5.15 Set location of spaces.

After this the corridor, which was isolated earlier, is added at the end together with the other spaces, and all these spaces are added to the dictionary, as seen in Figure 5.16. A dictionary is defined by Dynamo (2019) as *"a data type composed of a collection of key-value pairs where each key is unique in each collection."* Using a dictionary allows a user to add, delete or search for data into a collection.

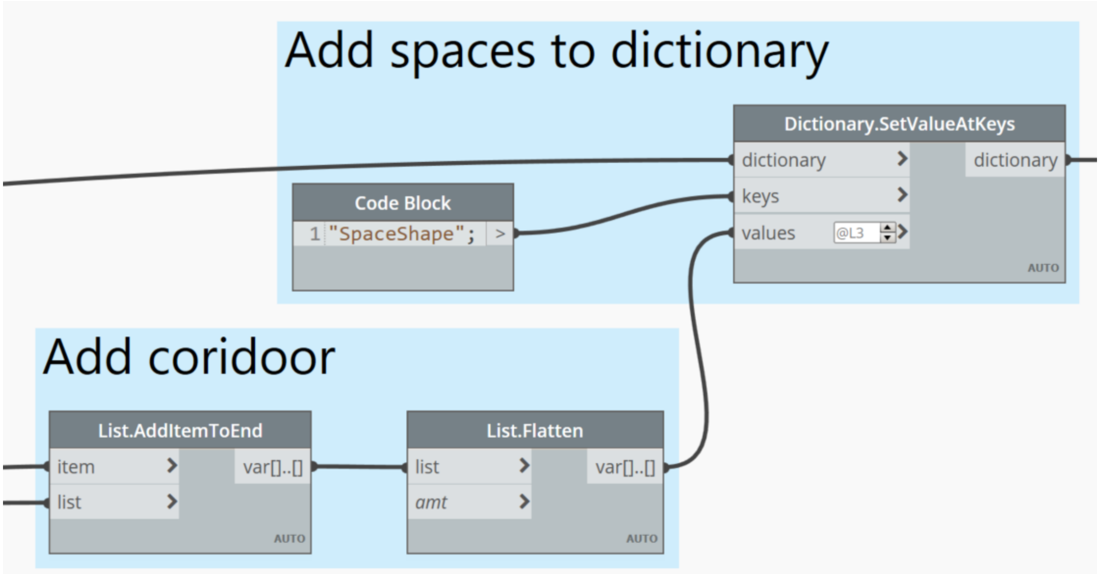


Figure 5.16 Add corridor.

Next, the set of nodes seen in Figure 5.17 creates surface of spaces generated by the script based on the spreadsheet.

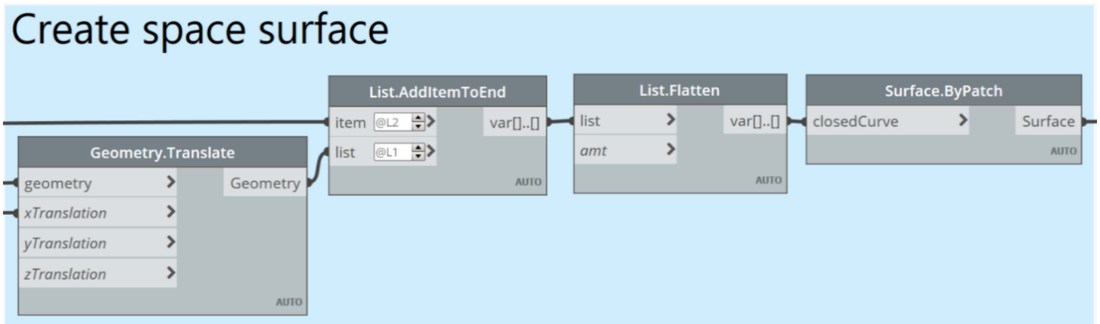


Figure 5.17 Creating surface for spaces.

The next set of nodes, as seen in Figure 5.18 will produce the output geometry in Dynamo that can be visualised and analysed by the user. However, the output using the script outlined so far will simply create a spatial layout based on the order of spaces in the data spreadsheet, which cannot be changed or manipulated without changing the order of spaces in the spreadsheet.

Another set of nodes were also added, as seen in Figure 5.19, that can generate a mass model of the design that is currently being visualised.

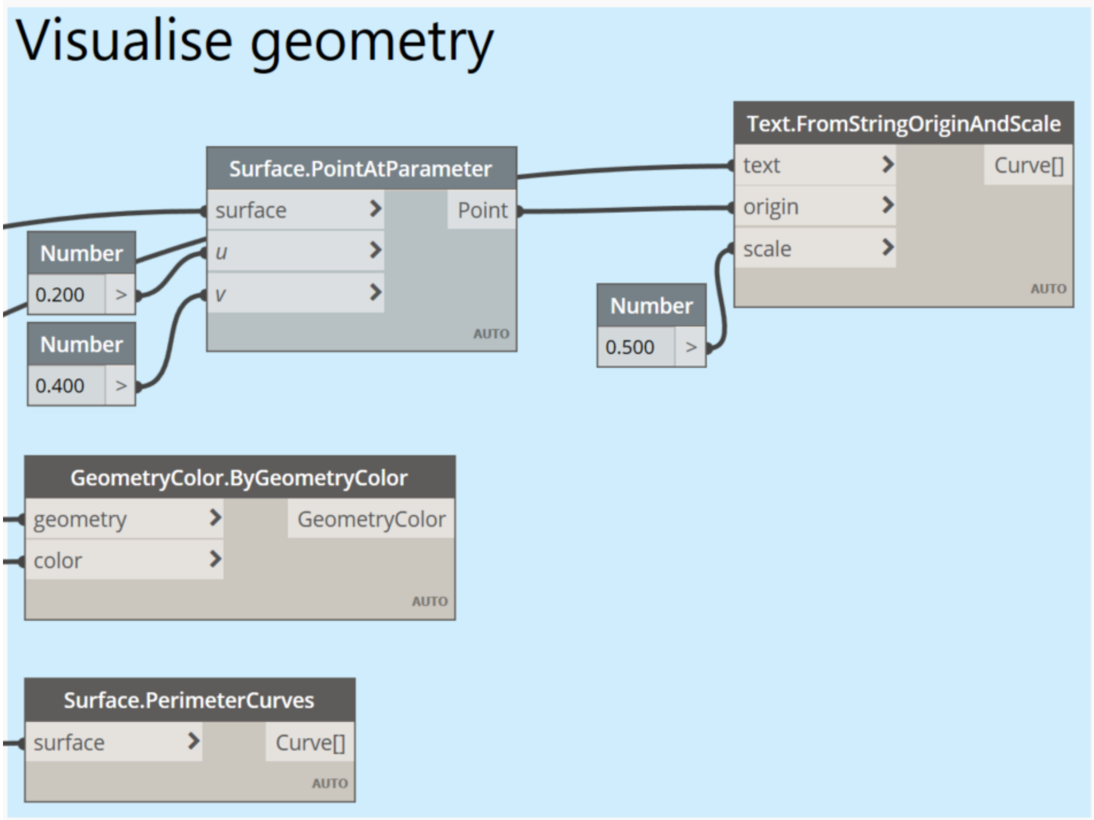


Figure 5.18 Visualise geometry.

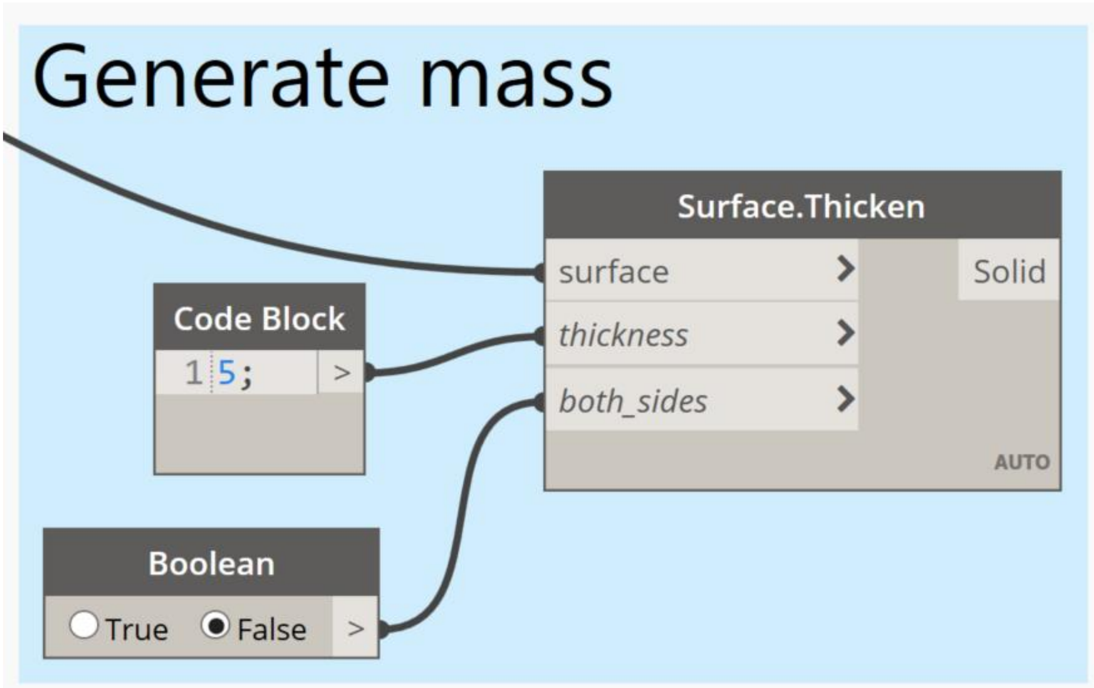


Figure 5.19 Set of nodes that generates mass.

For the script to be able to generate multiple spaces that can be manipulated without changing the data in the spreadsheet, another set of nodes need to be added to the script, which can be seen in Figure 5.20 below.

This was achieved through the use of a node that calculates the permutation of spaces in the data spreadsheet. Permutation is the *"... act of arranging all the members of a set into some sequence or order"* (Byjus, 2020). In simpler words, permutation the process of rearranging items or elements from a set such as the list of spaces in the data spreadsheet used in this study. For example, if we take the first 3 letters of the alphabet and calculate the permutation using all 3 letters, then these letters can be arranged in 6 different ways, which are {a,b,c}, {a,c,b}, {b,a,c}, {b,c,a}, {c,a,b} and {c,b,a}.

$$ {}_{n}P_{r} = \frac{n!}{(n-r)!} $$

The formula used to calculate the permutation is:

Here, nPr is the permutation.

n is the total number of items

r is the number of items selected

The permutation node carries out the same calculation and provides output for all the possible ways the spaces can be arranged from the list in the data spreadsheet. The toggle slider can be used to visualise the various outputs generated by the script.

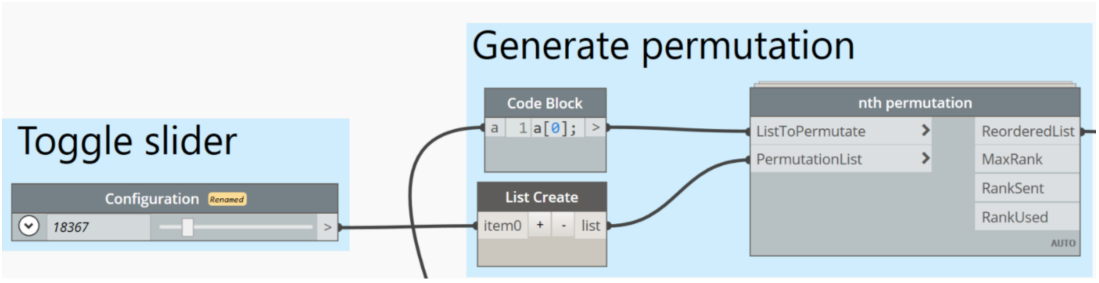


Figure 5.20 Generate permutation of spaces.

5.4.4.4 Output result

The outputs are generated in the form of conceptual floor plans. Some examples of this can be seen in Figure 5.21. Each of the squares denotes a space listed in the spreadsheet and is filled with the assigned colours. Each of the spaces are also labelled. The corridor runs between the spaces, has a fixed width of 3m and is not dynamic, meaning that the shape and position remains the same. The spaces, however, are dynamic, and different layouts can be visualised using the toggle slider.

Due to the permutation node used in the script, the number of outputs generated will be in the billions which cannot be analysed manually. Hence, the script was executed with the 12 ‘General Classroom’ excluded from the permutation calculation which would reduce the number of outputs, but the results were still in the millions. This also means that the location of the 12 classrooms will remain constant. Hence, in order to analyse all the generated spaces and identify the most suitable ones, the script needs to run through Project Refinery in Revit.

In order to visualise more desirable designs within dynamo, a rating system was implemented as seen on the top left side in Figure 5.21 below. Ratings are generated using the adjacency requirement outlined in the MS Excel file and then calculating the distance between 2 or more rooms. Every layout generated is provided with a rating. The lower the rating is the better the design is based on adjacency requirements. For example, the Excel file requires the Headmaster's office and the office of the PA to the Headmaster to be adjacent to one another. If the prototype generates a layout where the two rooms are together then it achieves a lower rating than another where the two rooms are not together, which means that the design is better suited to the needs of the client.

