DEVELOPMENT OF SUPPLY CHAIN MANAGEMENT FRAMEWORK FOR BUILDING INFORMATION MODELLING IMPLEMENTATION IN PUBLIC SECTOR CONSTRUCTION PROJECTS

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by

NUR HIDAYAH BINTI AHMAD

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DEDICATION

I dedicate this research to my soulmate and husband, Muhammad Helmi bin Che Radzi, my beloved parents, Hasnah binti Shaari and Ahmad bin Ismail, my adoring parents-in-law, Zainub binti Jusoh and Che Radzi bin Abd Hamid, my wonderful sons, Muhammad Amiruddin and Muhammad Safiuddin, and my lovely daughter, Nur Dini Raihanah, who believe in me and who have supported me throughout this journey.

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LIST OF ABBREVIATIONS

4D-ACT	Automated Construction Activity Tracking System
AGC	Associated General Contractors of America
AIA	American Institute of Architects
ARC	Ask, Record and Confirm
BCA	Building and Construction Authority
BEP	Building Execution Plan
BIM	Building Information Modelling
BPR	Business Process Reengineering
CAD	Computer-Aided Drawing
CIDB	Construction Industry Development Board
CITP	Construction Industry Transformation Program
CSP	Construction Strategic Plan
DACF	Dispute Avoidance and Control Framework
DyCE	Dynamic Communication Environment
ECI	Early Contractor Involvement
ERP	Enterprise Resource Planning
FDM	Fuzzy Delphi Method
FGD	Focus Group Discussion
GDP	Gross Domestic Product
ICT	Information and Communications Technology
IFC	Industry Foundation Classes
JIT	Just-In-Time
MVH	My Virtual Home
NBS	National Building Specification

NFB	National Federation of Builders
NIBS	National Institute of Building Sciences
PDM	Project Document Management
PFPF	Project Failure Pathogens Framework
PWD	Public Works Department
RICS	Royal Institution of Chartered Surveyors
RMK11	Eleventh Malaysia Plan
ROI	Return on Investment
SCI	Supply Chain Integration
SCM	Supply Chain Management
TQM	Total Quality Management

LIST OF APPENDICES

PEMBANGUNAN KERANGKA PENGURUSAN RANTAI BEKALAN UNTUK PELAKSANAAN PEMODELAN MAKLUMAT BANGUNAN DALAM PROJEK PEMBINAAN SEKTOR AWAM

ABSTRAK

Pertikaian telah menghalang Pemodelan Maklumat Bangunan daripada mencapai potensi penuhnya. Akibatnya, kajian ini cuba mengurangkan pertikaian pelaksanaan BIM dalam projek pembinaan awam Malaysia. Pakar terlibat dalam dua fasa kajian kaedah campuran. Fasa 1 ialah temu bual awal dengan enam pakar (untuk menentukan keperluan untuk mengurangkan pertikaian di kalangan pelaku rantaian bekalan untuk pelaksanaan BIM). Fasa 2 bermula dengan pendekatan kuantitatif menggunakan Kaedah Fuzzy Delphi (FDM) ke atas 14 pakar untuk menentukan penyumbang utama yang mempengaruhi pertikaian (Objektif Nombor 1). Ini diikuti dengan pendekatan kualitatif, iaitu pengelompokan sendiri untuk mengenal pasti patogen dan subkategori patogen pertikaian (Objektif Nombor 2) dan dua sesi Perbincangan Kumpulan Fokus (FGD) melibatkan enam pakar ke arah akhirnya membangunkan rangka kerja SCM yang disahkan untuk pelaksanaan BIM (Objektif Nombor 3). Hasil daripada pendekatan kuantitatif, tiga penyumbang utama yang mempengaruhi pertikaian telah ditentukan. Pendekatan kualitatif mengenal pasti: (i) dua patogen sebagai isu manusia, (ii) hanya satu patogen dan dua sub-patogen sebagai masalah proses, dan (iii) ketidakpastian produk terhad kepada satu patogen dan satu subkategori patogen. Selain itu, 15 alat SCM yang sesuai untuk pengurangan pertikaian telah dikenal pasti. Dalam hal ini, kajian ini menyumbang pengetahuan BIM secara teori, sistematik dan praktikal kepada literatur semasa dengan menunjukkan pemahaman yang kukuh tentang penggabungan alat SCM ke dalam pelaksanaan BIM untuk pelakon rantaian bekalan dalam projek awam Malaysia.

DEVELOPMENT OF SUPPLY CHAIN MANAGEMENT FRAMEWORK FOR BUILDING INFORMATION MODELLING IMPLEMENTATION IN PUBLIC SECTOR CONSTRUCTION PROJECTS

