BIM Roles and Responsibilities: Towards a Dedicated Matrix for Developing Countries

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ABSTRACT

Building information modeling (BIM) through its data-rich digital representation of building elements has brought a revolution in the architecture, engineering and construction (AEC) industry. To ease the process of BIM implementation various BIM roles have been discussed, but the BIM roles related to project delivery methods have not been standardized. Stimulated by this need, this study aims to provide a matrix for BIM roles and responsibilities in context of DBB project for developing countries. Objectives of the study include: (1) To identify and analyze the existing BIM roles and responsibilities. (2) To determine the BIM roles and responsibilities for developing countries in the context of DBB projects (3) The formulation of a matrix for the adoption of relevant BIM roles and responsibilities. A questionnaire survey was conducted to obtainan industry perspective. 105 retrieved questionnaire responses were analyzed. The results indicate the BIM roles that are BIM manager (Design), BIM manager (Construction), BIM coordinator (Design), BIM coordinator (Construction), Information manager (Design), Information manager (Construction), Model manager, BIM modeler and their relevant responsibilities required on DBB projects. Subsequent to the validation from experts, the BIM roles and responsibility matrix was developed.

KEYWORDS

Building information modeling (BIM); BIM roles; BIM responsibilities; Roles & Responsibilities matrix.

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LIST ABBREVIATIONS

AEC Architectural, Engineering and Construction Industry

AECO Architecture, Engineering, Construction and Operation

BEP BIM Execution Plan

BIM Building Information Modeling

BIM-R&R BIM Roles and Responsibilities

CIC Construction Industry Council

DBB Design-Bid-Build

ICT Information and Communications Technology

IPD Integrated Project Delivery

ISO International Organization of Standardization

QA Quality Assurance

QC Quality Control

PPT Process, People, and Technology

CHAPTER 1: INTRODUCTION

1.1 GENERAL

The nation's economy is braced by the Architecture, Engineering, and Construction (AEC) industry (El-adaway et al., 2017). To observe the input of new technology in economic growth, the industry should adopt and implement new technologies (Takim et al., 2013). Technology is growing rapidly around the globe (Takim et al., 2013) and Building information modeling (BIM) is among such technological advancements (Akintola et al., 2017). The existence of BIM has been noted over the last 20 years (Takim et al., 2013) but the noteworthy progression is seen during the last ten years in construction-associated collaborative technologies (Akintola et al., 2017).

The construction industry has been revolutionized due to the use of BIM (Sistani & Rezaei, 2016). Multiple challenges like communication issues, rework, and delays that influence the accomplishment of the project can be resolved by the application of this technology (Ismail et al., 2017). Because of its integrated approach in design, construction, and maintenance processes, BIM provides simple solutions to complicated construction projects (Namlı et al., 2019). Ghaffarianhoseini et al. (2017) define BIM as "a digital representation for a facility's physical and functional properties, that helps the users to transmit design data and requirements between different software applications across a multidisciplinary team". The virtual BIM model helps in clash detection and identification of potential problems that can arise at a later stage of construction (Azhar, 2011). Geometry and other essential information i.e., spatial relationship, topographical information, quantities, specifications and properties of components, analysis and costs that are required for design, construction, and operation purposes is contained within the building information model

(Ghaffarianhoseini et al., 2017). It is therefore possible to view BIM as a process that encompasses multiple aspects, disciplines, and structures of a facility within the model (Arroteia et al., 2020; Takim et al., 2013).

BIM implementation is strongly being imposed in developed countries (Bhatti et al., 2018; Georgiadou, 2019). However, the construction industry in developing countries is facing difficulties in implementing BIM despite its rapid adoption (Akdag & Maqsood, 2020; Malik et al., 2021). Due to the constrained and infrequent technological innovations, these countries lag the requisite expertise (Bui et al., 2016). Among the major challenges involved such as changing the traditional work processes (Akdag & Maqsood, 2020; Arroteia et al., 2020; Ismail et al., 2017), insufficient knowledge of work practices (Arroteia et al., 2020; Bui et al., 2016), extensive financing in guidance and skill needed for BIM (Akdag & Maqsood, 2020; Arroteia et al., 2020), there still exists an insufficient understanding of the BIM roles and responsibilities in the developing construction industries, which is one of the major challenges involved (Akintola et al., 2017; Arroteia et al., 2020).

Worldwide BIM implementation has caused a change in customary project roles and positions to technically competent ones (Hosseini et al., 2018). Moreover, BIM implementation also results in the development of new work practices, roles, and responsibilities in construction projects (Sijtsema et al., 2019). Several types of studies have been conducted in the past on various BIM roles. Following a thorough literature review, several BIM-related roles like BIM manager, BIM facilitator, BIM modeler, modeling specialist, etc., were summarized in a study (Barison & Santos, 2010). Sijtsema and Gluch (2019) discussed the BIM coordinator and the BIM manager roles and actions in the Sweden construction industry. Similarly, Jacobsson & Merschbrock (2018) discussed BIM coordinator roles and responsibilities through the literature