Figure 5.21 Examples of conceptual plans generated by the script.

Additionally, a mass model can also be generated, which is based on the spaces generated by the script. This means that as the script generates different conceptual floor plans, the mass model also changes accordingly. Figure 5.22 shows the same mass model in a Revit environment where elements, materials, and components can be added for further development or manipulation.

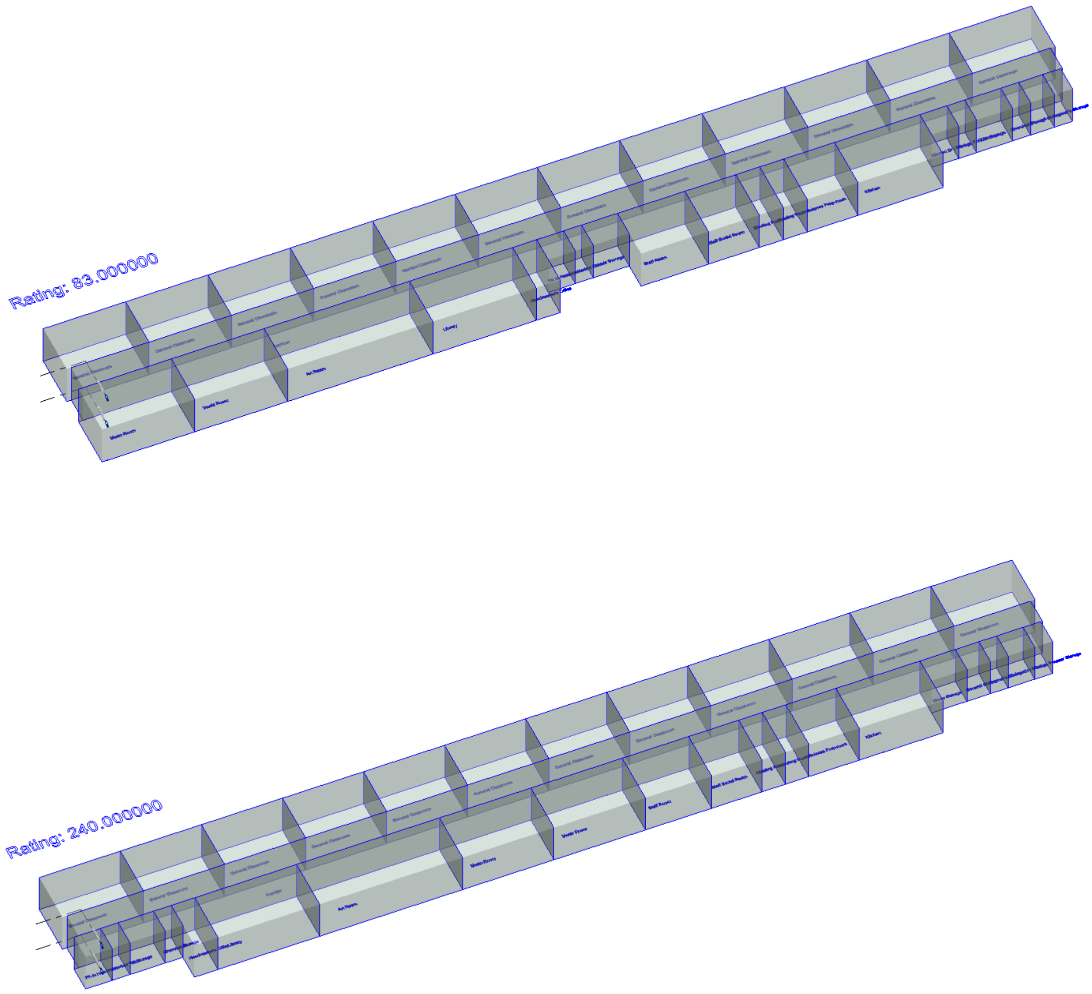


Figure 5.22 Conceptual model generated on Revit.

Once the user has selected a design this can be transferred into Revit and further changes can be made or data can be added. This can also be shared as any normal Revit design or model and other stakeholders can add information based on their knowledge and experience.

5.4.5 Debugging, testing and improvement

Debugging of the script developed for the prototype was carried out on every notable progress made during the development as well as at the end of the development. This was part of the prototype development process explained earlier in the chapter. One of the first indicators that a script was developed correctly was Dynamo's own execution feature which flags up any issues with the nodes or any strings that are not correctly attached. Once the errors within the nodes had been debugged and that portion of the algorithm had been executed successfully, then that portion was deemed successful. For example, the first set of nodes was responsible for importing the spreadsheet, pointing towards the correct file, then the correct sheet, then dropping items in the first column which were headings, and then transposing the list of items. If the nodes are not strung correctly or there is an error in the spreadsheet data, then an error is provided that needs to be debugged before moving on to the next step. An example of this can be seen in Figure 5.23, where an incorrect sheet number was used.

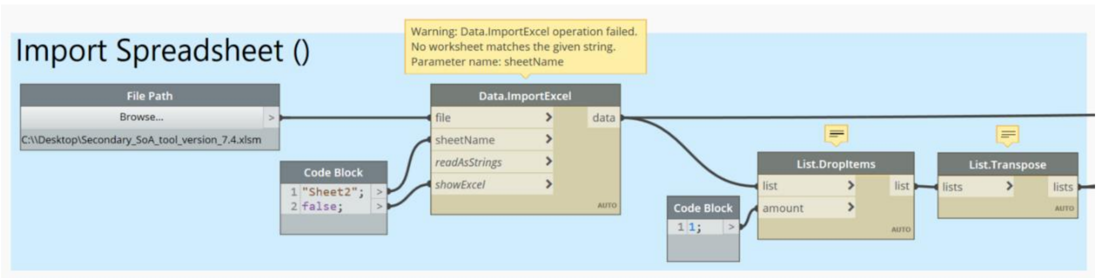


Figure 5.23. Example of an error within Dynamo

Similar tests were carried throughout the development and the only indication that the entire script was working as intended was the visualisation of a primary design. One of the first issues encountered after visualisation was related to the colours of the spaces. Initially, the spreadsheet simply contained a list of colours. However, after looking for solutions on the internet it was realised that Dynamo cannot directly read a colour and generate an exact colour output as a single colour can have numerous shades. Hence, the names of the colours were replaced by colour codes in the spreadsheet and the issue was resolved.

Another major issue encountered was related to the permutations of the spaces. In order to generate spaces and make them dynamic, a combination node was first used, where the idea was to generate spaces with various possible combinations. However, after executing the script, multiples of the same spaces were generated even though the spreadsheet consisted of only 1 of a particular space. For example, the list only consists of 1 art room, but the script was generating multiples of this one room. It was later realised that the combination node allowed repetitions of spaces when creating combinations, hence creating multiples of the same room. If it takes the previous example of the first 3 letters of the alphabet, it would result in 10 combinations, which are {a,a,a}, {a,a,b}, {a,a,c}, {a,b,b}, {a,b,c}, {a,c,c}, {b,b,b}, {b,b,c}, {b,c,c} and {c,c,c}. As seen in this example the items are repeated multiple times. In order to resolve this issue, the permutation node was then used, and the desired outcome was achieved.

Several improvements were also made to the script to generate better outputs. One of the final iterations of the script generated results where the depth of the spaces was not aligned as the script made calculations using a square root formula. An example of this can be seen in Figure 5.24 below. In order to overcome this issue, the depth of the spaces was set at 6m for general rooms and 3m for affixed rooms, based on architectural design principles (Hetreed *et al.*, 2017).

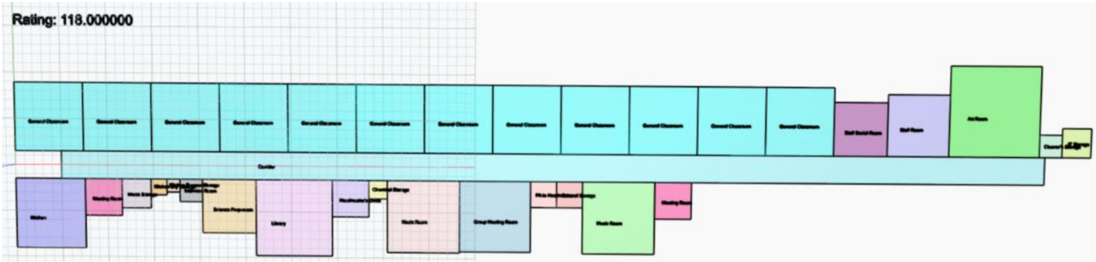


Figure 5.24 Misaligned depth of spaces.

An improvement made to the script that was not originally planned was the addition of a rating system. After the development of the initial script, an attempt was made to add scripts that could analyse all generated outcomes and select the most effective designs. However, this proved to be a challenge that would probably require a team of programmers to develop a substantial amount of code. Hence, this plan was abandoned, and a simple rating system was added where the script will provide a simple rating to a design based on the adjacency requirements set in the spreadsheet.

It should be noted that there are various tools and Revit add-ons available in the market that can carry out analysis of plans and models. However, these tools first require the user to develop a conceptual design based on the design brief. The conceptual spatial layout generated by the prototype software also requires further development by adding elements, components, and materials to carry out analysis. The analysis software tested during the early phase of this research was Xinaps, which is capable of carrying out fire safety, costing and other types of analysis on developed designs.

There were a few more issues that were encountered during the development of the prototype. However, these are discussed in the 'limitations' section in the next chapter.

5.5 Proposed user interface

The development of a user interface (UI) is an important part of software development. This research mainly focused on the development of the prototype of a BIM-based design briefing tool, which could demonstrate some major functionalities of the tool. However, the user interface is also an integral part of this tool, which has been described below.

i. Dashboard View: Upon launching the add-on, users will be presented with a clean and intuitive dashboard view. The dashboard acts as a central hub, allowing users to access various functionalities and settings.

ii. Import Data: The UI incorporates a dedicated "Import Data" button that will enable users to import their Excel-based data file directly into the add-on.

iii. Preview and Adjustment: Before generating the final floor plans, users will be provided with a real-time preview of the floor plan layout based on the imported data. This interactive preview will allow users to review and make adjustments if required, ensuring accuracy and customization.

iv. Generation and Export: Once satisfied with the floor plan layout, users will be able to generate the final plans with a single click. The add-in will automatically generate the necessary views, places rooms and elements, and organise the sheets accordingly in Revit. Users will also have the option to make changes to the generated floorplans as necessary.

5.6 Summary

This chapter first outlined the traditional design briefing process based on the RIBA PoW 2020 that highlighted the lack of BIM-related activities that we carried out in the early pre-design stages. Next, a potential BIM-based design briefing process was outlined, which showed how briefing could be carried out through the early stages of the RIBA PoW 202 if BIM activities were implemented. It also highlighted the potential outputs in the form of conceptual plans or models in the pre-design stages, which does not currently happen through a traditional project process.

Next, the process of the prototype development was described beginning with the identification of industry demands, which in this case was the identification of functionalities for a BIM-based design briefing system. Then based on these functionalities and other learnings from the interview analysis and literature review, a conceptual system framework was developed, which acts as a blueprint for the prototype development. Multiple iterations of the conceptual system framework were developed before finalising. This framework was published as a journal article and also presented in seminars, providing it with validity.

Following this, a prototype was developed using Revit and Dynamo, a VPL that allows access to Revit's API in order to automate tasks and create custom scripts for the development of designs. This prototype consists of automation functions that were identified through the analysis of interviews. Firstly, it is able to generate spatial layouts based on the design brief that is stored within an MS Excel file. Based on the requirements of a client, the number of spaces can be changed within the Excel file to generate a newer layout. The layout of these spaces can also be manipulated by the user in order to generate multiple layouts based on the brief and the schema. The spaces can also be assigned various colours to identify different types of spaces.

The process of the development was outlined and explained in detail, including how the script calculates permutations and produces outputs based on the results. However, the script produces numerous results, which would be impossible for a user to analyse manually. Hence, these results need to be analysed through Revit's Project Refinery. Through Refinery, designs can be studied, and suitable outputs can be shortlisted more efficiently. In order to identify some designs that are more suitable than others, a points system was added based on the adjacency requirements listed in the Excel file.

The next chapter will discuss the findings from the development and testing of the prototype, the contribution to knowledge that this study and the development has provided, the potential uses of a BIM-based design briefing system and some of the limitations faced during the development.

Chapter 6: Analysis and Discussion

6.1 Introduction

This chapter provides discussions regarding testing of the prototype followed by discussions of the findings of the conceptual system framework and the prototype development carried out for this study. As the findings of the interview analysis have already been discussed in *Chapter 4: User Requirements Interview and Analysis*, only a short reiteration of those findings has been listed. Finally, some of the limitations faced by the researcher have been discussed followed by a summary of the chapter.

Before beginning the chapter, the research questions, aims and objectives have been reiterated below for the reader.