ABSTRACT

Disputes have kept Building Information Modelling (BIM) from reaching its full potential. Consequently, this study attempts to reduce BIM implementation disputes in Malaysian public construction projects. Experts were involved in two phases of the mixed methods study. Phase 1 was a preliminary interview with six experts (to determine the need for reducing disputes among supply chain actors for BIM implementation). Meanwhile, Phase 2 began with a quantitative approach using the Fuzzy Delphi Method (FDM) on 14 experts to determine the main contributors that influence disputes (Objective Number 1). This was followed by qualitative approaches, namely self-grouping to identify the pathogens and pathogen sub-categories of disputes (Objective Number 2) and two sessions of Focus Group Discussion (FGD) involving six experts towards finally developing a validated SCM framework for BIM implementation (Objective Number 3). As a result of the quantitative approach, three main contributors that influence disputes were determined. The qualitative approach identified: (i) two pathogens as people issues, (ii) only one pathogen and two sub-pathogens as process problems, and (iii) product uncertainty is limited to one pathogen and one pathogen sub-category. Additionally, 15 appropriate SCM tools for dispute reduction were identified. In this vein, the study contributed theoretical, systematic, and practical BIM knowledge to current literature by demonstrating a solid understanding of SCM tool incorporation into BIM implementation for supply chain actors in Malaysian public projects.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Chapter 1 outlines the research focus and presents the important issues that have garnered much attention in this research area. It briefly depicts the research background, clarifies the research problem, states the research purpose, points out the research questions, formulates the research aim and objectives to be addressed, identifies the research scope and highlights the research significance. This chapter further presents the research structure in the thesis outline and ends with an overall summary.

1.2 Research Background

The construction industry has been widely recognised for its major role in economic development across the globe. In fact, the progress of infrastructure construction is closely associated with economic power and maturity of the world communities. The consistent performance exerted by the construction sector has substantially contributed to employment ratios, socio-economic conditions, and Gross Domestic Product (GDP). The GDP growth of the Malaysian economy is contributed by several primary industries, including the construction industry with 4.5 per cent contribution for the fourth quarter of 2019 (Construction Industry Development Board [CIDB] Malaysia, 2020). The government's goal is to grow GDP at an average annual growth rate of 4.7 per cent from 2021 to 2030 (CIDB Malaysia, 2020). Hence, the Construction Strategic Plan (CSP) 4.0 for 2021-2025 was therefore established to cover five (5) primary values, namely: improving well-being; boosting productivity; enhancing sustainability and resilience; an effective safety and health program; and high integrity for the construction industry (CIDB Malaysia, 2020). Accordingly, the introduction of Building Information Modelling (BIM) in Malaysia was intended to realise the goals outlined in the CSP 4.0 (2021-2025), as BIM is regarded as critical to the construction industry's future success. The implementation of BIM appears to be integral to ascertain the successful delivery of projects and to hinder undesired risks (Marzouk et al., 2018). Moreover, BIM is seen to help the construction industry to increase efficiency and reduce disputes (Gibbs et al. 2015; Xiaoling & Xiaohai, 2016). At the beginning of BIM implementation in Malaysia, the idea of BIM was first introduced by the Director of Public Works Department (PWD) in 2007 (CIDB Malaysia, 2017a). The next step in the Construction Industry Transformation Program (CITP) (2016-2020) requires the Malaysian construction industry to implement level 2 BIM maturity by 2020, with the corresponding approaches and processes being implemented at a rate of at least 40 per cent for public projects worth RM 100 million and above (CIDB Malaysia, 2015). In accordance with the Eleventh Malaysia Plan (RMK11) agenda, greater emphasis is placed on promoting BIM implementation to improve construction process efficiency, productivity, and quality (Economic Planning Unit, 2018). Furthermore, it is intensified for the period of BIM implementation from 2021 to 2025 as specified in the CSP 4.0. To date, efforts have established the critical importance of BIM implementation for Malaysian public sector projects as the country moves toward Construction 4.0.

With reference to a study by Sacks et al., (2018), they asserted that the BIM includes a structured sharing scheme and digital information management throughout the life cycle of the construction project. As such, BIM has been regarded as an essential tool within the construction industry (Chou & Yang, 2017). The advantages of BIM tools have garnered much interest among researchers in this field to formulate frameworks based on benefits offered by BIM technology (Barati et al., 2013; Harun et al., 2016; Mahamadu et al., 2017; Papadonikolaki & Wamelink, 2017). Despite the vast interpretations and definitions of BIM, this study views BIM as modelling technology that serves as an associated set of knowledge sharing processes across all phases of the project life cycle with the collaboration of all project participants. Due to its ample advantages, BIM thus serves as a vital requirement for projects within the construction sector. However, the BIM implementation is still in its preliminary stage and the number of adopters is still low (CIDB Malaysia, 2020). Realising the significant value of BIM to construction industry in Malaysia particularly in public sector projects, BIM is therefore highlighted in this study.

The significance of Supply Chain Management (SCM) has been addressed in a number of studies (Love et al., 2004; Butkovic et al., 2016; Riazi & Nawi, 2018). Works pertaining to supply chain began to emerge during the mid-80s (London & Kenley, 2001; Papadonikolaki, 2016). The SCM approach was commonly associated with flows, such as transactional upstream flow, material downstream flow, and information bidirectional flow (Christopher, 1994; Mentzer et al, 2001; Papadonikolaki & Wamelink, 2017). The SCM describes the regulation activities in relation to the flows. Among supply chain actors, the advancement of SCM was viewed as a comprehensive network, stemming from the wide range of aspects that build the network to concurrently manage various flows among them (Christopher, 2005; Papadonikolaki et al., 2017; Wu & Xu, 2014). This view of the network (temporal and permanent), from the lens of SCM, dates back to the early 1990s (Davidow & Malone, 1992; Papadonikolaki, 2016). Christopher (2016) further claimed that the supply chain approach reflects a ‘supply-demand’ network or an organisational intricate and distributed network. Although SCM begins from the manufacturing industry, it is also effective with building construction projects. The advantages of SCM include effective risk management, improvement in adversarial relationships, better harmony in working relationships, and resolution of fragmented disputes (McGeorge et al., 2007; Riazi, 2014; Teng et al., 2018). The SCM, which aims to create transparent collaboration among all project participants, was proven effective in managing the network by creating revolution of improvement across all phases of construction life cycle processes (Christopher, 2016; Mentzer et al., 2001; Riazi & Nawi, 2018; Vrijhoef, 2011). Realising the vital contribution of the construction industry towards social and economic activities, thus SCM is regarded useful to ensure effectiveness of construction projects in Malaysia.