review and by conducting interviews with four experts in the Norwegian construction industry. In another study, Uhm et al. (2017) analyzed various online BIM jobs in which 35 different BIM-related job titles were found, having similar role requirements but different names. Furthermore, Davies et al. (2017) conducted a study to perceive how the BIM roles are defined in different BIM guides, handbooks, manuals, and standards. Besides research articles, US Veterans Affairs BIM Guide VA (2010) defines BIM manager and disciplines BIM coordinators roles. While UK has developed an information management specification BSI PAS 1192-2 (2013) for construction projects working in BIM that highlights the roles and responsibilities for information management. However, it is evident that many BIM-related roles are discussed in the literature, these studies are either reviewed or are defined differently depending upon the industry, region, and country. Moreover, there is a difference in the development and definition of roles in the industry across countries (Sijtsema et al., 2019). And BIM professional role description is in needs to be standardized (Davies et al., 2017). Thus, this highlights that there is an utmost need for an empirical study on BIM roles, tasks, and perceived responsibilities in the AEC industry for developing countries to fill in this gap.

In an attempt to address the research gap discussed in the literature, this study aims at defining the BIM roles and responsibilities for developing economies based on the prevalent project delivery method resulting in the establishment of a matrix for BIM roles and responsibilities. The prevalent project delivery method used in developing countries is Design-Bid-Build (DBB) (Kaini, 2013). Thus, the traditional and the prevalent project delivery method i.e., DBB is used in this study. This research intends to pave the way by providing clarity for the BIM roles and their corresponding

responsibilities on a project during the project lifecycle in developing construction economies.

1.2 OBJECTIVES

The research objectives are defined as follows:

- To identify and analyze the existing BIM roles and responsibilities.
- To determine the BIM roles and responsibilities in developing countries in the context of DBB projects.
- Formulation of a matrix for the adoption of relevant BIM roles and responsibilities.

1.3 RELEVANCE TO NATIONAL NEEDS

BIM is an emerging technology in developing countries like Pakistan. BIM implementation is at the initial stages and organizations are also not fully familiar with the benefits that BIM brings. There is no clear role and responsibilities description for BIM-enabled projects. Clarity is required on who will perform a particular task and who will be responsible for what task. This study will be helpful for the Pakistan AEC industry in better BIM implementation by proposing a matrix for BIM roles and responsibilities, ensuring suitable BIM personal selection on BIM-based projects.

1.4 ADVANTAGES

This research will help in better BIM implementation in the AEC industry within developing countries. Standardization of BIM roles and responsibilities will help in a better understanding of BIM actor roles, providing a clearer definition regarding who performs what task and who is responsible for what activity on the project. This will eventually help in identifying the right and appropriate BIM personal for BIM-enabled projects.

CHAPTER 2: LITERATURE REVIEW

2.1BIM AND ITS ASPECT

Building Information Modelling (BIM) is one of the promising advancements in the AEC industry (Azhar, 2011). It is being acknowledged as a novel management tool in the construction industry as the BIM model incorporates all aspects, disciplines, and structures which makes it favorable for all construction stakeholders (Arroteia et al., 2020; Takim et al., 2013). BIM allows the creation of 3D virtual models along with changes in workflows and project delivery methods (Azhar, 2011). It efficiently estimates and improves the time, cost, safety, quality, and functionality of construction projects (Takim et al., 2013). It also lessens the excess effort by design and construction process improvement (Eadie et al., 2013). BIM provides the easy sharing and reusing of information between all project parties (Azhar, 2011). Due to the excessive information exchange between parties, BIM's support for collaboration has become an unavoidable requirement (Liu et al., 2017). Therefore, BIM will improve the communication between project stakeholders (Sijtsema & Gluch, 2019) it will also have an impact on how they collaborate and work together (Liu et al., 2017).

BIM implementation influences the organizational practices and hence cannot be considered as software solely rather it is a process and software (Eadie et al., 2013). BIM model can be conveniently used in all project phases i.e., planning, design, construction, and the operational phase. BIM is effectively used to visualize the design, construction, or operational issues through digital simulations as it is beneficial to use BIM during these phases (Azhar, 2011). Comprising all the graphical and non-graphical data, BIM ensures the integration of information, data management, leads simulations and analysis efforts, improves coordination and communication among project members along enhanced productivity and facility management (Arroteia et al., 2020).

2.2 BIM ADOPTION AND IMPLEMENTATION IN AEC INDUSTRY

It is considered to be difficult to introduce and adapt modern day advanced technologies in the AEC industry as it holds on to the existing processes and procedures for the sake of convenience and adaptability (Takim et al., 2013). Regardless of the quick advancement of BIM, conventional practices limit its efficiency (Arroteia et al., 2020). An in-depth understanding is required to adopt and implement the new technology. It has been revealed from the studies that the adoption of new technology is exceptionally intricate (Takim et al., 2013). The adoption of BIM by the AEC industry requires a broader framework of laws and regulations to structure the use of the technology throughout the chain of services and professionals involved in the building process (Arroteia et al., 2020). Despite the benefits this paradigm brings along, the construction industry is still hesitant to utilize the innovation (Takim et al., 2013). The absence of extensive acceptance of BIM seems, by all accounts, to be connected to the risks and challenges that are possibly hindering its viability (Ghaffarianhoseini et al., 2017).