For this study set of research questions were first developed in order to gain a better understanding of the areas of research i.e., design briefing and BIM as well as various sub-topics with the two areas. Those have been listed below.

1. What is the current sentiment towards the traditional process of design briefing?

2. Can the design briefing process be improved with the implementation of BIM, and if so, how?

3. What kind of advantages could a BIM-based design briefing method present?

4. What kind of functions and outputs would a BIM-based design briefing tool require?

Based on these research questions, the aim of this study was defined as the development of a framework and prototype to improve the quality and performance of building projects using innovative BIM based design-briefing methods. In order to achieve the aim, the following research objectives were then developed.

i. Understanding research background relevant theory and techniques and current research.
ii. Exploring users and designers demand of BIM-based design briefing tools/solutions via interviews.
iii. Based on the demands of BIM-based design solutions, develop a system framework to demonstrate general functionalities and data structure of the design briefing system
iv. Based on the system framework, develop a prototype.
v. Testing and analysis of the prototype and discussions of the overall development and industry impacts.

6.2 Testing and feedback of the system framework and prototype

Based on the cyclical prototype development method used in this study, one of the essential steps is to test, evaluate and evolve both the conceptual system framework as well as the prototype developed for this study. These tests were carried out through demonstrations, discussions, and dissemination with industry practitioners as well as academics. Although the prototype in its current version only demonstrates a small part of the system, it still covers some of the fundamental functions necessary for the implementation of BIM in the briefing stages. Further development is necessary in order to expand the functions of the software and to create more complex schemas in the database. This test carried out in this study mainly focused on the functionality of the system and the use of data sets. As mentioned previously, the core functionality that this prototype seeks to achieve is the automation of design through the use of a design brief structured in MS Excel files.

It was discussed in Chapter 5 that the conceptual system framework was presented to academics and peers from relevant fields at university seminars, where feedback was received and implemented in the final version of the framework. This framework was also published in a peer-reviewed journal as part of a paper.

The testing of the prototype was carried out in two stages. It was first tested by the researcher in order to check if the prototype has achieved some of the function defined in the conceptual system framework. Primary checks were carried out in order to check if the output generated by the software achieved the desired design results. As a minimum, the researcher sought to generate designs based on areas provided in the design brief, while adhering to some basic architectural design principles such as setting a maximum depth of a room in order to receive adequate natural light. In order to accommodate different requirements of various clients, the database files were also tested with a number of different spaces and checked if the generated design were accurate or not.

After this first stage of testing was satisfactorily completed, the next stage of testing involved demonstration and discussion with industry professionals as well as academics and receiving feedback from them. It was explained to them before the demonstration that the prototype was still an early iteration of a BIM-based design briefing tool. It only consisted of some simple functions that allowed the generation of feasible spatial layout designs, and the user was free to make changes as per their requirement. They were also informed that the purpose of this tool was to simply assist the users with their designs, and it was not aimed to become a tool that would replace the design professionals.

The feedback received from the discussion first focused on the functionality of the prototype software and the use of Excel-based databases. The overall sentiment towards the implementation of BIM with the use of this prototype was positive. One of the professionals commented that *"...this system reflects major functions that support design briefing which will be particularly useful in projects that use design briefs in spreadsheet format."*

Another topic of discussion included communication between the client and the architectural team. They agreed that further evolution of this prototype could help enable better communication between the client and the architectural team. By generating multiple design options, architects can present concept designs more clearly to the client, which would definitely reduce the chances of miscommunication or confusion. This could also help in checking if the requirements in the design brief have been met or not.

The topic of costing was also briefly discussed, where comments were made regarding the use of the prototype with other analysis tools to carry out early costing of the project. Costing is already carried out in every project, but by implementing BIM in the design briefing process, costing can be carried out relatively early in the project. This will also allow for a more accurate calculation of the cost of the project as the architect and the client will have visualised and discussed the potential design solutions during the design briefing stages.

The final topic of discussion was incorporating POE information from past projects into the design brief. The attendees noted that there was potential for a BIM-based design briefing tool such as the developed prototype to integrate POE data directly into the database. However, this would require further programming of the prototype as well as adding more schemas to the database. One of the potential uses discussed was a feedback loop where data regarding thermal comfort, air quality, lighting, acoustics etc can be captured from users. This data can then be incorporated into the design brief database to identify areas for improvement and inform future designs.

As mentioned earlier, the professionals and academics were reminded this prototype was an early iteration of a BIM-based design briefing tool and further work was required to evolve this tool into a fully parametric designing tool. The attendees agreed that the tool still required further improvements and the addition of some more functions, but this was still an innovative tool in the area of design briefing. They were also able to visualise how this tool could help implement BIM in the design briefing stages and potentially improve the project process. The academics, in particular, commented on the difficulty of developing a fully functioning tool that could perform multiple innovative functions, while competing with organisations that consist of multiple designers and professional software developers.

6.3 The potential impact of BIM-based design briefing

After the development of the conceptual system framework and a foundational prototype, some of the impacts of a BIM-based design briefing can be discussed. Ever since the innovation of BIM, the AEC industry has struggled to adopt it despite the numerous benefits that it can provide not only in the design stages but also during the construction and in-use phase of a building. Over the past few years, BIM adoption has grown exponentially, particularly in the UK with the government requiring all public projects to adopt BIM level 2. Whether this has been achieved or not is outside the scope of this study, however, it has been identified that BIM is still not fully implemented in the pre-design stages. The reason for this is not clear, but it can be concluded from some of the remarks made during the interview that this could be due to the lack of a model or a design at this pre-design stage. This study sought to change this narrative and develop a BIM-based design briefing tool, through the identification of issues in the briefing process that needed to be resolved. Along with this, some functionality requirements were also captured, that could be utilised in a BIM-based design briefing tool. This eventually would bring about the adoption of BIM in the pre-design stages. This section of the chapter provides a detailed discussion of the potential impacts this research can have on the implementation of BIM in the design briefing process, on the building project process, and on the quality of building projects.

6.3.1 Impact on building project process.

The first impact that a BIM-based design briefing may potentially have is on the process of project development. The potential process of briefing with the implementation of a BIM-based design briefing process was discussed in *Chapter 5* and compared with the traditional process of briefing. This section will discuss the wider impact that BIM-based briefing may have on the development of projects based on the RIBA PoW 2020.

As mentioned earlier, this process may not have much of an impact during stage 0 of the PoW where feasibility studies will be carried out and the design team as well as the client may not have enough information to fully implement BIM at this stage. However, BIM-based design briefing can assist in the earlier implementation of BIM in stage 1. Moreover, the inclusion of other stakeholders in the briefing process can further improve the quality of the brief, helping the client and the design team to make informed decisions from the beginning of the project. In addition to these, the outcome at the end of this stage can now also include some conceptual designs based on the spatial designs generated by the developed tool, which is generally only required at the end of stage 2.

As the project moves forward and into stage 2, which requires the development of a conceptual design approved by the client, the design team, through the use of BIM-based briefing, may find themselves ahead of the PoW requirements as the conceptual design will have already begun in the earlier stage. And now that the design brief is finalised, albeit still 'live', the design team can add more details to the concept design or generate more designs if required.

The BIM-based briefing can also have some impact on the stage 3: Spatial coordination, which is related to testing and validating the conceptual designs developed in the previous stage. The current version of the prototype tool can to an extent coordinate spaces based on permutations, which then needs to be analysed in Project Refinery to select some of the desirable designs. However, with further development (discussed later in the chapter), the tool can also be linked with regulation checking software such as Xinaps that can check the generated design in stage 1 and notify the user if the design is valid and adheres to regulations or not.

6.3.2 Impact on quality of projects

The second impact of a BIM-based design briefing process is on the quality of building projects. One of the methods of improving the design briefing process, identified through interviews, was the early involvement of non-design related stakeholders such as contractors, suppliers, facility managers etc. These stakeholders are traditionally not involved in the briefing process and usually do not directly contribute to the development of the final project brief. However, they possess immense knowledge and experience in their respective fields, which can be captured by the design team to develop a more comprehensive brief.

BIM is an integrated process where multiple stakeholders communicate and produce information that are relevant to various phases of a project such as design, construction, supply, management etc. This integrated approach of BIM can be implemented in the BIM-based design briefing process where various stakeholders contribute information to the design brief that can be used to develop more detailed conceptual designs. For example, in the requirements spreadsheet that consists of space and adjacency details, a facility manager can provide early input on security and service point locations, based on their knowledge that can help select and develop better outputs. This in turn can also assist the client or the client team to visualise and understand how facility management works and take an educated decision regarding the project. Contractors and suppliers can also provide early input on the use of specific materials and process of construction rather than using generic terminology. This allows the client to make better financial decisions early and reduce over-spending.

On projects utilising BIM, the client team is also required to develop an Asset Information Requirements (AIR), which is a document that outlines and details all the information required by the client for the management and operation of the building throughout its lifespan (Designing Buildings, 2022b). In response to the AIR, an Asset Information Model (AIM) is developed collaboratively by the design team, contractors, and suppliers. AIM refers to the comprehensive collection of information obtained from various sources, which facilitates the continuous management of an asset (NBS, 2017b). The AIM needs to be extremely thorough which can be a huge undertaking on larger projects. Hence, earlier involvement of other stakeholders could lead to a more detailed AIM procured from the briefing stage, where information can be attached to the BIM-based briefing model for user in later stages.

Although the AIM and the design brief are two separate entities, the information contained with a geometric model is derived from the design brief and this model later becomes part of the AIM, in addition to other written documents.

The largest cost involved in any project is the cost to run the property over its lifespan. There are simulations that can analyse a building's potential energy usage and other running costs; however, these simulations can only be carried out once the model of the building has been developed. Depending on the simulation's output the design team may need to make changes if it does not mee their expectations or if requested by the client. But even after running multiple simulations the performance of buildings and maintenance costs may not always be completely accurate in real use cases. Contrary to this, if a facility manager is added to make contributions and suggestions to the design brief, then this process can be reversed, and improvements can be made early in the pre-design stages itself.

The design briefing process is also largely communication driven, where the client and the design team on larger projects spend weeks or months discussing and negotiating the requirements contained within the brief It is imperative that all parties involved have a clear idea about the direction of the project and understand each other's objectives and solutions. Through the use of BIM-based design briefing, which allows early conceptual design visualisation as well as involvement of other stakeholders in the briefing process, the client and their team can gain a clear understanding of the design solutions proposed by the design team. This in turn helps the design team develop accurate design solutions and reduce conflicts later down the stage.

There may be some issues of involving multiple stakeholders in the briefing process, one of which is the potential for conflict between various teams. For example, the architect and the design team may not agree with suggestions made by the suppliers regarding materials used for construction that would affect the façade of the building. A hint of this potential conflict was identified in the interviews where some of the architects did not want the stakeholders too involved in the briefing process that they begin to influence the actual design of the project.

6.3.3 Impact on BIM implementation in the design briefing process

a. Earlier implementation of BIM

One of the first impacts of BIM-based design briefing would be on the implementation of BIM itself on architectural projects. As identified during the literature reviews and explained in *Chapter 5*, the actual use of BIM only begins in stage 2 of the RIBA PoW 2020. The only BIM-related activities that are carried out in stage 0 and 1 is advising the client about using BIM in their projects and its advantages and disadvantages; preparation of BIM protocol; defining BIM inputs and outputs; designing responsibility matrix etc. Hence, one of the impacts that this study has is on the earlier implementation of BIM.

Design briefing is generally carried out in three stages which are strategic, initial and final project brief, respectively. At each stage the design brief become more detailed as the client and the design team gain a better understanding of the client's needs and requirements. With the use of BIM-based design briefing, which currently uses a Dynamo based tool to generate a conceptual design, the implementation of BIM can be brought forward. This can be as early as stage 1 of the RIBA PoW where the client has a site, a more detailed list of spaces that they require and any required adjacencies. Based on these requirements, the tool can be used to generate spatial designs that can be used by the design team to analyse on design analysis tools such as Project Refinery to refine and extract some of the suitable designs that they can use to further develop or use as a study for their own designs. Furthermore, these spaces generated through the BIM-based briefing tool can also be exported into Revit where the design can be further developed by adding various materials, elements, and components.

Depending on the user's preference this tool can also be used in stage 2 of the RIBA PoW where the design brief is more or less developed but is still live and prone to changes. The required outcome during this stage is an architectural concept and the use of the tool can assist in the early stages of this development. Although this does not bring forward the stage at which BIM is implemented, it does allow the design team to generate numerous conceptual designs quicker and earlier than manual designing.