Moreover, the SCM approach offers support in managing flows of BIM (Papadonikolaki & Wamelink, 2017). Hence, this study proposes an effective SCM framework to address the issue of BIM implementation in the public sectors of Malaysia. SCM is an important framework, realising that earlier government plans were found to be ineffective with a lack of contemporary strategies in implementing the concept. SCM is also recognised as a good initiative of the public sector (Riazi & Nawi, 2018). Therefore, it is with great hope that this framework could benefit the public sector to strategise the implementation of BIM in future projects.

1.3 Research Problem

While BIM is seen to reduce one construction challenge without a dispute among the supply chain actors (Latiffi, et al., 2015; Olatunji, 2016; Sacks et al., 2018;

Vacanas et al., 2015; Xiaoling & Xiaohai, 2016), this view goes against the view expressed by Bodea and Purnuş (2018) that a dispute is a problem for the supply chain actors in implementing BIM. The critical issues of BIM readiness highlighted by Antwi-Afari et al. (2018) and Won et al. (2013) reflected the same view as Bodea and Purnuş (2018). Implementation of the BIM has been influenced by possible disputes over revisions to drawings, expenditure, estimates of time and site work in the contractual documents (Bodea & Purnuş, 2018). Failure to resolve the dispute between supply chain actors has resulted in delays to the project (Charehzehi, et al., 2015; Hasmori et al., 2018; Moledina et al., 2017; Rahman, 2018). It is very disappointing when the first hospital project using BIM technology has been delayed by one year from the planned date (Amin, 2019; Pauzi, 2018). Hence, these developments are worrying because they reinforce the existence of disputes between supply chain actors while implementing BIM in Malaysian public sector construction projects.

However, a fully accomplished BIM project requires awareness from the supply chain actors to transform their work practice and give their utmost dedication to commit to the project. BIM, which has been put under study by several authors in the relevant literature, proves that disputes can be reduced owing to the fact that BIM technology itself has become the medium for organisations to work as a team (Gardezi et al., 2013; Olatunji, 2016). This research, on the other hand, argues that BIM construction projects have yet to reach the convincing level of minimising the construction dispute figures. In many cases, there are constraints in the implementation of BIM, as it demands commitment and willingness to replace the conventional approach with a more innovative and systematic practice with regard to the project delivery process (Olatunji, 2016; Sacks et al., 2018). Disputes occur among the supply chain actors due to the limited BIM skills and knowledge that they have. According to

Sacks et al. (2018), belief is that disputes have arisen as a result of disappointments throughout the delivery of BIM, where high expectations of users have not been met. Meanwhile, Bodea and Purnuş (2018) stressed that the main causes of disputes are a challenge within the supply chain actors to implement BIM due to weak communication, and inefficient information exchange, in contrast to Cesarotti et al. (2014) and Olatunji (2016), who argued that the intricate processes that come with cultural differences have been the main catalysts in the BIM project dispute among the supply chain actors. This ongoing dispute within the BIM project has prevented supply chain actors from accessing the benefits of BIM implementation. This issue has led many industry professionals to stay away from BIM until now, as they fear ending up in costly disputes (Alp & Manning, 2014; Holzer, 2016). As a result, the maturity level of BIM will be impacted. According to CIDB Malaysia (2015), the CITP 2016–2020 anticipated BIM implementation to be at level 2 by 2020, with at least 40 per cent of public projects worth more than RM100 million implementing BIM. This goal demonstrates the Malaysian government's commitment to implementing BIM in the construction industry over the next few years. The Malaysia BIM Report 2016 shows that over 91 per cent of respondents who are familiar with BIM agree that the government initiative mandating BIM use in the construction industry is a good idea (CIDB Malaysia, 2017b). Theoretically, BIM implementation can be completed in a short period of time if government directives are followed by supply chain actors with strategic support approaches. However, the target was not met due to CIDB Malaysia (2020) stating that BIM implementation in Malaysia is still in its early stages, with a small user base. Therefore, there is an urgent need to support the implementation of BIM in Malaysia's public works to enlighten them about the necessary actions to be taken to tackle the main contributors that influence disputes among the supply chain actors.

The construction industry, over the years, has attempted to prevent litigation and manage disputes by establishing new techniques to be accomplished during several stages of a construction project (Charehzehi, 2015; Mohd et al., 2017). Reason (2000) has introduced the term ‘pathogens’ for fault-related studies which are also defined as underlying conditions hidden in the device prior to proof of failure. This means that the troublesome routines of projects that have not yet become problems or failures are carried out on an ongoing basis so that the parties are exposed to error risks. Thus, the main step in the stability of the process is to stop the occurrence of such errors in the future by addressing them right from their roots in construction (Abidin & Ingirige, 2018; Busby & Hughes, 2004; Dubas & Pasławski, 2017; Love et al., 2008b; Riazi et al., 2018). As such, the identification of pathogens and the pathogen sub-categories of disputes is necessary to assist supply chain actors in the effective implementation of the BIM.