BIM implementation has been noticeably increased in developed countries (Malik et al., 2021) while the construction industry for developing countries is still facing challenges in BIM implementation (Bui et al., 2016; Akdag & Maqsood, 2020). For the purpose of adopting and implementing BIM in developed economies, international BIM guides have been developed for successful BIM implementation (Belgian Guide, 2015; HKIBIM, 2011; ISO 19650-1 2018; NZ BIM Handbook, 2019; PAS 1192-2 2013; VA, 2010). However, BIM implementation is yet an ultimatum for developing countries. One of the major hurdles involved in BIM implementation in developing countries is the insufficient understanding of BIM roles and responsibilities (Arroteia et al., 2020). While, in an attempt to observe the changes that BIM brings in an

organization in developing countries, such as the Brazilian construction industry, Almeida & Brito, (2017) indicates that for adopting new technology, a new BIM role such as BIM manager should be appointed to avoid difficulty in BIM implementation. The Malaysian building industry's BIM project guide proposes appointing a BIM manager to handle the information management of models (CIDB, 2019). Similarly, Hafeez, (2016) discussed in its findings that no role and responsibilities are defined in the EIR in construction projects in developing economies. However, it can be observed from the abovementioned studies that only the role of the BIM manager is identified for developing countries, and the responsibilities of this role is yet not defined for them. It can be observed that despite its advantages BIM brings, it has its own challenges for developing economies that effects it rapid adoption.

2.3 ROLES AND RESPONSIBILITIES EVOLUTION THROUGH BIM

Stakeholders at all levels are progressively incorporating BIM in their projects. Implementation of Building Information Modelling causes several changes within an organization related to the project (Eadie et al., 2013). BIM has also infiltrated into the practices of a large number of interdisciplinary professionals (Papadonikolaki & Van Oel, 2016). Studies acknowledge that BIM transforms the roles among the project team members including the designer, contractors, and the client (Latiffi & Brahim, 2016; Papadonikolaki & Oel, 2016; Sebastian, 2011). Papadonikolaki & Van Oel (2016) in their study highlights that BIM transforms the roles of construction participants due to its significant impact on collaborative processes by modifying information exchange and instigating denser interactions. Similarly, Sebastian (2011) made a deeply cognate study about the evolving roles of clients, designers, and contractors due to BIM and

discovered that the BIM projects demand the continuous emergence of BIM roles for construction professionals.

It has been further observed that the enterprises and organizations that are utilizing BIM innovation are facing obstacles such as insufficient communication between those engaged in the planning and the construction phase of the project. These organizations need to realize the requirement of BIM-related professionals, who would not only be responsible for practicing BIM but also for the coordination and communication in the BIM environment (Barison & Santos, 2019). Therefore, new BIM roles and responsibilities have been formed due to the BIM evolution (Akintola et al., 2017). Jacobsson & Merschbrock (2018) states that the BIM formal professional role appearance, due to the initiation of BIM was among the preliminary and noticeable changes. These newly formed roles and responsibilities make sure of the success of the organization's transformation to BIM-based methods and projects and have subsequently kept on multiplying (Akintola et al., 2017).

2.4 CURRENT STATE OF BIM ROLES AND RESPONSIBILITIES

Building information modeling has given rise to new roles in the construction industry. These roles can be found in BIM guides as well as in research studies. The literature has been highly encouraging on the development of new BIM positions such as BIM manager, BIM coordinator, BIM modeler, etc. (Sijtsema et al., 2019). These BIM actors can be part of the client, architect, and contractor firms (Akintola et al., 2017; Barison & Santos, 2019).

BIM roles are evolving (Hosseini et al., 2018) and there are numerous BIM titles available (Mathews, 2015). Initially, Barison (2010) classified BIM roles into BIM manager, BIM modeler, BIM facilitator, modeling specialist, etc. In another study by Mathews (2015), BIM job titles identified were BIM manager, BIM project manager,

BIM coordinator, and BIM technicians. While in a recent study by Wang et al. (2020), BIM roles identified on a construction project are BIM manager, BIM coordinator, and BIM modeler.

US Veterans Affairs BIM Guide VA (2010) while defining BIM manager and disciplines BIM coordinators responsibilities indicates that these roles are the core responsible person in every BIM project. Similarly, The Singaporean BIM guide (BCA Singapore, 2013) emphasizes that two BIM professional roles, namely BIM manager and BIM coordinators during the design and construction phase, are recognized for facilitating the BIM process. While, Norwegian Home Builders' Association (BoligBIM, 2012) defines the BIM coordinator role as the key BIM role. PAS 1192-2 (2013) a BIM information management specification summarizes the roles and responsibilities required for information exchange on BIM-based projects. Furthermore, the Information manager role is also mandated in the Construction Industry Council (CIC) BIM Protocol as information management is an important aspect in the Level 2 BIM process (CIC, 2018).