Implementing BIM in stage 0 can be difficult as the requirement of the client is not very clear at this stage and the site for development may not have been finalised. The client may have an initial idea about the type of building and some of the spaces that they may require, along with some of their objectives and activities that will be carried out on the premises. However, this may not always be enough for the implementation of BIM with the use of BIM-based design briefing.

b. Earlier implementation of automatic design development

Before discussing the impact of this BIM-based design briefing tool on automatic generation of spaces, it must be clarified that generative design or design automation in the field of architecture and engineering is not an entirely new concept and has been around for a few years. One of the most notable tools is Revit's generative design feature, which was released in 2020, during the development of this study. However, the aim of this study is not just to build a tool that can automatically generate spaces but to systematically investigate the demand for BIM implementation in the design briefing stages and then develop a BIM--based design briefing tool based on the findings. The focus of this study is on improving the design briefing process through the use of BIM and the process chosen is through the development of a tool that can develop conceptual designs based on the quantifiable requirements from the design brief. This focus on design briefing and the development of a tool focused on developing conceptual designs is what differentiates this study from commercial tools.

Furthermore, there are also tools such as Dall•E by Open AI and Midjourney that uses artificial intelligence (AI) to generate designs from texts, known as text-to-image. The idea behind this is to enter descriptor texts into the tool and it searches for images in its database and combines various images and textures to generate a set of images based on the texts. The output generated here, however, is a 2D image file that cannot be linked to BIM-authoring tools or converted into 3D models automatically. Hence, these types of AI-generated designs are not directly comparable to the output generated by this study. The automatic generation of conceptual design through the use of this tool provides the user with the ability to begin generative design studies earlier in the project.

c. Impact on BIM standards

Another notable impact of BIM-based design briefing can be on the BIM standards, namely ISO 19650, the international standard that provides guidance for managing the lifespan of a building with the use of BIM. Although the standard does not greatly concern the design brief on its own, with only a few mentions within the document itself, it does provide recommendations for managing and delivering information between various parties with the use of BIM and the Common Data Environment (CDE). However, with the implementation of BIM in the design briefing process, the design brief can have an increased impact on some parts of the standard.

Within ISO 19650, there are various information requirements that the client or the client team can request that are related to the delivery and operation of the built asset. In response to these information requirements, the design team along with other stakeholders such as the contractors, engineers, suppliers, etc. develop information models that contain all the information requested. Two of these information models where BIM-based design briefing can impact are the Project Information Model (PIM) and the Asset

Information Model (AIM). The PIMs are information models developed that are related to the design and construction of a building, whereas the AIMs are information models related to the operation of the building.

6.3.4 Impact of early stakeholder involvement

Early involvement and collaboration between the architectural team and non-design-related stakeholders is a key feature in the implementation of BIM in the design briefing process. The fragmented process of working in the AEC is well known and was discussed in *Chapter 2: Literature Review* as well. With the development and adoption of BIM, the aim has shifted towards a more collaborative approach, which has been achieved to an extent. However, this fragmentation still exists in the design briefing stages. The BIM-based briefing prototype developed in this study can assist in enabling collaboration even in the pre-design stages. Through its database, the prototype allows stakeholders to provide input on the conceptual designs, which can improve communication and collaboration between various stakeholders and the design team. Moreover, such a tool can also provide a platform for stakeholders to provide review and feedback on the design from the early stages, which improves the efficiency of a project.

It was also discussed in Chapter 5 that some of the architects who were interviewed for this study preferred that other stakeholders such as contractors do not dictate the design process. They view this as their sole responsibility and want to maintain control over the design process and ensure that the designs meet their professional standards as well as the requirements of the client. However, on the other hand, architects also believe that the stakeholders possess adequate knowledge and experience to make valuable contributions in the design briefing process and should be involved during this stage. This raises an issue where the design team want other stakeholders to be involved and contribute to the design briefing process, but at the same time do not want them to dictate or interfere with the design process.

This contrasting issue can be resolved to an extent with the use of the BIM-based briefing tool. The database, which is cloud-based, can provide other stakeholders with opportunities to provide their input on various aspects of design. This way they are still able to provide recommendations while allowing the architectural team to maintain design control over the project. The architects can take these suggestions into account but have the final say in implementing the changes or not.

6.3.5 Impact on development time of projects.

Another potential impact of the implementation of BIM in the design briefing process is related to the improvement in the time it takes to develop a project. The focus here is primarily on the pre-design and early conceptual design stages, where a designer can quickly generate a conceptual design with the use of software such as the prototype developed for this study. Further changes and improvements can then be made by the designer and then elements and components can be added to develop a design. While it may not seem like a substantial amount of time is being saved when looking at a single conceptual design, the prototype software can develop multiple designs that the designer can select manually or run through an analysis tool such as Project Refinery.

The prototype tool along with the Excel based database can also be used to collaborate with other stakeholders to review, provide feedback and add their own improvements to the design. This can help the architect and the design team refine the designs quickly. Feedback from other stakeholders can also assist the architects in identifying issues with the conceptual designs and eliminate designs with flaws. This all contributes towards saving time and possibly cost in the early stages of design.

6.3.6 Effective use of POE information

The final potential impact of this study is improvement in the use of POE information in the design briefing process. Currently, POE is used as a means of collecting data regarding a building that has been completed and using that data to analyse if the requirements have been met or not. It is also used to provide real-world data to future projects, so that mistakes are not repeated or to learn from past success. Though the use of a BIM-based design briefing process, the POE data gathered from previous projects could be imported and overlaid on top of the conceptual designs. This could help the designers predict how the building will perform and where improvements could be made. Furthermore, these data can also be used to generate design suggestions and optimisation strategies. For example, if POE data reveals that a building has poor indoor air quality, the BIM-based briefing software could suggest design options that could help improve ventilation. Alternatively, if the POE shows that a certain type of building material was damaging indoor air quality then it could suggest alternative building materials.

The use of POE information can potentially resolve issues of other stakeholders dominating the design of a project by controlling the level of their involvement. Their suggestions and recommendations can be added directly to the POE data which the design team can implement if they choose to. This will also encourage the design team to work in collaboration with other stakeholders and also make sure that they don't feel dominated on their design tasks.

6.4 Technical limitations and potential for prototype development

6.4.1 Software and hardware

During the development of the prototype, the researcher faced some issues and limitations that affected the development of the prototype to its fullest. One of the first major issue faced was with the use of Dynamo itself. One of the reasons for choosing to use Dynamo for the development of the prototype was because Dynamo is presented as a programming tool for use by design professionals without any programming background. However, it was realised that although visual programming does not require learning codes, the user still needs to understand how various nodes needs to be strung together in order to develop a working program. Furthermore, throughout the development process various errors and warnings were also encountered that required constant debugging and sometimes changing a long list of nodes. However, this issue has also been a learning curve.

Another major issue faced during the prototype development was related to the demand of the software, i.e., Revit and Dynamo. Although the researcher had access to a relatively powerful laptop as mentioned earlier, that has been able to create and render Revit models without any issues in the past, Dynamo presented a number of issues. The first issue was the constant crashing of Revit and Dynamo when the program was executed. Some solutions on specialist Dynamo forums suggested turning off auto-execution of the program and keeping the nodes to as minimum as possible. However, these solutions were either not applicable as the minimum number of nodes were already being used or did not solve the issue at all.

The second issue was the actual processing of the algorithm which took 2-3 minutes each time a new run was successfully executed. As the algorithm was developed the execution time also increased and reached up to 4-5 minutes to execute a 176-cell data in Excel (44-rows and 4 columns). Due to this the delay in execution time, the number of rows were reduced to 34 or a total of 136 cells, as the researcher felt that 34 spaces was the minimum number of spaces required to test the prototype. However, this was only able to reduce the execution time by a few seconds. The program was also executed in the PCs provided by the university however, these either simply crashed the system or proved to take even longer to process the data and provide an output with its Intel i3 processor and 8GB RAM. The more powerful Apple iMacs were not suitable for this study as Revit and Dynamo is not supported by these devices.

Due to these issues, some of the aspirations of the study could not be implemented such as developing 3D masses or multi floor conceptual plans, although these were executable on its own without other nodes in the researcher's laptop.

6.4.2 Schema development

This study utilises a simple schema that was developed within the Excel database file. The schema was used to create an adjacency rule between various rooms which would allow the prototype to generate a rating for that particular layout. The lower the rating number the better the design is based on the overall adjacency requirements. This was achieved with a relatively simple schema. However, a much more complicated set of schemas would have been necessary for the prototype to be able to carry out more advanced optimisation functions. It would also require a team of researchers and also requires them to possess software development and design experiences to develop such features. As this is an early study into the use of BIM in the design briefing stages, further development is needed in order to develop more complex features.

6.4.3 Building design

One of the imposed limitations of the prototype was the absence of any schemas or scripting related to the appearance of the building. The reason for adding this limitation was that, firstly, this would require extensive programming to the prototype that would require a team of researchers to achieve. It would also require the development of complex schemas in order to generate buildings that looked visually different and appealing. Secondly, this study is more focused on the spatial design that allows the user to generate and study a wide range of possible design options and accelerate the pace of the project.

6.5 Summary

This chapter has discussed the process of testing the prototype as well as the feedback received from professionals and academics. It has also outlined and discussed the potential impacts that the BIM-based design briefing tool and the process associated with it may have on the design and construction of a building project.

The first impact of a BIM-based design briefing is on the process of a building project, particularly within stage 1 of the RIBA PoW 2020. This is due to the proposed implementation of BIM in the pre-design stages. The second impact is on the quality of building projects which can be achieved with the reduction of issues in the design briefing process with the help of the developed tool.

Currently, BIM is not fully implemented in a project until stage 2 of the RIBA PoW 2020, which means that the design briefing stages have so far lacked any actual use of BIM. Hence, the third impact of this study is the development of the BIM-based design briefing tool and the potential implementation of BIM in the design briefing process with the use of the developed tool. This is possible due to the use of Dynamo to generate conceptual designs that can be directly exported to Revit where the design can be further developed, and information can also be added to the geometry.

Along with the earlier implementation of BIM in projects, earlier implementation of design generation and automation is also possible through the BIM-based design briefing tool. Unlike in traditional development which uses generative design and automation in its workflow, a certain level of manual design is not strictly required with this tool. The user can simply extract space requirements from an unfinished brief and generate several outputs based on those requirements to begin a study in Revit's Project Refinery.

The fourth potential impact is due to the early involvement of stakeholders, where their knowledge and experience can aid the design team in developing better design solutions as well as provide more information for the client to make informed decisions.

The fifth impact is on the timeline of projects, particularly in the per-design stages. With the use of a BIM-based design briefing tool, the designer can quickly develop multiple design options for further consultation with the client. This will also help in developing designs that are already compliant with regulations, which can further improve the time it takes to develop designs.

The final potential impact of this study is on effective use of POE information. Through the use of a BIM-based design briefing tool, more accurate predictions can be made regarding a design or the use of materials.

Finally, some of the limitations of the BIM-based design briefing tool that was developed were discussed. The prototype that has been developed for this study is a foundational tool that needs further development in order to accommodate all the functional requirements identified through the interviews with professionals. The limitations of the research itself has been discussed in *Chapter 7: Conclusions.*

Chapter 7: Conclusions

7.1 Introduction

This chapter provides a conclusion to this study into the implementation of BIM in the design briefing process. This chapter sets out by reviewing the aim and objectives. This is followed by a summary of the findings, followed by the contributions to knowledge and implication of research. Finally, a reflection on this research study as well as the limitations of this research are provided along with some recommendations for future research.

7.2 Review of research aims and objectives.

This section reviews the aim and objectives of this research and discusses how each of these have been fulfilled. The aim of this study was **to develop a framework and prototype to improve the quality and performance of building projects using innovative BIM based design-briefing methods**. In order to achieve the aim, the following research objectives were developed.

i. Understanding research background, relevant theory and techniques and current research: At the beginning of this research a thorough literature review was carried out in order to gain knowledge mainly regarding the design briefing process and BIM. Three types of literature review were carried out, namely, Narrative, Systematic and Scoping. The literature review was also used to understand the issues of the past and present along with the any solutions that had been proposed through past research.

ii. Exploring users' and designers' demands of BIM-based design briefing tools/solutions via interviews: Two types of data were captured in order to fulfil this objective. The first was primary data from interviews and secondary data from various sources of literature. Semi-structured interviews were carried out with professionals and academics in order to understand the feasibility of implementation of BIM in the design briefing process; identify some of the current issues with the process of design briefing; identify demands of a BIM-based design briefing tool; and potential impacts of the proposed process. The interviews were also used as an opportunity to capture some functional requirements for the briefing tool that this study sought to develop.

iii. Based on the demands of BIM-based design solutions, develop a system framework to demonstrate general functionalities and data structures of the design briefing system: After the analysing the interview data and extracting some identified functionalities, a conceptual system framework was developed. A 4-step process was used during development of the system framework. Multiple iterations of the framework were developed before finalising the most suitable one.

iv. Based on the system framework, develop a prototype: The prototype was developed using Dynamo, a Revit based tool that allows the user to code custom programs. For the development, a partial prototyping model was used consisting of 4 of the 6 steps as the final 2 steps were outside the scope of this study. A prototype was developed that is capable of generating multiple spatial designs based on a database of spaces.

v. Testing and analysis of the prototype and discussions of the overall development and industry impacts: Upon successful development, the prototype was demonstrated to a group of professionals and academics in order to gain their feedback. Through this process various impacts of the implementation of a BIM-based design briefing process were identified.