Poor strategy in executing BIM is also an influence that discourages BIM implementation in a construction project (Guo et al., 2019) due to absence of a standard BIM framework (Tan et al., 2019; Yaakob et al., 2016). Meaning, a comprehensive guide on BIM implementation for the construction sector is yet to be devised (Chong et al., 2017), and neither is there any available instruction for BIM application (Zainon et al., 2016). Furthermore, non-standard frameworks practised by the supply chain actors have created more confusion and misleading in the impression that BIM is irrelevant and wasteful (Hasni et al., 2019). Therefore, a framework is essential, and it should be built in detail, with the presence of supply chain actors.

Taken from reported SCM success stories, SCM has proven successful in managing the flows of content, knowledge and cash across a variety of strategically aligned supply chain actors (Rathnasinghe et al., 2018). It provides mutual benefit, as SCM establishes long-term relationships of trust between the various supply chain actors (Papadonikolaki, 2016). It is in line with the objective of the SCM to create trustworthy and transparent cooperation between the various supply chain actors, return mutual profits and balance the project uncertainties (Jaradat et al., 2017; Papadonikolaki et al., 2015c; Vrijhoef, 2011). Therefore, the combination of SCM in the construction projects undertaken by the public sector in Malaysia is vital to reduce disputes. SCM is seen as an effective strategy to prevent disputes (Costa et al., 2019; Love et al., 2008b; Mashwama et al., 2021; McGeorge et al., 2007).

Hence, the motivation for this research was to gain a better understanding of how to reduce dispute among supply chain actors in order to facilitate the implementation of BIM in Malaysian public sector projects. The gap in the problem statement indicates the need to determine the main contributors that influence disputes among supply chain actors with regard to BIM implementation in the Malaysian public sector projects. Nevertheless, the number of literary works on contributors that influence disputes in BIM-based projects in Malaysia's public sector is very scarce. Therefore, this research indicates the main contributors that influence disputes that prevent supply chain actors from accessing the benefits of BIM implementation, which in turn affect the successful rendering of BIM projects. Such problems, however, will help decide the current course of the BIM movement in Malaysia and develop steps to reduce the challenges of disputes in BIM projects by identifying pathogens and the pathogen sub-categories of disputes. At the same time, it is recognised that using SCM tools helps to create mutual trust and cooperation among supply chain actors, restore mutual benefits and offset project uncertainties. As such, this study is developing a framework that integrates the SCM to assist dispute reduction for BIM implementation in Malaysia's public sector projects. The incorporation of SCM tools into the process will help the supply chain actors to improve their effectiveness in managing the life cycle of a construction project and make full use of benefits presented in BIM.

1.4 Research Questions

The following are related research questions designed to elicit responses to the research objectives:

1. What are the main contributors that influence disputes among supply chain actors for BIM implementation in Malaysia's public sector projects?
2. What are the pathogens and pathogen sub-categories of disputes among supply chain actors for BIM implementation in Malaysia's public sector projects?
3. How does the SCM framework develop by incorporating suitable SCM tools to reduce disputes among supply chain actors for BIM implementation in Malaysia's public sector projects?

1.5 Research Aim and Objectives

This research aims to develop an SCM framework by incorporating suitable SCM tools to reduce disputes among the supply chain actors for BIM implementation in Malaysia's public sector projects. In order to achieve this aim, the study has outlined the following objectives:

1. To determine the main contributors that influence disputes among supply chain actors for BIM implementation in Malaysia's public sector projects.
2. To identify the pathogens and pathogen sub-categories of disputes among supply chain actors for BIM implementation in Malaysia's public sector projects.
3. To develop an SCM framework by incorporating suitable SCM tools to reduce disputes among supply chain actors for BIM implementation in Malaysia's public sector projects and validate its reliability and applicability.

Adapted from Zairul (2017), a priori codes derived from the literature were used to establish the three (3) main deductive codes, which were then used as the primary coding for this research. This study elaborates on each deductive code in Chapters 2, 3, and 4 to address research questions and achieve research objectives, as shown in Table 1.1.

Table 1.1 Research Question, Research Objective and Deductive Code

RESEARCH QUESTION	RESEARCH OBJECTIVE	DEDUCTIVE CODE
RQ1: What are the main contributors that influence disputes among supply chain actors for BIM implementation in Malaysia's public sector projects?	**RO1:** To determine the main contributors that influence disputes among supply chain actors for BIM implementation in Malaysia's public sector projects.	• Contributors that influence disputes in BIM implementation *(Chapter 2)*
RQ2: What are the pathogens and pathogen sub-categories of disputes among supply chain actors for BIM implementation in Malaysia's public sector projects?	**RO2:** To identify the pathogens and pathogen sub-categories of disputes among supply chain actors for BIM implementation in Malaysia's public sector projects.	• Pathogens and pathogen sub-categories of disputes *(Chapter 3)*
RQ3: How does the SCM framework develop by incorporating suitable SCM tools to reduce disputes among supply chain actors for BIM implementation in Malaysia's public sector projects?	**RO3:** To develop an SCM framework by incorporating suitable SCM tools to reduce disputes among supply chain actors for BIM implementation in Malaysia's public sector projects and validate its reliability and applicability.	• Incorporating suitable SCM tools to reduce disputes *(Chapter 4)*

1.6 Research Scope

This area of study is limited to projects carried out by the public sector in Malaysia that have put BIM into practice. The study focuses on design and build of public sector projects worth more than RM 100 million under the RMK11. The projects were chosen based on the preliminary interview carried out in phase 1. A special emphasis was placed on design and build projects that appeared to have the potential for success with the BIM implementation platform but had not yet achieved the full benefits of BIM due to disputes among supply chain actors, as determined by the preliminary interview. Therefore, the design and build projects need to be studied carefully to ensure that BIM implementation in Malaysia is taking place successfully.