Mathews (2015) in his research claimed that the industry is confused about the meaning and interpretation of the BIM roles i.e., BIM manager, BIM coordinator, and BIM technician. While, Davies et al. (2017) conducted a study to perceive how the BIM specialist roles are defined in different BIM guides, handbooks, manuals, and standards. The study concluded that similar BIM role titles are used to describe different tasks within the project teams. However, Jacobsson & Merschbrock (2018) discussed BIM coordinator roles and responsibilities in detail. Whereas, (Bilge & Yaman, 2021) explained the importance of information management in BIM and Integrated Project Delivery (IPD) real estate projects and also defined the responsibilities of the Information Manager and Information Coordinator along the project lifecycle.

It is observed that for management roles, there is a BIM manager, who can be from client, design, contractor, or subcontractor firms (Barison & Santos, 2019). The BIM manager's role is the frequently cited one in the literature. This role has received extensive coverage in comparison to others (Boton & Forgues, 2018; Davies et al., 2017). BIM managers are being hired by many companies, yet their roles and responsibilities are not clearly defined (Barison & Santos, 2019). Moreover, according to studies, BIM coordinator and BIM manager roles are blurred and there is a similarity between their tasks (Sijtsema & Gluch, 2019; Sijtsema et al., 2019; Hosseini et al., 2018). Likewise, Zanni et al., (2017) indicate that clash detection will be the responsibility of either the BIM manager or BIM coordinator. Whereas, Jacobsson & Merschbrock (2018) highlights that the BIM coordinator is mainly responsible for clash detection. However, Hosseini et al. (2018) state that the BIM coordinator has always been a key role in the AEC industry in BIM-based projects. While Davies et al. (2017) state that the BIM coordinator role is secondary and is led by the BIM manager. It was further stated that the role of BIM coordinator is unchangeable and it is in a unique position for managing BIM (Liu et al., 2017). Furthermore, Wang et al. (2020) in their study states that the responsibilities of a BIM modeler are comparable to those of a BIM coordinator. If the modelers are more expert with technical skills, they can do much more BIM coordinator work like clash detection and model coordination.

It can be observed that for BIM implementation and practices, multiple guides are introduced by many countries, industry bodies, research coalitions, and independent organizations. These documents define key roles which are required to successfully implement BIM. Several different titles can be identified among various documents available but similarities can be often found among different role descriptions (Davies et al., 2017). Furthermore, the studies also show that there is a difference in the

definition of roles in the industry across countries (Sijtsema et al., 2019). Depending on the standards followed in each scenario, different interpretations of the identical roles are visible (Davies et al., 2017). With the increase in BIM-based projects, BIM-based role titles also started increasing, which resulted in increased nomenclature. With so many different positions held by the diverse participant, it has become very important to define BIM roles for successful BIM implementation in the AEC industry (Davies et al., 2017).

CHAPTER 3: RESEARCH METHODOLOGY

A 4-step process has been adopted towards the proceeding of this study as displayed in Figure 3.1 and the sections given below thoroughly explain the research methodology.