7.3 Summary of the research

During the initial stages of this research, it was identified through the review of literature that, (1) the design briefing process had been relatively neglected both in practice as well as in research, although numerous issues have been known for years; and (2) practitioners aspire to implement BIM into their projects, but the actual use of BIM only begins in stage 2 of the RIBA PoW 2020. However, the issue here is not just the negligence of the design briefing process or the delay in implementing BIM into projects, but also the lack of research into the integration of the two crucial components, with only a handful of research encountered on this topic. There were no reasons found for this lack of focus on briefing and BIM integration, but one reason that can be derived from an interviewee's comment is that there are still professionals in the industry who view BIM simply as a 3D model or a modelling tool. And because there is a lack of design/model in the briefing stages, apart from some sketches by the architect, BIM is simply not perceived as a useful solution in the briefing process. Hence, due to this reason, the implementation of BIM in the briefing stages may not have happened yet. Along with this, this research has uncovered some more findings which have been summarised in this section.

a. Identification of issues in the traditional process of design briefing: One of the initial research questions was related to understanding the sentiment of professionals towards the traditional design briefing process. Similarly, the first research objective was to understand the background of the topics of this research. The researcher sought to answer the research question and fulfil the objective via semi-structured interviews. The analysis of the interviews revealed several issues with the process of design briefing, such as unrealistic expectations from the clients, inaccurate design briefs, and misunderstanding between the client and the design team. These findings from the interviews concurred with findings of older research, which were at least a decade old. This confirmed two things; first, that the findings of this research were accurate, and that the researcher was on the right track; and second, that although these issues have been known for so many years, not much has been done in order to minimise their impact or eliminate them completely.

   The significance of these findings of design briefing issues does not solely lie with their identification as these have been identified multiple times before by multiple researchers. The significance lies in the fact that this research has shown that although these issues were identified many years ago, with multiple suggestions for improvement, these issues are still prevalent and affect the workflow of architectural professionals and possibly the clients as well. This has shown that there is still a gap in knowledge in the field of design briefing that needs to be filled.

After conducting some background study on the solutions proposed by other researchers, it was clear that there were only a couple of researchers (Koutamanis, 2017; Meel & Størdal, 2017) who discussed the possible implementation of BIM to improve the design briefing process. Hence, the decision was made to research the possibility of implementing BIM in the briefing process with the development of a tool.

b. Identification of demand for a BIM-based design briefing solution: Along with the identification of design briefing issues, another goal of the semi-structured interviews was to identify if there is a demand for a BIM-based solution to these issues or not. This was in relation to the second research question which sought to understand if the briefing process can be improved with BIM implementation and the corresponding research objective of exploring the demand of a BIM-based solution.

   The analysis of the interviews showed that the demand for a BIM-based solution is present and also being thought of by professionals in the industry. Claims were also made by an interviewee that BIM was already being used by their practice in the briefing stages, although it was limited to the development of the Employer's Information Requirements, which is normal to be developed at the outset of a project. However, this shows the willingness to adopt BIM early in the project process, possibly to improve their workflow or to adopt more parts of BIM in order to stay ahead of guidelines and requirements.

This finding is significant because in the past researchers and organisations have tried to develop solutions that can help structure and manage a design brief, but that is the limit of what they wanted those tools to achieve. And although those solutions were useful and efficient in their own right, they still lacked features where the brief could be linked to the model and generate outputs. In contrast with other proposed solutions, this study has identified that the use of BIM is in demand and that it can be beneficial in the briefing process.

Besides all the positive responses, there was pushback from an interviewee who did not agree that the use of BIM in the briefing stages would be beneficial or useful. The reasoning for this was somewhat vague but the gist of their response was that BIM needs to be used as a design tool that supports the design and not something that tries to become the designs negative response is somewhat significant to this study as it informs the researcher there will still be professionals that will probably be hesitant to adopt BIM in the early stages of a project and may not agree with the generation of conceptual designs before the end of the briefing phase.

c. Capturing functional requirements of a BIM-based design briefing tool: One of the most significant findings of this study was the identification and capturing of functional requirements from professionals for a BIM-based design briefing tool. As this is a novel approach to implementing BIM in the briefing process, the types of functions that could be useful for a BIM-based briefing tool were not available from literature reviews. Hence, a part of the third objective of this study was to capture some of the functional requirements via interviews.

The significance of this finding lies in the novelty of the functionalities identified, which in itself is not novel in any shape or form. But the demand for such functions for a tool that is novel increases the value of this finding. As this is a new approach, there were a few interviewees who had difficulty grasping the idea behind a BIM-based design briefing tool and hence providing accurate functionality requirements. However, this study has still been able to outline the kinds of functionality and outputs that are desirable in such a tool, which includes automation, Dynamo integration with Excel-based databases and early simulations.

One of the key requirements was the automatic generation of conceptual design solutions from the design brief itself. Based on some of the interviewee's responses on how they use spreadsheet to manage requirements and also use Dynamo to develop scripts to help them automate repetitive tasks, the idea of developing a functionality that could automate generation of conceptual designs and spatial layouts was developed.

d. Development of a conceptual system framework and BIM-based design briefing prototype tool: The main aim of this study was the development of a framework and a prototype that would help improve the briefing process. The two sources of information used for the development of the framework were literature reviews and analysis of interviews with industry professionals. The literature reviews provided background information regarding the briefing process, the participants, the flow of information in traditional briefing and other factors that had an effect on the final design brief. Additionally, it also provided the researcher with the knowledge and process of developing a framework. The analysis of the interview mostly contributed to the deciding the flow of information in the prototype and the addition of other stakeholders as a source of information. Based on this framework, a prototype was developed, which can act as a foundation for further development of a more robust tool that can consist of additional functionalities.

The significance of this development is two-fold. First is the development of the prototype itself, which shows a way in which BIM can be implemented and integrated into the pre-design stages. As discussed earlier, there are some commercial design briefing tools available that can be used to structure and manage requirements leading to a more effective briefing process. However, the scope of the prototype developed in this study is different from other briefing tools as this tool seeks to extract quantitative information from a spreadsheet and develop conceptual designs. These designs can then be exported into Revit where changes can be made, and data can be added to the elements of the model.

The second significance of this prototype is the generation of conceptual layouts without any design work carried out by the design team. Currently, generative designs are carried out after the architect, or the design team has carried out some designs manually, and they need to generate further options based on that particular design. This can also be used after developing designs with Dynamo, but the requirements do not stem from a design brief. This can be the answer for those who cannot fathom the idea of how BIM can be implemented in the pre-design stages where a conceptual design has not been developed.

e. Importance of stakeholder integration in the briefing process: One of the essential outcomes of this study has been the identification of lack of inclusion of other stakeholders for design briefing purposes. Both the literature review and findings from the interviews suggested that the briefing process generally does not include other stakeholders such as project managers, contractors, suppliers, facilities managers etc. Even the RIBA PoW 2020 does not require contractors to be appointed before stage 2, and facility managers before stage 7. However, these stakeholders are a crucial part of the BIM-based design briefing process as they can begin contributing data based on their knowledge and experience in their respective fields. Their inclusion can also help in minimising miscommunication and polishing out inaccuracies that are common in the briefing process. The data that they provide can be attached to the conceptual models in the pre-design stages, which essentially collates fragmented information into a single model, reducing the risk of errors.

f. Impact of BIM on the design briefing method and process: The final notable findings of this study are the impacts of the BIM-based design briefing, which includes earlier implementation of BIM, automation of conceptual design, and the impacts on standards, the quality of projects, and the overall project process. These answer the final research question and fulfil part of the final objective of this study. As far as implementing

BIM in the briefing stages within an architectural practice is concerned, some limitations were identified through interviews with professionals. Some of the design briefing solutions that have been suggested in the past range from educating the client to developing a new process of briefing as well as the development of briefing tools/software. However, none of the interviewees mentioned the use of briefing software in their practice and rather opted to use a simple Excel spreadsheet to manage requirements. There could be a variety of reasons for this lack of use of briefing tools. One of the reasons evident from the interviews was that learning to use new software and integrating it into their daily workflow was not always preferred. This could be due to the time and cost involved in training and purchase of new software or because of preference. And this is not just limited to briefing tools, but any new complex software that they are not familiar with can be a challenge to implement in a practice. Considering the fact that BIM implementation in the pre-design stages is a relatively novel concept, it is understandable why this has not been implemented in practice.

Some of the professionals mentioned that they have opted to use software that they are familiar with, such as spreadsheets to extract quantifiable information that can then be structured and managed more efficiently. They have also developed scripts with Dynamo that can help them automate repetitive tasks such as setting up new projects or tagging components or creating multiple sheets in Revit. This shows that although this may not be common in all practices, there are individual professionals who try to develop new methods of working and are attempting to automate tasks in order to transform workflows and working more efficiently. It is also evident that architectural professionals want to improve the briefing process but are hesitant to adopt newer tools but are happy to use software that they know and can use for their benefit. And with the programming power that Dynamo provides, they are beginning to develop their own individual programs to suit their needs. Moreover, some interviewees have also claimed that they already use BIM in the design briefing stages in their practices, although this mostly involved development of the Employer's Information Requirement (EIR) only and did not involve any conceptual designs at this stage.

After analysing the interviews, it was identified (as discussed in *Chapter 4*) that the tool this study aspired to develop had to (A) require minimal learning/training; and (B) be able to utilise a BIM-authorising tool that professionals are familiar with. These 2 points were kept in mind during the development of the conceptual system framework that formed the base for the development of the BIM-based design briefing tool.

7.4 Knowledge contribution and implication of the research

The issues in the design briefing process have been known for at least two decades. There has been research carried out in the past that acknowledges these issues and has proposed solutions to reduce the impact or eliminate these issues. However, these issues in the briefing process such as misunderstanding, confusion, unrealistic client expectations, and inaccuracies still remain unresolved in the briefing process. This study sought to minimise these issues by understanding the industry's demand for a BIM-based design briefing method through the development of a BIM-based design briefing tool.

BIM has already become a crucial part of the AEC industry, where BIM-authoring software such as Revit already has powerful functions that support the development of drawings and 3D models. Along with this these tools can also aid in space planning, which is one of the main targets of design briefing. Hence, this is why the researcher saw potential in the development of a BIM-based design briefing tool to resolve issues in the briefing process.

The study of design briefing with the implementation of BIM in the pre-design stages with the development and use of a prototype tool is a novel topic in the field of AEC. The scope of the study itself was also narrow and sought to develop a software prototype that could be used to implement BIM in the design briefing stages through a systematic process of research.

The answer provided by this study is through the development of a BIM-based design briefing prototype tool with capabilities to generate conceptual design solutions based on a design brief structured within Excel files. Although BIM is a process or a way of working collaboratively, the development of a model with embedded data is the final target. This is then used by almost all stakeholders as a source of information and a method of visualising the potential asset. Due to this reason, emphasis was given to the development of a spatial design or a model in this study as well. Once a conceptual design is available, it can be used as a base for further development by the design team. This can also be used as a mode of communication with the client and their team, as currently only verbal communication and sketches are used for communicating design ideas. The addition of conceptual designs can help improve the client's understanding of the proposed solutions and reduce confusion and miscommunication.

As the research moved on, other smaller gaps in knowledge were realised such as understanding the views of professionals regarding the implementation of BIM in the briefing process and the inclusion of other stakeholders during this process. This study has shed some light on these matters and has found that there are professionals in the industry who believe that BIM can help improve the design briefing process. However, there was some hesitation regarding the involvement of other stakeholders as the architects felt that they should be the ones carrying out the design work without too much influence from other stakeholders. With the use of a tool such as the prototype developed for this study, other stakeholders can make suggestions on the Excel database or the designs that can be made available on the Common Data Environment (CDE). This will allow the architects to remain in control of the design, while possibly reducing the feeling of being dictated by other stakeholders.

7.5 Limitations of research

In hindsight towards the end of this research, it was felt that there were several things that could have been added or done differently in order to achieve better results or provide even more validity to the results. Although the research is now complete and has provided satisfactory results, this section has been added to reflect on the research itself and provide some ideas for anyone who may find this useful.

Firstly, the method used for this study was qualitative with semi-structured interviews as the method. During that time, when the professions of interviewees were being decided, the researcher believed that architects, BIM-managers, and academic professionals would make up a good sample of interviewees. However, it has been realized that interviewing other stakeholders such as project managers, suppliers and contractors would also have been useful in gaining a better insight into their potential contributions to the design briefing process from their own perspective. Moreover, this research could have also benefited from understanding what these stakeholders think about being involved during the pre-design stages of a project and what kind of value they could add to the proposed BIM-based design briefing process.

Secondly, using a quantitative approach may have also helped the research gain even more validity by asking questions related to the implementation of BIM in the design briefing process, the inclusion of stakeholder early in a project and even the kinds of functionalities that professionals would want to see in a BIM-based design briefing tool. Although these questions have been answered through interviews alone, adding a second method may have solidified the evidence.