To gain a better understanding of this, inquiries should be made to those with experience and knowledge of implementing BIM in Malaysia's public sector projects. Due to this, a purposive sampling is used to identify supply chain actors who are relevant to the investigation's purpose. The study focused on the supply chain actors with experience in the current project(s) that employ BIM. Despite the fact that purposive sampling does not allow for generalisability or representativeness, it is more important to gain a thorough understanding of the research problem than of proportionality.

In order to obtain a thorough understanding, the sample should be drawn from experts who are prepared to provide information on the research problem, to be ready and sensitive to the views of others and to be able to provide a vast amount of information (Delbecq et al., 1975). Aside from that, experts must have continuous involvement in the related field for more than five (5) years (Berliner, 2004; Cha & Lee, 2018). This argument was endorsed by Pill (1971), who claimed that the chosen expert must have a background or experience in the construction field. This criterion is integral to capture their comprehension and experiences in handling construction project work, particularly for the past five (5) years. As a result of the significance of this criterion, criterion sampling is used in phases 1 and 2 of the research.

1.7 Research Significance

The advancement of the global construction industry notably indicates the economic progress that takes place in a country. Realising the fact that the government is the largest client of the construction sector, thus this sector is an essential enabler to the growth of other industries (Teng et al., 2018). To illustrate the significance of the construction sector, its poor performance is bound to adversely affect the industry image, confidence among investors, and GDP growth.

The BIM approach was introduced in Malaysia to support the CSP 4.0 (2021-2025). In line with the government's exertion through the CSP 4.0 for 2021-2025, which strongly emphasises efficiency improvement within the master plan, BIM has been recognised as a key tool. Although both periodic and long-term plans have been incorporated into the government plans, disputes faced by the supply chain actors are yet to be reduced.

Having said that, this study develops a framework using SCM tools to impart a vivid approach in carrying out the BIM projects. This framework is presented to propose better performance based on success stories narrated in previous SCM-related studies. Amendments made to the framework are bound to assist the construction projects at varying intricate levels to ensure successful accomplishment. This step is important in realising that exceptional industry execution will lead to better GDP growth that exerts positive impacts upon other sectors that depend on the construction industry. In precise, the enhanced performance by the public sector will positively influence the general public.

The SCM framework proposed in this study is meant to reduce disputes among the supply chain actors for BIM implementation in Malaysia's public sector projects. This is bound to increase BIM implementation across construction projects within the study context. Furthermore, the developed framework, along with SCM tools, will assist the supply chain actors to gain benefits of BIM in managing construction projects handled by the public sector in the country.

1.8 Thesis Outline

This thesis consists of nine (9) chapters, as described in the following:

Chapter 1 presents a general outlook on disputes that occur among the supply chain actors for BIM implementation in projects undertaken by the public sector in Malaysia. This chapter begins with an introduction, research background, research problem, research questions, research aim and objectives, the research scope, research significance and thesis outline.

Chapter 2 draws up a comprehensive review on the contributors that influence disputes in BIM implementation. This chapter includes academic writing on BIM, implementation of BIM and the contributors that influence disputes. This chapter ends with a summary.

Chapter 3 basically aims at presenting the pathogens and pathogen sub-categories of disputes. There is also a recommendation proposed for a better approach to disputes under study. This approach will be further explored, along with its justifications, and later finalised with an overall summary.

Chapter 4 deals with the incorporating of SCM tools to reduce disputes, the concepts, definitions and aspects of SCM in the Construction Industry and the public sector. Next, the following section defines the key components of the framework using SCM tools to reduce disputes. This chapter further continues with the theoretical frameworks used in the study, including the Dispute Avoidance and Control Framework (DACF) (McGeorge et al., 2007) and the Project Failure Pathogen Framework (PFPF) (Riazi & Nawi, 2018). Then are the conceptual frameworks, and finally the chapter summary.

Chapter 5 explains the research methods used in conducting the study. The research framework is discussed first, followed by a description of the research design. Then, this chapter further presents a description of the two phases involved in the study, namely the needs analysis phase and development of the framework phase. Each phase is explained with detail about the methods used. Next, sampling of experts, data analysis procedures, ethical consideration and framework development are presented and followed by a concluding summary.

Chapter 6 presents the outcomes retrieved from the quantitative approach. The detailed and step-by-step explanation is provided for the result and analysis presented. It begins with an introduction, then goes into detail about the results and analysis for the main contributors that influence disputes and concludes with a summary.

Chapter 7 describes in detail the results and analysis obtained from the qualitative approach. The chapter presents an introduction, results and analysis of pathogens and pathogen sub-categories of disputes, followed by the development of an SCM framework, by incorporating suitable SCM tools to reduce disputes and a summary.

Chapter 8 discusses the overall research outcomes in accordance with each phase. This chapter is divided into phases and written in response to the research objectives and questions.

Chapter 9 outlines the overall research findings, which are concluded by looking into the framework development, significant findings, the contributions offered in this study, the drawbacks endured, and several recommendations for future studies in developing frameworks related to the construction industry.