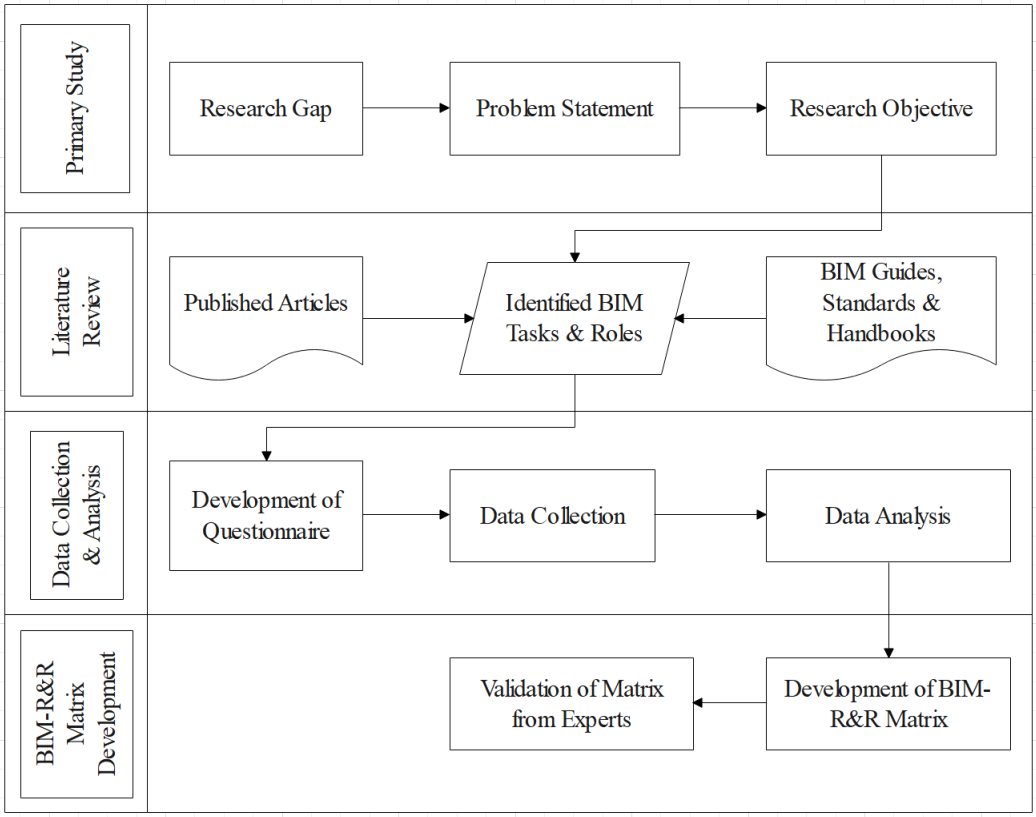

Figure 3.1: Research Methodology

3.1 PRELIMINARY STUDY

As an initial step, a significant number of recent papers were analyzed. The most recent publications on information and communications technology (ICT) and automation in civil engineering and construction were studied, leading to the current status of BIM development. Afterward, a comprehensive study was carried out on the published articles in the area of BIM that highlighted the research gap. It was found in the research gap that the BIM-based roles and responsibilities need to be identified and addressed in detail for their relevant adoption in developing countries. BIM implementation is limited in developing countries regarding roles and responsibilities since it requires

clarity towards defining and assigning a task (Akintola et al., 2017; Arroteia et al., 2020). Through the identified research gap, research objectives were defined to find out the roles and responsibilities for the prevailing delivery methods in developing countries. Following the defined research objectives, this study aims at proposing a matrix for defining the BIM roles and responsibilities, which will help in properly inducting BIM roles into the construction projects.

3.2 LITERATURE REVIEW

A two-step literature review has been performed in this study to address the research gap and to identify BIM roles and responsibilities. Firstly, through BIM guides, standards, and handbooks, and secondly through published research articles. BIM guides, standards, and handbooks were searched online on Google & Microsoft Bing search engine using the keywords “BIM guides”, “BIM standards”, “BIM Handbooks” and “National BIM guides/standards/handbooks” till June 2021. The idea behind this was to gather the maximum data possible for the study. A total of 51 BIM guides were retrieved. As initial screening, their introduction and contents were studied to extract the roles and responsibilities section, which resulted in only 28 documents, which were then studied extensively. While published articles were searched online using the keywords like “Building Information Modelling”, “BIM”, “BIM roles”, “BIM responsibilities”, “BIM professional roles” and “BIM tasks” from ASCE library, Web of Science, and Scopus libraries, Science Direct, Google Scholar, Taylor & Francis Online, and Emerald Insight. In our study, only publications in the English language were considered. Initially, 70 papers were retrieved out of which 37 papers were obtained on BIM roles and responsibilities from the years 2010 to 2021. To extract the most relevant papers, the keywords mentioned above were used in the search string of

the articles to look up for the discussion regarding BIM roles and tasks. The papers having information about BIM roles and responsibilities were scrutinized and accessed individually, which resulted in the 23 shortlisted articles to be analyzed further. Therefore, 28 BIM guides and 23 shortlisted research papers resulted in 51 relevant documents.

Tasks along with their roles were extracted from both the BIM guides and the published articles and they were scrutinized in two steps. In the first step, tasks were extracted and grouped along the project lifecycle phases used in BIM-based projects namely initiation, planning and design, construction, monitoring and control, and operation and maintenance as envisaged by multiple BIM studies (Eadie et al., 2013; Fadeyi, 2017; Hussain, 2020; Ma et al., 2018; Muller et al., 2019). A total number of 555 BIM-based tasks were extracted. Identical tasks were merged in the respective phase, which resulted in 125 BIM tasks. Depending on their significance these tasks were then divided into primary and secondary tasks. The primary category was kept for tasks that are more exclusive in terms of BIM and are performed by BIM personnel. Whereas, the tasks that are part of the project phases even without BIM implementation, as well as the roles that are already involved in completing those tasks, were placed in the secondary category. This exercise resulted in the identification of 82 BIM tasks in the primary category and 43 tasks in the secondary category.

In the second step, BIM roles were analyzed for each corresponding BIM task depending on their frequency of appearance in the shortlisted documents. The maximum of the top 3 most frequently occurred roles were shortlisted for a task while for those tasks where only one role was mentioned in the literature, the same role was selected. It was observed that 50 tasks have only one role identified. This was because the tasks appeared only once in the literature, or only one role was commonly used for

that task. All these identified tasks are important concerning BIM and it is also important to identify their correct role in context with DBB. So the BIM roles were separated for design and construction phases considering the DBB project delivery method. Thus the identified BIM tasks and corresponding BIM roles are shown in Table 3.1. These roles and primary tasks will form the basis for the development of the questionnaire as it is important to identify the correct roles for the BIM-based tasks.