The final limitation of this research as felt by the researcher was that there could have been a follow-up interview with the previous participants in order to gather more functional requirements for the prototype. As the idea is new, some of the interviewees could not see how a BIM-based briefing tool would function. Hence, as mentioned previously, some of the functional requirements provided were vague in nature. If the researcher had the opportunity to go back and carry out individual interviews, they may be able to better understand the process and provide more detailed functionalities.

7.6 Recommendation for future research.

The field of BIM has been widely researched over the past few years; however, the area of design briefing has remained stagnant. There has been research conducted in the past in this field, but there are aspects of the briefing process that still needs more research. This study has developed a small tool that can help in the implementation of BIM in the briefing process, however, more development needs to be carried out in order to fully develop a program that can not only develop conceptual designs based on numbers but also written texts. This means employing the use of Artificial Intelligence (AI) and Machine Learning.

The topic of AI generated designs was briefly discussed in the previous chapter, where it was concluded that this at its current state was not comparable to this study. However, in the past few years, AI-generated images have become very popular, particularly within the online social media space. Its capabilities of almost instantly generating a set of images based on a few texts used as input from the user is highly commendable and impressive. And although the output is only a 2D image, further research can certainly be carried out into the use of this technology in developing architectural spaces that can be imported into BIM-authoring tools such as Revit and further developed into useable and editable models. Organisations such as Open AI provides access to their application programming interface (API) that can be used by anyone with programming skills to integrate with

BIM in the future. Furthermore, one of the limitations of this research was that only quantifiable requirements from a design brief could be used in this BIM-based design briefing tool. But with the use of text-to-image AI technology, there might be a possibility that the design brief in its entirety could be used as input to instantly generate a set of parametric outputs that the user can use in the project directly with minimal changes.

As mentioned previously, this research has not focused on the appearance but rather on the spatial layout and floor plans of the building. Hence, further research that could be carried out in the future as an extension of this study or a separate study could be the addition of appearance of the building generated by the tool with the help of AI such as Midjourney or Comfy UI. Currently, Midjourney (V5) allows users to upload an image and use that image as a reference to generate similar images with further addition of various elements. This could be taken further with Comfy UI, a stable diffusion graphical user interface which uses nodes (Github, 2023) similar to Dynamo in order to generate images, where every aspect of the image generated can be controlled and changed by the user. Generating images with the help of these AI tools is extremely fast and could potentially help in communicating the design solutions with the client more efficiently and effectively.

7.7 Conclusion

The design and construction industry today are facing immense challenges with regards to improving quality, sustainability, and efficiency, keeping costs low, adopting new technologies and stretching the boundaries of possibilities in order to stay ahead of competitors. In the UK particularly, BIM has received widespread popularity due to the governments backing and requiring all public projects to adopt Level 2 BIM. There are numerous studies being conducted in the field of AEC, particularly on or around the subject of BIM. However, there is a serious lack of research on the use of BIM in the early pre-design stages of projects. One of the reasons for this may be that most professionals in the industry associate BIM with 3D models or the process of modelling that they do not see any use of BIM during stages such as design briefing. This chapter delved into the possible implementation of BIM in the design briefing process where a conceptual system framework was developed based on the outcomes of the interview analysis and learnings from the literature review. Then based on this conceptual system framework a partial prototype was developed.

This study has looked into a neglected area within architectural projects, which is the design briefing process and has developed a tool that can be used to implement BIM in these pre-design stages. Rather than simply developing what the researcher believed would be correct, this study has followed a series of steps in order to develop a tool that keeps the requirements of the professionals in mind.

These requirements were identified through semi-structured interviews with professionals and academics in the field of architecture and the built environment. Additionally, the demand for a BIM-based solution was also identified, where it was also seen that some professionals were already trying to develop simple programs to improve their workflow.

Based on these requirements identified through interviews a conceptual system framework and a prototype were developed. The database for the prototype was based on MS Excel that consisted of a structured design brief. The prototype was developed on Dynamo, which is a Revit add-on that can read the Excel based database and generate multiple spatial design solution. These solutions can then be run on design analysis tools to identify one or more desirable designs.

Various internal tests were carried out during and after the development of the prototype. Professionals from the industry as well as academics were also provided with a demonstration of the prototype in order to gain some feedback from them regarding the functionality use of the prototype. Overall, the feedback was positive with some recommendations on adding further functionalities.

The development of this prototype has begun the process of implementing BIM into the design briefing process, which has the potential to provide multiple positive impacts on the building project process, the quality of projects and the development time of projects. BIM has already made a great impact on the AEC and by implementing BIM in the design briefing process, further improvement is possible in the front end of building projects.

References

- Abdi, E., 2015. Theoretical Literature Review on Lack of Cardiorespiratory Fitness and Its Effects on Children. International Journal of Humanities and Social Sciences, 9(7), pp.2529-2533.
- Abrishami, S., Goulding, J. & Rahimian, F. (2021). Generative BIM workspace for AEC conceptual design automation: Prototype Development. *Engineering, Construction and Architectural Management,* 28 (2), p. 482-509.
- Adams, W. (2015) 'Conducting semi-structured interviews', in Newcomer, K. E., Hatry, H. P. & Wholey, J.S. (4th ed.) *Handbook of practical program evaluation.* London: Jossey-Bass, p. 492-505.
- Al-Ashmori, Y. Y., Othman, I., Rahmawati, Y., Amran, Y. H. M., Sabah, S. H. A., Rafindadi, A. D. & Mikic, M. BIM benefits and its influence on BIM implementation in Malaysia. Ain Shams Engineering Journal, 11 (4), p. 1013 – 1019.
- Allen, J. (2021). *What is a Common Data Environment and Why it matters.* [Online]. Available at: https://constructionblog.autodesk.com/construction-common-data-environment/
- Atkin, B. & Flanagan, R. (1995). I*mproving Value for Money in Construction*. Royal Institution of Chartered Surveyors: London.
- Autodesk University (2019). *Architecture in the age of automation.* [Online]. Available at: https://medium.com/autodesk-university/architecture-in-the-age-of-automation-

2c67e56fe47a#:~:text=It%20helps%20us%20to%20improve,at%20AU%20Las%20Vegas%202019

- Avison, D. & Fitzgerald, G. (2008). *Information systems development: Methodologies, techniques, and tools.* 3rd ed. McGraw Hill: Berkshire.
- Awad, E. M. & Ghaziri, H. M. (2007). *Knowledge Management*. Upper Saddle River: Pearson.
- Azarello, N. (2017). 'Digital Grotesque II': a 3D printed grotto with 1.35 billion algorithmically-generated surfaces. [Online]. Available at: https://www.designboom.com/architecture/digital-grotesque-grotto-2-3d-printed-michael-hansmeyer-benjamin-dillenburger-07-14-2017/
- Baiden, B. K., Price, A. D. F. & Dainty, A. R. J. (2006). The extent of team integration within construction projects. *International journal of project management*, 24(1), p. 13-23.
- Barnes, P. & Davies, N. (2014). *BIM in Principle and in Practice*. 2nd ed. London: ICE Publishing.
- Barrett, P. and Stanley, C.A., 1999. *Better construction briefing*. London: John Wiley & Sons.
- Baumeister, R. F. & Leary, M. R. (1997). Writing Narrative Literature Reviews, *Review of General Psychology*.1(3), p. 311-320.
- Bhargav, D. & Koskela, L. (2009). Collaborative knowledge management - A construction case study. *Automation in Construction*, 18 (7), p. 894 - 902.
- Billings, C. E. (1997). *Aviation Automation: The search for a human-centred approach.* 1st ed. Taylor-Francis: New Jersey.

- BIM Think Space (2015). *Episode 22: The wedge and the S-curve*. [Online]. Available at: http://www.bimthinkspace.com/bim-maturity/
- Blyth, A. and Worthington, J. (2010). *Managing the brief for better design*. 2nd ed. London: Routledge.
- Bogers, T., Meel, J. V. and Voordt, T. J. M. (2008). Architects about briefing: Recommendations to improve communication between clients and architects. *Facilities*. 26(3/4), p.109 - 116.
- Bouchlaghem, D., Rezgui, Y., Hassanen, M., Cooper, G., Barrett, P., Rose, D. & Austin, S. (2000) IT tools and support for improved briefing, *Proceedings of Construction Information Technology 2000*, CIB W78 and IABSE, Reykjavik.
- Branes, P. (2019). *BIM in principle and in practice.* 3rd ed. ICE Publishing: London.
- Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, p. 77–101.
- Brief Builder (No Date). *Home*. [Online]. Available: https://www.briefbuilder.com/ [Accessed: 20/08/2019]
- BriefBuilder (2020). *About us.* [Online]. Available at: https://www.briefbuilder.com/pages/about/
- BSI (1995). *British Standards Document BS 7832: Performance standards in building. Checklist for briefing. Contents of brief for building design.* [Online]. Available at: https://landingpage.bsigroup.com/LandingPage/Undated?UPI=000000000000551395

- BSI (2013). PAS 1192-2: Specification for information management for the capital/delivery phase of construction projects using building information modelling. BSI Standards Limited: London.
- BSI (2013). *PAS 1192-2:2013: Specification for information management for the capital/delivery phase of construction projects using building information modelling*. London: BSI Standards.
- Byju's (2020). *Permutation and combination.* [Online]. Available at: https://byjus.com/maths/permutation-and-combination/ [Accessed: 12/10/2021].
- Byrde, D., Broquetas, M. & Volm, J. M. (2013). The project benefits of Building Information Modelling (BIM). *International Journal of Project Management,* 31(7), p. 971 – 980.
- C. & Hwang, G. J. (2008). A Delphi-based approach to developing study of knowledge management system with the cooperation of multiple experts. *Expert Systems with Applications*, 34(4), p. 2826 – 2840.
- Caetano, I., Santos, L. & Leitão, A. (2020). Computational design in architecture: Defining parametric, generative, and algorithmic design. *Frontiers of Architectural Research*, 9(2), p. 287 – 300.
- Carillo, P. (2005), Lesson learned practices in the engineering, procurement and construction sector. *Engineering, Construction and Architectural Management*, 12(3), p. 236 – 250.
- Chappell, D & Dunn, M. (2016). *The architect in practice.* 11th ed. Wiley Blackwell: Chichester.

- Chevin, D. (2018). *BIM Benefits Quantified For The First Time*. [Online]. Available at: http://www.bimplus.co.uk/news/bim-benefits-report-government-could-save-400m-yea/
- Chua, C. K., Leong, K. F. & Lim, C. S. (2017). *Rapid prototyping: Principles and applications.* 3rd ed. Singapore: World Science.
- Chung, J. K. H., Kumaraswamy, M. M. & Palaneeswaran, E. (2009) *Automation in Construction.* 18 (7), p. 966-974
- Coad, P. & Yourdon, E. (1991). *Object oriented analysis.* 2nd ed. New Jersey: Prentice Hall.
- CodeBook (No Date). *Room Data Collector.* [Online]. Available at: http://codebookinternational.org.uk/products/roomdatacollector/
- Coleman, A. (2017) What Is "African Bioethics" as Used by Sub-Saharan African Authors: An Argumentative Literature Review of Articles on African Bioethics. Open Journal of Philosophy, 7, p. 31-47.
- Creswell, J. W. & Creswell J. D. (2018). *Research design: Qualitative, quantitative & mixed methods approaches.* 5th ed. Los Angeles: Sage publications.
- Creswell, J. W. (1998). *Qualitative enquiry & research design: Choosing among five traditions.* Sage Publications: USA.
- Davis, D. (2020). *Generative design is doomed to fail.* [Online]. Available at: https://www.danieldavis.com/generative-design-doomed-to-fail/
- Delaqua, V. (2021). *A brief history of automation in architecture.* [Online]. Available at: https://www.archdaily.com/964683/a-brief-history-of-automation-in-architecture

- Demaid, A. & Quintas, P. (2006). Knowledge across cultures in the construction industry: sustainability, innovation and design. *Technovation,* 26(5), p. 603 – 610.
- Demiris, G., Oliver, D. P. & Washington, K. T. (2019). *Chapter 3 – Defining and Analyzing the Problem*; in Behavioral Intervention Research in Hospice and Palliative Care, Academic Press: London, p. 27 – 39.
- Designing Buildings (2021). *Concept design*. [Online]. Available at: https://www.designingbuildings.co.uk/wiki/Concept_design
- Designing Buildings (2022). *Procurement route*. [Online]. Available at: https://www.designingbuildings.co.uk/wiki/Procurement_route
- Designing Buildings (2022b). *Asset Information Requirements AIR*. [Online]. Available at: https://www.designingbuildings.co.uk/wiki/Asset_information_requirements_AIR
- Designing Buildings (2023). Employer's Information Requirements (EIR). [Online]. Available at: https://www.designingbuildings.co.uk/wiki/Employer%27s_information_requirements_EIR
- Designing Buildings (2023b)*. Traditional Procurement Method.* [Online]. Available at: https://www.designingbuildings.co.uk/wiki/Traditional_procurement_method
- Deutsch, R. (2011) *BIM and Integrated Design.* John Wiley & Sons: New Jersey.