CHAPTER 2

CONTRIBUTORS THAT INFLUENCE DISPUTES IN BUILDING INFORMATION MODELLING IMPLEMENTATION

2.1 Introduction

Chapter 2 is a review of the contributors that influence disputes in BIM implementation. The review will begin by exploring the different dimensions of the BIM. This section discusses how the implementation of BIM works, how it contributes and how it affects the different sectors of the industry in the context of past research studies. The contributors that influence disputes are then discussed, and the chapter summarised.

2.2 Definitions of Important Terms

This research covers several terms that make up the scope of this study. These terms, which are set out and defined operationally in Table 2.1, provide a fundamental understanding of the context in which they are applied in this study.

Table 2.1: Definitions of Important Terms Used in the Study

NO.	TERM	DEFINITION
1	Building Information Modelling (BIM)	Modelling technology that serves as an associated set of knowledge sharing processes across all phases of the project life cycle with the collaboration of all project participants (Gardezi et al., 2013; Gibbs et al. 2015; McGraw-Hill, 2014; Olatunji, 2016).
2	BIM team members	BIM Manager, BIM Coordinator, and BIM Modeller are established team members that include a project manager, project engineer, site engineer, architect, civil and structural consultant, mechanical and electrical consultant, and other related consultants (CIDB Malaysia, 2017a; PWD, 2016).
3	Supply chain actors	A comprehensive network among BIM team members, stemming from the wide range of aspects that build this network for managing various flows among them concurrently (Broft et al., 2016; Papadonikolaki, 2016; Patrucco et al., 2020).
4	Disputes among supply chain actors	Where the supply chain actors are unable to resolve a project-related issue proactively, promptly and mutually acceptable and where each actor has an opposite opinion on a matter that needs to be resolved (Engebø et al., 2018; Koc & Skaik, 2014; Love et al., 2010a; Reason, 2000).
5	Pathogens	A latent condition, a period of latent, or it could be described as the underlying cause or root cause of a problem before the pathogen emerges as a fault or dispute (Abidin & Ingirige, 2018; Busby & Hughes, 2004; Love et al., 2010a; Riazi & Nawi, 2018).
6	Supply Chain Management (SCM)	SCM is a network management and construction process that encourages collaboration in construction projects by enabling participants to work together in all phases of the construction life cycle (Christopher, 2016; Mentzer et al., 2001; Riazi & Nawi, 2018; Vrijhoef, 2011).
7	SCM framework	A framework incorporating suitable SCM tools to reduce disputes for BIM implementation in Malaysia's public sector projects.

2.3 Building Information Modelling (BIM)

2.3.1 BIM Definition

The origin of BIM as a concept can be traced back to the 1970s (He et al., 2017; Sacks et al., 2018). Nederveen and Tolman first introduced the term in 1992 (Dainty et al., 2017). The extensive use of terms such as 'Building Information Model' and 'Building Information Modelling' later begins to take place, ensuring a release of an authoritative report entitled, ‘Building Information Modelling’ by Autodesk in 2002 (Holzer, 2016).

The definition of BIM is extensive, which makes it different from what BIM represents (Ghosh, 2015; Gurevich et al., 2017). The term is frequently mentioned in the literature, with reference to the Royal Institution of Chartered Surveyors (RICS) in their definition of BIM as a unity of three (3) facets namely, the model itself; the process to build on the model; and the utilisation of the model (Oesterreich & Teuteberg, 2019; Sawhney, 2014). Realising the wide-ranging definitions of BIM, the concerned parties in the related field, involving researchers, academia and professional bodies, have investigated the possibility of BIM definition. BIM is described using different terms in particular different professions. There are three (3) different levels of BIM in theory. Some classify BIM as useful software applications, while some consider it a process to design and document building information. At the same time, others have described BIM as a new approach that needs support from various supply chain actors to optimise the BIM potential. A number of BIM definitions were put under study in construction-related fields for almost twenty years. For this reason, the BIM definition is significantly important to fulfil a research perspective. Table 2.2 shows some definitions presented in previous literary works.

Table 2.2: BIM Definition

NO.	AUTHOR	DEFINITION
1	Autodesk (2002)	Solutions create and operate on digital databases for collaboration, manage change throughout those databases so that a change to any part of the database is coordinated in all other parts, and capture and preserve information for reuse by additional industry-specific applications.
2	Lee et al. (2003)	An nD model that combines various aspects of design information required at each stage of the life cycle of building facilities.
3	Associated General Contractors of America (AGC) (2005)	The development and use of a computer software model to simulate the construction and operation of a facility. Produced models equipped with a variety of data, object-orientation, digital data representation of intelligent and parametric facilities, whose views and the data needs of multiple users can be extracted and analysed to produce information that can be used to make decisions and improve process delivering building services.