Table 3.1: Identified BIM Tasks and Roles

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected References
T1		Facilitate the development of a project BIM brief	BIM Manager (Design)	(NZ BIM Handbook, 2019)
T2		Define, complete and update the BIM execution plan	BIM Manager (Design), BIM Coordinator (Design)	(Akintola et al., 2017; NATSPEC, 2016)
T3		Identify BIM standards	BIM Manager (Design), BIM Coordinator (Design)	(Akintola et al., 2017; USF, 2018)
T4	**Initiation**	Facilitate the identification and implementation of BIM standards	Model Manager	(Barison & Santos, 2019)
T5		Define project BIM protocols	BIM Coordinator (Design), BIM Facilitator (Design)	(Akintola et al., 2017; LACCD, 2017)
T6		Establish project information requirement and information protocols	Information Manager (Design)	(Bilge & Yaman, 2021)
T7		Coordinate BIM tasks in design discipline	BIM Coordinator (Design)	(Davies et al., 2017)

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected References
T8		Provide guidelines to the team on agreed project rules	BIM Coordinator (Design)	(Davies et al., 2017)
T9		Provide design guidelines to the team on project rules as agreed	Model Manager	(COBIM, 2012)
T10		Communicate BIM vision to the team	BIM Manager (Design)	(CoD, 2011)
T11		Establish asset information requirements and the process to maintain asset information model	Information Manager (Design)	(Bilge & Yaman, 2021)
T12		Coordinate and organize BIM training and workshops	BIM Manager (Design), BIM Coordinator (Design), BIM Facilitator (Design)	(Sijtsema & Gluch, 2019; NYC-DDC, 2012)
T13		Coordinate modeling standards among project team	Model Manager	(COBIM, 2012)
T14	**Planning & Design**	Manage all the graphical model development related tasks (i.e., setting design templates, classification of all spaces, creation of model geometry and specific BIM content) and non-graphical model development related tasks (i.e., adding parameters, pdf, URL to the model) in accordance with BIM execution plan	BIM Manager (Design), BIM Coordinator (Design), BIM Facilitator (Design)	(Sijtsema et al., 2019; USF, 2018)

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected References
T15		Create, coordinate & extract design drawings from BIM models	Model Manager, BIM Modeler	(Barison & Santos, 2019)
T16		Coordinate all technical discipline and trade specific BIM activity i.e tools, content, standards, requirements	BIM Coordinator (Design)	(NATSPEC, 2016; NYC-DDC, 2012)
T17		Lead the BIM documentation and analysis efforts of the internal project team	BIM Coordinator (Design)	(Massport, 2015; VA, 2010)
T18		Perform internal model reviews and interdisciplinary checks	Model Manager	(Barison & Santos, 2019)
T19		Oversee the fully integrated set of project models from all disciplines	BIM Manager (Design), BIM Coordinator (Design)	(Wang et al., 2020; Wu & Issa, 2014)
T20		Coordinate multidisciplinary tasks	BIM Manager (Design), BIM Coordinator (Design), Model Manager	(FIU, 2014; USF, 2018)
T21		Assure assembling of merged models	BIM Manager (Design), BIM Coordinator (Design), BIM Facilitator (Design)	(LACCD, 2017; Merschbrock & Munkvold, 2015)
T22		Assure and inspect the functionality of merged models and the integration of the design models	Model Manager	(COBIM, 2012)

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected References
T23		Carry out clash detection and resolution activities	BIM Manager (Design), BIM Coordinator (Design), Model Manager	(FIU, 2014; Wang & Leite, 2014)
T24		Manage model transfer and version control	BIM Manager (Design)	(NZ BIM Handbook, 2019)
T25		Schedule, coordinate, and facilitate BIM meetings between the design and construction team as well as all design disciplines	BIM Manager (Design), BIM Coordinator (Design)	(BoligBIM, 2012; USF, 2018)
T26		Participate and coordinate in internal BIM meetings	Model Manager	(COBIM, 2012)
T27		Prepare project outputs and revise them regarding Quality Assurance (QA) and Quality Control (QC) protocols	Model Manager, BIM Modeler	(BIM4VET, 2017)
T28		Assist in preparation of project outputs	BIM Manager (Design),Information Manager (Design)	(CIC, 2013; Davies et al., 2017)
T29		Coordinate with the construction manager on the BIM execution plan	BIM Manager (Design)	(FIU, 2014)
T30	**Construction**	Create BIM execution plan in coordination with design team	BIM Manager (Construction), BIM Coordinator (Construction)	(FIU, 2014; Massport, 2015)

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected References
T31		Establish software protocols for efficient BIM delivery	BIM Manager (Construction)	(USF, 2018; VA, 2010)
T32		Coordinate software training	BIM Manager (Construction)	(USF, 2018; VA, 2010)
T33		Coordinate sub-contractor BIM development	BIM Manager (Construction)	(Massport, 2015)
T34		Integrate and coordinate the construction schedule with developed models	BIM Manager (Construction)	(FIU, 2014)
T35		Integrate 3D fabrication models with the updated design model to ensure compliance with the design intent	BIM Manager (Construction), BIM Facilitator (Construction)	(LACCD, 2017; Massport, 2015)
T36		Carry out clash detection and resolution activities	BIM Manager (Construction)	(FIU, 2014; Massport, 2015)
T37		Schedule, coordinate, and facilitate BIM meetings between the design and construction team and all design disciplines	BIM Manager (Construction), BIM Coordinator (Construction), BIM Facilitator (Construction)	(USC, 2012; USF, 2018)
T38		Update models for shop drawings development	BIM Coordinator (Construction)	(Massport, 2015; Takashi Kaneta et al., 2016)
T39		Create construction and as-built models	BIM Coordinator (Construction)	(BCA Singapore, 2013)