- DfE (2014). *Area guidelines for mainstream schools.* [Online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/905692/BB103_Area_Guidelines_for_Mainstream_Schools.pdf
- DFE (2022). *Schedule of Accommodation tools for schools and colleges*. [Online]. Available at: https://www.gov.uk/government/publications/mainstream-schools-schedule-of-accommodation-tools
- DiCicco-Bloom, B. & Crabtree, B. F. (2006). The qualitative research interview. *Medical Education,* 40, p. 314 – 321.
- DoE (2015). *Schedule of Accommodation tool for schools and colleges.* [Online]. Available at: https://www.gov.uk/government/publications/mainstream-schools-schedule-of-accommodation-tools
- DoH (2014). *Health Building Note 00-01 General design guidance for healthcare buildings*. [Online]. Available at: https://www.england.nhs.uk/wp-content/uploads/2021/05/HBN_00-01-2.pdf
- dRofus (2021). *Get more out of your planning.* [Online] Available at: https://www.drofus.com/product
- Dusty Robotics (2021). *Build better with BIM-driven layout*. [Online]. Available at: https://www.dustyrobotics.com/ [Accessed: 30/08/2021].
- Dynamo (2018) *What is Dynamo?* [Online]. Available at: https://primer.dynamobim.org/01_Introduction/1-2_what_is_dynamo.html

- Dynamo (2019). *Dictionaries.* [Online]. Available at: https://primer.dynamobim.org/09_Dictionaries/9-1_What-is-a-dictionary.html
- Egan, J. (1998). *Rethinking construction: the report of the construction task force*, DTI (URN 98/1095), Construction Task Force, UK.
- Endsley, M. R. & Kaber, D. B. (1999). Level of automation effects on performance, situation awareness and workload in a dynamic control task. *Ergonomics*, 42 (3), p. 462-492.
- Enscape (2022). *BIM vs CAD.* [Online]. Available at: https://enscape3d.com/bim-management/bim-vs-cad/
- ESRC (2015). *ESRC Framework for research ethics: Updated January 2015*. [Online]. Available: https://esrc.ukri.org/files/funding/guidance-for-applicants/esrc-framework-for-research-ethics-2015/
- Evbuomwan, N. F. O. & Anumba, C. J. (1998). An integrated framework for concurrent life-cycle design and construction. *Advances in engineering software*, 29(7-9), p. 587-597.
- Eynon, J. (2013). *A design manager's take on the new Plan of Works*. [Online]. Available at: http://www.constructionmanagermagazine.com/management/riba-planwork-moving-stages/
- Faatz, S. (2009). Architectural programming: providing essential knowledge of project participants needs in the pre-design phase. *Organisation, technology and Management in construction,* 1(2), p. 80 - 85.

- Fakhry, M., Kamel, I. & Abdelaal, A. (2021). CAD using preference compared to hand drafting in architectural working drawings coursework. *Ain Shams Engineering Journal,* 12(3), p. 3331 – 3338.
- Falqi, I. I. A. (2011). Knowledge capture and retrieval in construction projects. PhD Thesis, Herriot-Watt University, Edinburgh.
- Fink, A. (2014). *Conducting research literature reviews: From the internet to Paper.* 4th ed. Sage: California.
- Fletcher, P. & Satchwell, H. (2015). *Briefing: A practical guide to RIBA plan of work 2013 stages 7, 0 & 1*. 1st ed. London: RIBA Publishing.
- Flick, U. (2015). *Introducing research methodology.* 2nd ed. London: Sage publications.
- Frazer, J. (2002). Creative design and the generative evolutionary paradigm. In: Bentley P.J. & Corne D.W. (eds*). Creative evolutionary systems*. San Francisco: Elsevier, p. 253–274.
- Frey, C. B. & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation. *Technological Forecasting & Social Change,* 114, p. 254-280.
- Frohm, J., Lindstrom, V., Stahre, J. & Winroth, M. (2008). Levels of Automation in Manufacturing. *International Journal of Ergonomics and Human Factors,* 30(3), p. 1-28.
- Fruchter, R. (2002). *Metaphors for knowledge capture, sharing and reuse*. In: eWork and eBusiness in Architecture, Engineering and Construction. Turk, Z & Scherer, R. Taylor & Francis: Netherlands, p. 17 – 26.

- Fulford, R. & Standing, C. (2014) Construction industry productivity and the potential for collaborative practice. *International journal of project management*, 32(2), p. 315-326.
- Gedded, D. (2020). *The history of computer-aided design and computer-aided manufacturing (CAD/CAM).* [Online] Available at: https://www.technicalfoamservices.co.uk/blog/blog-history-of-cad-cam/#:~:text=The%20first%20true%20CAD%20software,(Massachusetts%20Institute%20of%20Technology).
- Github (2023). *Comfyanonymous / ComfyUI.* [Online]. Available at: https://github.com/comfyanonymous/ComfyUI.
- Glenigan (2018). *UK Industry Performance Report*. [Online]. Available at:
- Gough, D., Oliver, S. & Thomas, J. (2017). *An introduction to systematic reviews.* 2nd ed. London: SAGE.
- Green, S. D. (1996) A metaphorical analysis of client organisations and the briefing process, *Construction Management and Economics*, 14(2), p. 155 - 164.
- Haley, M. (2022). *Sustainability starts in the design process, and AI can help*. [Online]. Available at: https://www.technologyreview.com/2022/01/19/1043819/sustainability-starts-in-the-design-process-and-ai-can-help/
- Hansen, K. L. and Vanegas, J. A. (2003). Improving design quality through briefing automation. *Building Research and Information*, 31(5), p. 379 - 386.
- Hardgrave, B. C. (1995). When to prototype: Decision variables used in industry*. Information and software technology,* 37(2), p.113-118.

- Hari, S, Egbu, C and Kumar, B (2005); A knowledge capture awareness tool: An empirical study on small and medium enterprises in the construction industry. Engineering, Construction and Architectural Management, 12(6), p. 533-567.
- Hetreed, J., Ross, A. & Baden-Powell, C. (2017). *Architect's Pocket Book.* 5th ed. Routledge: Oxon.
- Hisham, S. (2018). *Can computers design buildings? What automation means to architects.* [Online]. Available at: https://www.geospatialworld.net/article/can-computers-design-buildings-what-automation-means-to-architects/
- Holliday (2016). *Doing and writing qualitative research.* 3rd ed. London: Sage publications.

  https://www.greenwoodconsultants.com/app/download/5792421442/CE_IndustryPerformanceReport2017_20171121.pdf
- Hudson, J., Gameson, R. N. & Murray, J. P. (1991). The use of computer systems to improve communication between clients and construction professionals during the briefing process, in Barrett, P. & Males, R., *Practice Management: New Perspectives for the Construction Professional*, E & FN Spon, London, p. 175-181.
- Hyams, D. (2001). *Construction companion to briefing*. 1st ed. RIBA Publications: London.
- IBM (2018). *What is a database schema?* [Online]. Available at: https://www.ibm.com/topics/database-schema.
- Jabi, W. (2013). *Parametric design for architecture.* 1st ed. Laurence King Publishing: London.

- Jallow, A. K., Demian, P., Baldwin, N. & Anumba, C. (2014). An empirical study of the complexity of requirements management in construction projects. *Engineering, Construction and Architectural Management*, 21 (5), p. 505-513.
- Jenkins, P., Scott, I., & Challen, A. (2012). Client Briefing: Eliciting Design Preferences from Building Users with Communication Impairments. *Buildings*, *2*(2), p. 83-106.
- Joyner, R. L., Rouse, W. A. and Glatthorn, A. A. (2013). *Writing the winning thesis or dissertation: A step-by-step guide.* 3rd Ed. California: Corwin.
- Kamara, J. M. & Anumba, C. J. (2001). ClientPro: A prototype software for client requirements processing in construction, *Advances in Engineering Software,* 32 (2), p. 141–158.
- Kamara, J. M., Anumba, C. J. & Evbuomwan, N. F.O. (2002). *Capturing client requirements in construction projects.* 1st ed. London: Thomas Telford Publishing.
- Kelly, G. (1997). Integrating construction software, Construction Computing 57, p. 24–25.
- Kilkelly, M. (2018). *What is Dynamo and 5 reasons you should be using it.* [Online]. Available at: https://archsmarter.com/what-is-dynamo-revit/
- King, N. (2004). *Using templates in the thematic analysis of text*. In Cassell, C. & Symon, G. (Eds.). Essential guide to qualitative methods in organizational research (p. 257–270). London: Sage.

- Kivrak, S., Arslan, G., Dikmen, I., and Birgonul, M. T., (2008). Capturing Knowledge in Construction Projects: Knowledge Platform for Contractors, *Management in Engineering*, 24 (2), p. 87 - 95.
- Koutamanis (2017b). Briefing through BIM in the lifecycle of a building. In *24th Annual European Real Estate Society Conference*. ERES: Conference. Delft, Netherlands
- Koutamanis, A. (2017). Briefing and building information modelling: Potential for integration. *International journal of Architectural Computing,* 15(2), p. 119-133.
- Krish, S. (2010). A practical generative design method. *Computer-Aided Design*, 43(1), p. 88-100.
- Kumar, B. (2015). *A practical guide to adopting BIM in construction projects*. 1st ed. Scotland: Whittles.
- Latham, M. (1994*). Constructing the team: Joint Review of Procurement and Contractual Arrangements in the United Kingdom Construction Industry.* 1st ed. London: HMSO.
- Lee, B., Choi, H., Min, B., Ryu, J. & Lee, D. (2021). Development of formwork automation design software for improving construction productivity. *Automation in Construction,* 126, p. N/A.
- Lee, H. W., Oh, H., Kim, Y. & Choi, K. (2015) Quantitative analysis of warnings in BIM. *Automation in Construction*, 51, p. 23–31.
- Li, Y., Yang, M., Klein, G. and Chen, H. (2011). The role of team problem solving competency in information system development projects. *International Journal of Project Management*, 29 (7), p. 911-922.

- Liberati, A., Altman, D. G., Tetzlaff, J., Murlow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J. & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *Annals of Internal Medicine*, 151, p. W-65.
- Liu, Y., Nederveen, S. V. & Hertogh, M. (2017). Understanding effects of BIM on collaborative design and construction: An empirical study in China. *International Journal of Project Management,* 35(4), p. 686 – 69.
- Lorenz, B., Nocera, F. D. & Parasuraman, R. (2001). Human performance during simulated space operations under varied levels of system autonomy. *Proceedings of Bioastronautics Investigators workshop,* January 2001, Texas, USA.
- Love, P. E. D., Edwards, D. J., Han, S. & Goh, Y. M. (2011). Design error reduction: Toward the effective utilization of building information modelling. *Research in Engineering Design*, 22, p. 173–187.
- Ma, W., Wang, X., Wang, J., Xiang, X. & Sun, J. (2021) Generative Design in Building Information Modelling (BIM): Approaches and Requirements. *Sensors* 21(16). MDPI AG: 5439.
- MacPherson, S., Kelly, J. & Male, S. (1992). *The briefing process: A review and a critique*. London: RICS.
- Martin, C. G. (2012). *The Sidney [sic] Opera House construction: A case of project management failure.* [Online]. Available at: http://www.eoi.es/blogs/cristinagarciaochoa/2012/01/14/the-sidney-pera-house-construction-a-case-of-projectmanagement-failure/

- McCombes, S. (2019). *Sampling methods: Types, Techniques & Examples.* [Online]. Available at: https://www.scribbr.com/methodology/sampling-methods/
- Meel, J. V. and Størdal , K, B. (2017). *Briefing for Buildings: A practical guide for clients and their design teams*. 1st ed. Netherlands: ICOP.
- Merchant (2015). Capturing and integrating the design brief in Building Information Models*. Proceedings of the 32nd CIB W78 Conference 2015 held at Eindhoven, The Netherlands.*
- Mordue, S. (2016). *Explaining the levels of BIM*. [Online]. Available at: http://www.bimplus.co.uk/management/explaining-levels-bim/
- Morse, J. & Richards, L. (2002). *Read me first for a user's guide to qualitative methods*. 3rd ed, California: Sage.
- Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A. & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BCM Medical Research Methodology, 18 (143).
- NBS (2017). *What is a BIM Execution Plan (BEP)?* [Online]. Available at: https://www.thenbs.com/knowledge/what-is-a-bim-execution-plan-bep.
- NBS (2017b). *What is the Asset Information Model (AIM)?* [Online]. Available at: https://www.thenbs.com/knowledge/what-is-the-asset-information-model-aim
- NBS (2020). *NBS' 10th National BIM Report.* [Online]. Available at: https://www.thenbs.com/knowledge/national-bim-report-2020

- NBS (2021). *NBS: Digital Construction Report 2021*. [Online]. Available at: https://www.thenbs.com/digital-construction-report-2021/_download/NBS_digital_construction_report.pdf
- Neve, T. O. (2003). Right question to capture knowledge. *Electronic Journal of Knowledge Management*, 1(1), p. 47 – 54.
- Nevo, D. & Chan, Y. (2007). A Delphi study of knowledge management system: Scope and requirements. *Information & Management*, 44(6), p. 583 – 597.
- Nickerson, R. S. (1998). Confirmation bias: A ubiquitous phenomenon in many guises. *Review of general psychology,* 2 (2), p. 175 – 220.
- Nowell, L. S., Norris, J. M., White, D. E. & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods,* 16 (1).
- NYU (2014) *What is research design?* [Online]. Available at: https://www.nyu.edu/classes/bkg/methods/005847ch1.pdf
- O'Reilly, J. J. N. (1987). *Better briefing means better buildings.* 1st ed. BRE: Bracknell.
- Oathman, A. A., Hassan, T. M. & Pasquire, C. L. The brief development management as an IT tool for managing dynamic brief development in construction. *The International Journal of Construction Management*, 6 (2), p. 27 – 43.
- Oh, M., Lee, J., Hong, S. W. & Jeong, Y. (2015) Integration system for BIM-based collaborative design. *Automation in Construction*, 58 (10), p. 196 – 206.