Table 2.2: Continued

4	Penttilä (2006)	Set of reactions between policies, processes and technology to produce a method for managing the importance of building design and project data in digital format or virtual through the building life cycle.
5	Associated General Contractors of America (AGC) (2006)	The development and use of technology to simulate the construction and operation of the facility from which views and data appropriate to various users' needs can be extracted and analysed. This data is then used to generate information for making a decision that improves the process of delivering the facility.'
6	American Institute of Architects (AIA) (2007)	A project delivery approach that integrates people, systems, structures and practices in the process together and takes advantage of the views of all stakeholders to optimise the production of projects, increase value to the owner, reduce waste, and maximise efficiency through all phases of design, fabrication and construction.
7	National Institute of Building Sciences (NIBS) (2007)	A digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle.
8	Azhar et al. (2008)	The development and use of a computer-generated model for planning, design, construction and the operation of a facility.
9	Kymmell (2008)	BIM acts as a simulation project that consists of the components of the 3D model of a project that has to do with all the necessary information relating to project planning, design, construction or operation.
10	Glick and Guggemos (2009)	A novel approach of project delivery to integrate people, systems, business structures and practices into collaborative processes to reduce waste and optimise efficiency through all phases of the project life cycle, which also supports the concept of Integrated Project Delivery (IPD).
11	Aranda-Mena et al. (2009)	A completely new approach to practice, arguing that the profession requires the implementation of new policies, contracts and new relationships to support the connection between stakeholders in a project.
12	Succar (2009)	An approach that fully integrates people, systems, business structures and practices into a collaborative and highly automated process.
13	Dossick et al. (2009)	It is a digital integration of previously disparate processes and technologies that allows organisations to support physical and functional requirements in the form of visualisation.
14	Smith and Tardif (2009)	A new technology which boosts the communication between all project participants in accordance with the entire project lifecycle.
15	McGraw-Hill (2010)	The creation and use of digital models and related collaborative processes between companies to leverage the value of the models
16	Nisbet and Dinesen (2010)	Technology that brings with a new way of working.
17	Krygiel et al. (2010)	BIM refers to a 3D parametric model used to produce plans, sections, elevations, perspectives, details and schedules, for which all the components are required for documenting the design of the building.

Table 2.2: Continued

18	National Building Specification (NBS) (2011)	A way of working by which everyone can understand a building through the use of a digital model.
19	Eastman et al. (2011)	A modelling technology and associated set of processes to produce, communicate and analyse building models
20	Cho et al. (2011)	Set of technology developments and processes that have transformed the way infrastructure designed, analysed, constructed and managed.
21	Reddy (2011)	An improvement methodology process that leverages data to analyse and predict outcomes through a different phase of the building life cycle.
22	Vandezande et al. (2011)	Digital representation of the physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward.
23	National Building Specification (NBS) (2012)	Rich information model, consisting of potentially multiple data sources, elements of which can be shared across all stakeholders and be maintained across the life of the building from inception to recycling.
24	Newman (2013)	A process of generating and managing building data during a structure's life cycle.
25	Abdullah et al. (2014)	Process of drawing and design, construction of a building by using a technology approach, and it involves a procedure in Architecture, Engineering, Construction and Operation (AECO)
26	Miettinen and Paavola (2014)	Cooperation between multiple disciplines across the different phases of a project.
27	Bodea and Purnuş (2018)	BIM is the development and use of a computer software model to simulate the construction and operation of a facility.

Although differences of view still exist, there appears to be some agreement on the meaning of BIM from three (3) different aspects, namely technology, process and organisation. As shown from the table, the National Building Information Modeling Standards (2010) use the BIM definition close to National Building Specification (NBS) (2012) and Aranda-Mena et al. (2009). Throughout this thesis, the term is used to refer to BIM as a modelling technology that serves as an associated set of knowledge sharing processes throughout the entire process of the project, involving the participation of all team members. The BIM definition is as presented in Figure 2.1.

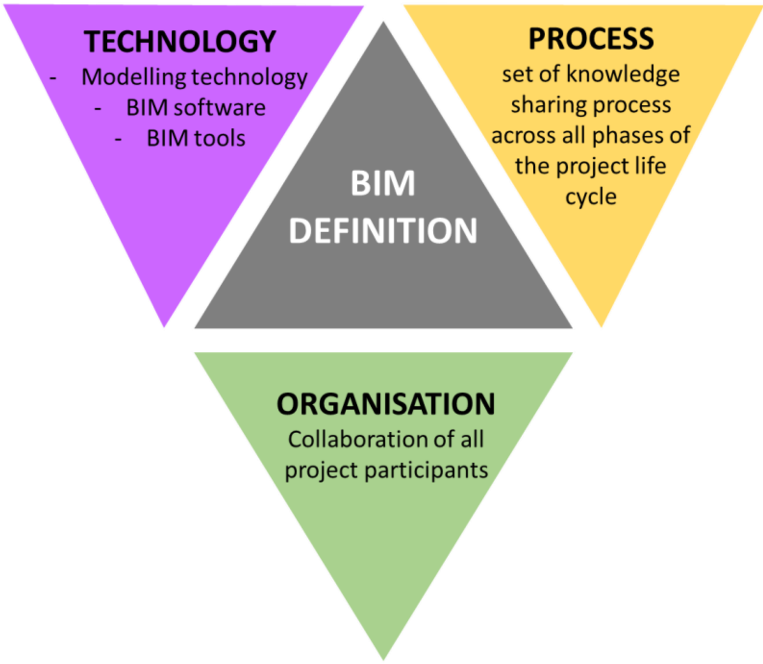

Figure 2.1: BIM Definition Components

Li et al. (2017) and Rokooei (2015), in a study, highlight the major benefits of BIM implementation for construction project management, which are as follows:

1. Enhanced project collaboration and control of all project participants
2. Improved productivity (less re-work, conflicts and changes)
3. Better project quality and performance
4. Faster project delivery
5. Reduced wastages
6. Reduced construction costs
7. New revenue and business opportunities

BIM functions as a centralised data storage whereby it is accessible to every team member involved in construction projects, thus reducing the risk of poor communication among team members who are controlling or administering the project (Ali et al., 2020). The increasing responsibility of the BIM task will require more decentralisation in organisational structures, thus, supporting the views highlighted in the literature that open and effective communications are the key to BIM success in general (Abbasnejad et al., 2016; Khalfan et al., 2015). Furthermore, the more complex the BIM responsibilities of a particular organisation, the higher the need for open and decentralised organisational structures to support the BIM process.