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected References
T40		Prepare as-built BIM	Model Manager	(Sebastian, 2011)
T41		Coordinate data extraction sets	BIM Manager (Construction), BIM Facilitator (Construction)	(LACCD, 2017; USF, 2018)
T42		Coordinate model commissioning and data handover	BIM Manager (Construction)	(Massport, 2015)
T43		Implement and manage BIM process i.e. BIM execution plan	BIM Manager (Design), BIM Manager (Construction), BIM Manager (Design & Construction)	(Barison & Santos, 2019; FIU, 2014)
T44		Participate in the updating of the BIM plan	Model Manager	(COBIM, 2012)
T45		Ensure compliance with BIM execution plan	BIM Manager (Design & Construction), BIM Coordinator (Design & Construction)	(Davies et al., 2017; USF, 2018)
T46	**Monitoring & Control**	Ensure compliance with standards	BIM Manager (Design), BIM Coordinator (Design), Task Information Manager	(BIM4VET, 2017; PAS 1192-2, 2013)
T47		Ensure BIM protocols implementation	BIM Coordinator (Design), Information Manager (Design)	(Akintola et al., 2017; CIC, 2013)
T48		Verify that all necessary configurations required for the seamless integration of design and	BIM Manager (Design)	(Massport, 2015; USF, 2018)

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected References
		construction model information have been implemented		
T49		Ensure the accuracy of construction documents in accordance with discipline BIM modeling	BIM Modeler	(Joseph, 2011)
T50		Ensure document management	BIM Manager (Design)	(Davies et al., 2017; VA, 2010)
T51		Ensure software installation, operation, and version control	BIM Manager (Design & Construction), BIM Facilitator (Design & Construction)	(Davies et al., 2017; VA, 2010)
T52		Ensure software operation	Model Manager	(BIM4VET, 2017)
T53		Develop & maintain graphical and non-graphical models in accordance with the BIM execution plan	BIM Modeler	(Joseph, 2011; Liu et al., 2017)
T54		Monitor model production and updating	BIM Coordinator (Design & Construction), BIM Facilitator (Design & Construction)	(Jacobsson & Merschbrock, 2018; USC, 2012)
T55		Manage model production and updating	Model Manager	(Barison & Santos, 2019; Ohio University, 2020)
T56		Brief, assist, and coordinate with stakeholders	BIM Manager (Design & Construction), BIM Coordinator (Design & Construction)	(NZ BIM Handbook, 2019; Wang et al., 2020)
T57		Assist the project manager in	Model Manager	(Sebastian, 2011)

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected References
		coordination with stakeholders		
T58		Communicate/Coordinate BIM issues with other members	BIM Manager (Design & Construction), BIM Coordinator (Design & Construction)	(NZ BIM Handbook, 2019; Liu et al., 2017)
T59		Manage the BIM resources (hardware, software, and people)	BIM Manager (Construction)	(Barison & Santos, 2019)
T60		Ensure BIM is used appropriately to test design requirements / criteria	BIM Manager (Design), BIM Facilitator (Design)	(LACCD, 2017; Massport, 2015)
T61		Perform and manage the QA and QC of models	BIM Manager (Design), BIM Coordinator(Design)	(Boton & Forgues, 2018; Davies et al., 2017)
T62		Look after design discipline based QA and QC of models	Model Manager	(COBIM, 2012)
T63		Coordinate update of as built conditions in the final model deliverable	BIM Manager (Construction)	(USC, 2012; VA, 2010)
T64		Adhere to the projects BIM deliverables and their submission	Model Manager	(Ohio Universi, 2020)
T65		Ensure final BIM deliverable requirements are achieved	BIM Manager (Design)	(USF, 2018; VA, 2010)
T66		Maintain local file transfers, control of access rights, and compilation of	Model Manager	(Barison & Santos, 2019)

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected References
		information from smaller models of other members		
T67		Manage digital outputs, data transmission, and archiving	BIM Manager (Design), Information Manager (Design), Model Manager	(SEC Group, 2017)
T68		Facilitate, plan, and manage interoperability issues	Model Manager	(Barison & Santos, 2019; Sebastian, 2011)
T69		Manage interoperability issues	BIM Coordinator (Design), BIM Facilitator (Design)	(Sijtsema, 2013; Jacobsson & Merschbrock, 2018)
T70		Enable integration and coordination of information within the information model	Information Manager (Design), Information Manager (Construction), Information Manager (Design & Construction)	(PAS 1192-2, 2013)
T71		Coordinate to assure completeness of interoperability information	BIM Manager (Design), BIM Manager (Construction), BIM Manager (Design & Construction)	(USF, 2018; VA, 2010)
T72		Ensure interoperability information is provided for milestone submittals	BIM Manager (Design), BIM Facilitator (Design)	(USC, 2012; VA, 2010)
T73		Liaise with the client's facilities management department to determine specific	BIM Manager (Design)	(NATSPEC, 2016)