- Olatokun, E. O. & Pathirage, C. (2015). *Importance of knowledge capturing (KC) in the design briefing process in the construction industry.* [Online]. Available at: http://usir.salford.ac.uk/35626/
- Oliver (2010). *The student's guide to research ethics.* 2nd ed. Berkshire: Open University Press.
- Ostime, N. (2020). *RIBA Job Book.* 10th ed. RIBA Publishing: London.
- Othman, A. A. E., Hassan, T.M. & Pasquire, C. L. (2004). Drivers for dynamic brief development in construction. *Engineering construction & architecture management.* 11(4), p. 248 - 258.
- Othman, A. A. E., Hassan, T.M. & Pasquire, C. L. (2006). The brief development manager as an IT tool for managing dynamic brief development in construction. International. *Journal of Construction Management*, 6(2), p.31 - 47.
- Oxman, R. (2017). Thinking difference: Theories and models of parametric design thinking. *Design Studies*, 52, p. 4 – 39.
- Patel, H., Pettitt, M. & Wilson, J. R. (2012). Factors of collaborative working: A framework for a collaboration model. *Applied Ergonomics,* 43(1), p. 1 – 26.
- Pena, W. M. and Parshall, S. A. (2001). *Problem seeking: An architectural programming primer*. 4th ed. New York: John Wiley & Sons.
- Peng, G., Wang, H., Zhang, H, Zhao, Y. & Johnson, A. L. (2017). A collaborative system for capturing and reusing in-context design knowledge with an integrated representation model. *Advanced Engineering Informatics,* 33, p. 314 – 329.

- Peters, M., Godfrey, C., Khalil, H., McInerney, P., Parker, D. & Soares, C. (2015). Guidance for conducting systematic scoping reviews. *International Journal of Evidence-Based Healthcare*, 13 (3), p. 141-146.
- Potter, M. (1995). *Planning to build: A practical introduction to the construction process.* 1st ed. CIRIA: London
- Pressman, R. S. & Maxim, B. R. (2015). *Software engineering: A practitioner's approach.* 8th ed. New York: McGraw Hill.
- PRINCE2 (2019). *What is PRINCE2?* [Online]. Available at: https://www.prince2.com/uk/what-is-prince2
- PwC (2018). *BIM Level 2 benefits measurement methodology.* [Online]. Available at: https://www.cdbb.cam.ac.uk/files/3._pwc_benefits_measurement_methodology.pdf
- Race, S. (2013). *BIM Demystified*. 2nd ed. London: RIBA Publishing.
- Ramage, M. (2022). *What is Computational Design?* [Online]. Available at: https://constructible.trimble.com/construction-industry/what-is-computational-design
- Renev, I., Chechurin, L. & Perlova, E. (2017). Early design stage automation in Architecture-Engineering-Construction (AEC) projects. In Proceedings of the *35th eCAADe conference* (pp. 373–382). Rome: Sapienza University of Rome
- Rezgui, Y., Bouchlaghem, D. & Austin, S. (2003). An IT-based approach to managing the construction brief. *International journal of IT in architecture, engineering, and construction*, 1(1), p. 25 - 37.

- RIBA (2020). *RIBA Plan of Work.* [Online]. Available at: https://riba-prd-assets.azureedge.net/-/media/GatherContent/Business-Benchmarking/Additional-Documents/2020RIBAPlanofWorktemplatepdf.pdf?rev=6f995f6f39d2414daf50889b00a7ecb4
- RIBA (2020b). *RIBA Plan of Work 2020 Overview*. [Online]. Available at: https://riba-prd-assets.azureedge.net/-/media/GatherContent/Business-Benchmarking/Additional-Documents/2020RIBAPlanofWorkoverviewpdf.pdf?rev=4fb72169b1fd4e52a164bdd5f9aa202a
- RIBA (2022). *RIBA Construction Contracts and Law Report 2022.* [Online]. Available at: https://riba-prd-assets.azureedge.net/-/media/Files/Contracts/RIBA-Construction-Contracts-and-Law-Report-2022.pdf?rev=131db86dc10b4ceca07551c939ac6d0f&hash=3E58876E8418A4B0FFC620CF2DD8961A
- Robertson, S. and Robertson, J. (2006). *Mastering the Requirements Process*, 2nd ed. Addison-Wesley: London.
- Robinson, H.S. (2005). Knowledge management practices in large construction organisations. *Engineering, construction and architecture management,* 12(5), p. 431-445.
- Rodrigues, M. R. & Lindhard, S. M. (2021). Benefits and challenges to applying IPD: experiences from a Norwegian mega-project, *Construction Innovation,* DOI:10.1108/CI-03-2021-0042
- Rossiter, D. (2016). *BIM Explainer*. [Online]. Available at: https://bimblog.house/bim-explainer/

- Ryd, N. (2004). The design brief as a carrier of client information during the construction process. *Design studies*, 25(3), p. 231-249.
- Ryd, N. and Fristedt, S. (2007), Transforming strategic briefing into project briefs: A case study about client and contractor collaboration, *Facilities*, 25 (5/6), p. 185 – 202.
- Sacks, R., Eastman, C., Lee., G. & Teicholz, P. (2018). *BIM Handbook: A guide to Building Information Modelling for Owners, Designers, Engineers, Contractors, and Facility Managers.* 3rd Ed. Wiley: New Jersey.
- Salisbury, F. (1998). *Briefing your architect.* 2nd ed. Oxon: Routledge.
- Sarshar, M., Christiansson, P. & Svidt, K. (2003). Distributed virtual workspace for enhancing communication within the construction industry – DIVERCITY, EU project IST1999-13365 Handbook, University of Salford.
- Shah, S. (2019). *7 Biases to avoid in qualitative research.* [Online]. Available at: https://www.editage.com/insights/7-biases-to-avoid-in-qualitative-research
- Sharma, K. L. S. (2017). *Overview of Industrial Process Automation.* 2nd ed. Elsevier: Oxford.
- Shea, K., Aish, R. & Gourtovaia, M. (2005). Towards integrated performance-driven generative design tools. *Automation in Construction*, 14 (2), p. 253-264.
- Shen, Q., Li, H., Chung, J. & Hui, P. (2003). A framework for identification and representation of client requirements in the briefing process. *Construction management and Economics*, 22, p. 213 – 221.

- Shokri-Ghasabeh, M. & Chileshe, N. (2014). Knowledge management: Barriers to capturing lessons learned from Australian construction contractors perspective, *Construction Innovation*, 14(1), p. 108 – 134.
- Smith, J. (2005). Creating a user performance brief: an action research study, *Proceedings of Combining Forces 11th Joint CIB International Symposium*, Helsinki, p. 253 – 266.
- Soliman-Junior, J., Baldauf, J. P., Tzortzopoulos, P., Kagioglou, M., Humphreys, J. S. & Formoso, C. T. Improving healthcare design with BIM-based tools. IOP Conf. Series: Earth and Environmental Science 588 (2020).
- Sun, M. & Meng, X. (2009). Taxonomy for change causes and effects in construction projects*. International journal of Project Management*, 27(6), pp.560 - 572.
- Systems Innovation (No Date). *Conceptual system.* [Online]. Available at: https://systemsinnovation.io/conceptual-system/
- Tamke, M., Nicholas, P. & Zwierzycki, M. (2018). Machine learning for architectural design: Practices and infrastructure. *International Journal of Architectural Computing,* 16(2), p. 123 – 143.
- Thompson, A. (2007). *Architectural design procedures*. 2nd ed. Elsevier: Oxford.
- Torraco, R.J. Writing integrative literature reviews: Guidelines and examples. *Human Resource Development Review*, 4, p. 356 – 367.
- Tranfield, D., Denyer, D. & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management,* 14, p. 207 – 222.

- Traversari, A.A.L., Den Hoed, M., Di Giulio, R., & Bomhof, F.W. (2017). Towards sustainability through energy efficient buildings design: semantic labels, *Entrepreneurship and Sustainability Issues*, 4 (3), p. 243- 256.
- Tunstall, G. (2007). *Managing the building design process.* 2nd ed. Oxford: Butterworth-Heinemann.
- Turner, D. P. (2019). Sampling methods in Research Design. *Headache: The Journal of Head and Face Pain*, 60, p. 8 – 12.
- UoY (2015) *Is this project research or not?* [Online]. Available at: https://www.york.ac.uk/staff/research/external-funding/research/
- Vermeulen, D. (2021). From design automation to generative design in AEC. [Online] Available at: https://www.autodesk.com/autodesk-university/article/Design-Automation-Generative-Design-AEC-2020
- Vliet, H. V. (2008). *Software engineering: Principles and practice.* 3rd ed. John Wiley& Sons: Chichester.
- Von Zedtwitz, M. (2003). Post-project reviews in R&D. *Technology Management*, p. 43 – 49.
- W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research.* 4th ed. Boston: Pearson.
- Winstanley, A and Fraser, N. (2013). *BIM for all – dummies or not!* [Online]. Available at: https://www.thenbs.com/knowledge/bim-for-all-dummies-or-not
- Wintour, P. (2021) *Generative design fail: Why aligning design goals and digital processes is important.* [Online]. Available at: https://parametricmonkey.com/2021/07/27/generative-design-fail/

- Wolstenholme, A. (2009). *Never Waste a Good Crisis*. London: Constructing Excellence.
- Wong, J. K. W., Zhou, J. X. & Chan, A. P. C. (2018). Exploring the linkages between the adoption of BIM and Design error reduction. *International Journal of Sustainable Development and Planning,* 13(1), p. 108-120

Appendix

Interview questions for professionals.

1. What is the traditional method of briefing used/ that you use?
2. What tools or mechanisms have you used for design briefing?
3. What are the key issues that needs to be covered in the design briefing process? Do you have standard templates?
4. Have you come across any poor briefs or issues with the current method of design briefing?
5. Is design briefings a dynamic process or static that ends before design begins?
6. Are there any innovative methods of design briefing that you have come across?
7. Who are the stakeholders involved during design briefings? Who should be involved?
8. What kind of dispute or misunderstanding can occur in the briefing stage?
9. At what stage of the RIBA PoW should BIM be implemented?
10. Do you believe BIM can have an impact on the design briefing process?
11. What do you think about other stakeholder collaboration if BIM is implemented at the design briefing stage?
12. Why do you think BIM has not been implemented in the briefing process so far?
13. What impacts (negative or positive) can BIM implementation have in the briefing process?

14. Do you think BIM implementation in the briefing stage can help reduce conflicts?
15. What barriers/challenges do you see with BIM implementation in the briefing stage?

Interview questions for academics.

1. What is the traditional method of briefing used in the industry?
2. What tools or mechanisms are used for design briefing purposes?
3. What are the key issues that needs to be covered in the design briefing process? Are you aware of any standard templates?
4. What are some of the types of poor briefs or issues with the current method of design briefing?
5. Is design briefings a dynamic process or static that ends before design begins?
6. Are you aware of any innovative methods of design briefing?
7. Who are the stakeholders involved during design briefings? Who should be involved?
8. What kind of dispute or misunderstanding can occur in the briefing stage?
9. At what stage of the RIBA PoW should BIM be implemented?
10. Do you believe BIM can have an impact on the design briefing process?
11. What do you think about other stakeholder collaboration if BIM is implemented at the design briefing stage?
12. Why do you think BIM has not been implemented in the briefing process so far?
13. What impacts (negative or positive) can BIM implementation have in the briefing process?
14. Do you think BIM implementation in the briefing stage can help reduce conflicts?
15. What barriers/challenges do you see with BIM implementation in the briefing stage?

Consent form

Please read the flowing statements and if you agree, please initial the corresponding box to confirm your consent.

I have been informed of and understand the purpose of the study ☐

I understand that the interview will be recorded. ☐

I understand that my participation is voluntary and I am free to withdraw myself from the study at any time without providing any reason. ☐

Any information that might potentially identify me will not be used ☐

I understand that my data will be treated confidentially ☐

I agree to participate in this study as outlined to me. ☐

________________________________ __________ ____________

Name of participant (Block letters) Date

Signature

Supreet Lama

________________________________ __________ ____________

Name of researcher (Block letters) Date

Signature

If you have any queries regarding the research, please e-mail me at: 21188658@student.uwl.ac.uk