Realising the advantages of BIM implementation, many countries have started to adopt the BIM approach. Currently, there are some countries like the United Kingdom, France, Finland, etc. that have already regulated the use of BIM in their public sector contracts. BIM implementation has started taking place in developing countries due to proactive measures by the governments that commissioned all their public construction projects to carry out a BIM approach (Antwi-Afari et al., 2018; NBS, 2013). However, according to Husain et al. (2018), Malaysia, as observed, adoption of BIM is still found to be at a low level, despite the fact that many countries have already moved towards BIM technology in the construction industry. Correspondingly, another study (Hasni et al., 2019) found that BIM practice in Malaysia is still in its early stages; thus, more active measures need to be taken for BIM to be fully exposed and familiarised.

2.3.2 BIM Concept

BIM, according to Tahir et al. (2018), creates a building through digital application, before physically constructing it, in order to iron out obstacles, model and evaluate possible impacts. The core of BIM lies in the reliability of its model in organising information.

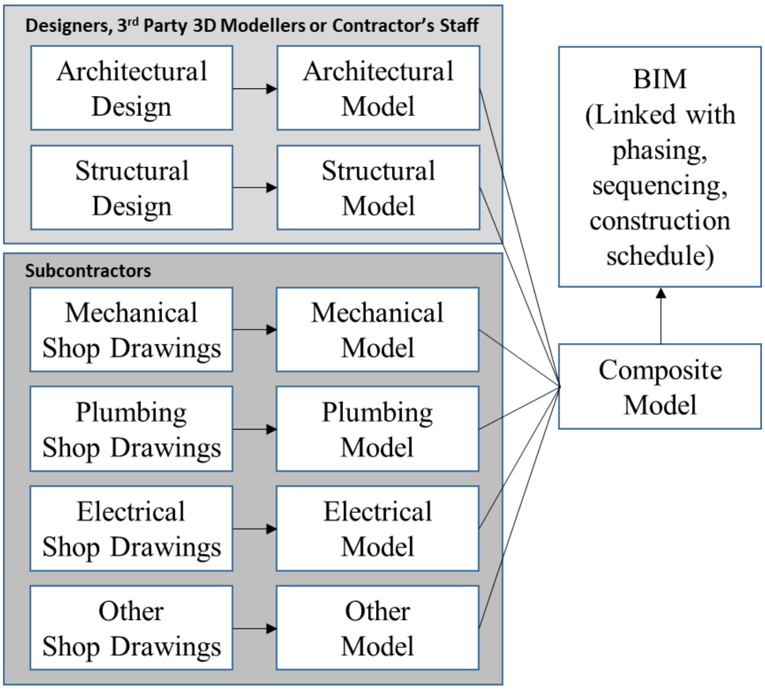

Figure 2.2: Multiple Models for a Single Project to Incorporate BIM
(Source: Associated General Contractors of America [AGC], 2006)

With reference to Figure 2.2, the Associated General Contractors of America (AGC) (2006) described BIM software as a structured set of data whereby its application begins with documentation of data and the process continues as the project takes place. The knowledge-sharing process involves every supply chain actor, members consisting of an architect, civil and structural consultant, mechanical and electrical consultant, contractor and subcontractor. The BIM approach requires the supply chain actors to work based on a paperless system. In other words, BIM users focus on the project model, which is digitally developed rather than dealing with 2D drawings or paper-based records to represent 3D information. Ali et al. (2015), in their study, accorded that digital building is feasible to practice design, experiment and make changes to the project before it is completed. Digital error in BIM does not generally cause critical damages, on the condition that the errors are detected and resolved earlier to avoid any consequences that will affect the real building works. Once designing and digitally constructing a building completed, all the relevant aspects will be reviewed and discussed before the team mutually agrees to the model design. It is similar to simulating a building model by considering all the processes and changes that take place in the design.

A study by Handayani et al. (2019) explained that a BIM database is easily accessible to release non-graphical information with 2D and 3D drawings such as specifications, cost data, scope data, schedules and other general documentation for convenience of the BIM users. Another research study by Allen and Shakantu (2016) that examined on the essence of information and model in BIM, has categorised all the available information that is part of, or related to, the components and the physical details featured in the model, such as scale, position, etc. It is essential that all the necessary particulars are recorded in the BIM to make an actual analysis. The knowledge types are as summarised as follows:

1. **Component information**: The basic data in the 3D model package, which contains visual information and remains like the model element. In a 3D model, components often have different positions in relation to one parent and another. An example of component information is a wall containing material or quantitative information such as part numbers (Scheffer et al., 2018).
2. **Parametric information:** Data that can be edited within the parametric object. It is placed with the model and the object. Some of the particulars may be visual, but much of it could also be scientific, such as distance, volume, or material-related qualities such as density (providing weight based on the object's geometry), R-value, etc. (Sacks et al., 2018).
3. **Linked Information:** Information that is not part of the model, but is connected by external links to the model. Links may be ‘flags’ that open a