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected References
		data and file exchange requirements		
T74		Maintain exchange information requirements	Information Manager (Construction)	(Bilge & Yaman, 2021)
T75		Initiate and implement the project information plan and asset information plan	Information Manager (Design)	(Bilge & Yaman, 2021)
T76		Enable reliable information exchange through a common data environment	Information Manager (Design)	(Bilge & Yaman, 2021)
T77		Manage the processes and procedures for information exchange on projects	Information Manager (Design)	(Bilge & Yaman, 2021)
T78		Ensure that the information exchanged between the different stakeholders corresponds to the rules fixed by the contract	BIM Manager (Design)	(Denis, 2015)
T79		Archive the project information model	Information Manager (Construction)	(Bilge & Yaman, 2021)
T80	**Operation & Maintenance**	Ensure information and model availability for operation and maintenance	BIM Coordinator (Construction)	(BoligBIM, 2012)

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected References
T81		Identify assets (model and physical) and the foreseeable trigger events for which information should be managed	Information Manager (Construction)	(Bilge & Yaman, 2021)
T82		Capture lessons learned for future projects	Information Manager (Construction)	(Bilge & Yaman, 2021)

3.3 DATA COLLECTION AND ANALYSIS

BIM tasks and roles identified from both the published articles and BIM guides were used to develop the questionnaire survey. The questionnaire was designed to identify BIM roles for BIM-based tasks in construction projects using the Design Bid Build project delivery approach, which is typically used in developing countries. There were two sections to the questionnaire. The first section inquiries about the respondent's demographic and organizational information. The second section was designed to identify the most appropriate BIM role for each BIM-related task. For BIM tasks where more than one role was identified from the literature, respondents were asked to choose one of the given roles or to indicate any alternative role of their choice. However, for the tasks where only one role was specified in the literature, respondents were given the option of selecting the same role or mentioning any alternative role of their choice. The objective was to provide respondents the option of selecting a role for each task.

The questionnaire was circulated online in the construction industry to gather responses from both the developed and developing economies. There is a justified reason for approaching both developed and developing nations, as developed countries have

greater experience in adopting BIM and a better knowledge of the BIM process than developing countries. However, it was equally crucial to know the point of view from developing countries, as several of them have begun to implement building information modeling (BIM). BIM managers, project and construction managers, BIM coordinators, and BIM modelers are among the industry professionals who were targeted for this survey. Additionally, employees from the consultant and contractor firms were approached with a minimum of 3 years of BIM experience for more credible responses. In the period between July 2021 and October 2021, the questionnaire was distributed online through official emails and professional networks such as LinkedIn. 105 valid responses were gathered from the 200 professionals that were contacted to participate in the survey, for a response rate of 52 percent.

The responses were then analyzed to determine which BIM role was most appropriate for each identified BIM task. Each role described by the respondents was examined, and the frequency with which each role was mentioned was listed. For each task, the role with the highest frequency of occurrence was chosen.

3.4 MATRIX DEVELOPMENT

Based on the analysis of the gathered data, the roles and responsibilities matrix was developed for developing countries along with the project lifecycle phases. Another project focus group is known as PPT i.e., process, people, and technology was used for further classification of BIM tasks. The matrix comprises BIM roles and BIM tasks, with each BIM task being specified as under the responsibility of a specific BIM role. Based on the matrix responsibilities can be assigned to the BIM roles on the BIM-based construction projects. However, future study recommendations can be derived from the proposed BIM roles and responsibilities matrix limitations.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 DEMOGRAPHIC INFORMATION OF RESPONDENTS

A significant number of experienced BIM professionals from the industry completed the survey. According to the statistics provided by Dillman (2014), a sample size of 105 responses was considered sufficient. The demographic information of the respondents is mentioned in Table 4.1.

Table 4.1: Demographic Information of Respondents

Demographic Variables		**Percentage (%)**
Organization Type	Client	5
	Design Consultant	37
	Supervisory Consultant	3
	Contractor	27
	Architect	17
	Other	11
Role in organization	Project Manager	2
	Construction Manager	3
	BIM Manager	41
	BIM Modeler	20
	BIM Coordinator	27
	0ther	7
Year of experience with BIM	1-3	27
	3-6	31
	6-9	21
	6-9	10
	Above 12	11

Table 4.1**:** Demographic Information of Respondents shows that a vast variety of respondents (40%) work with consultants, followed by contractor organizations (27%), as they are the primary stakeholders and have more experience with BIM implementation. Furthermore, the most common positions held by the survey participants were those of BIM manager (41%) and BIM coordinator (27%). This shows that the people who answered the survey are in high-ranking BIM positions. Aside from that, 34% of respondents worked in technical BIM jobs such as BIM modeler and management jobs such as project manager and construction manager. Furthermore,

83% of those who responded to the survey had less than ten years of experience. The main reason for this is that BIM is relatively a new technology that is gaining experience with time. So, the majority of the direct BIM experience will be limited.

Furthermore, the highest number of responses were received from Asia (58%) as shown in Figure 4.1. Moreover, a maximum number of responses were received from the country India in the Asian continent. In a similar vein, the top countries from the continents from where the majority of responses were obtained are Egypt from Africa, France from Europe, Canada from North America, Ecuador from South America, and Australia from Oceania. According to the findings of the Jung & Lee (2015) study, BIM adoption in Asia is seen to be comparable to that of any other developed continent, validating Asia's higher response rate in this survey.

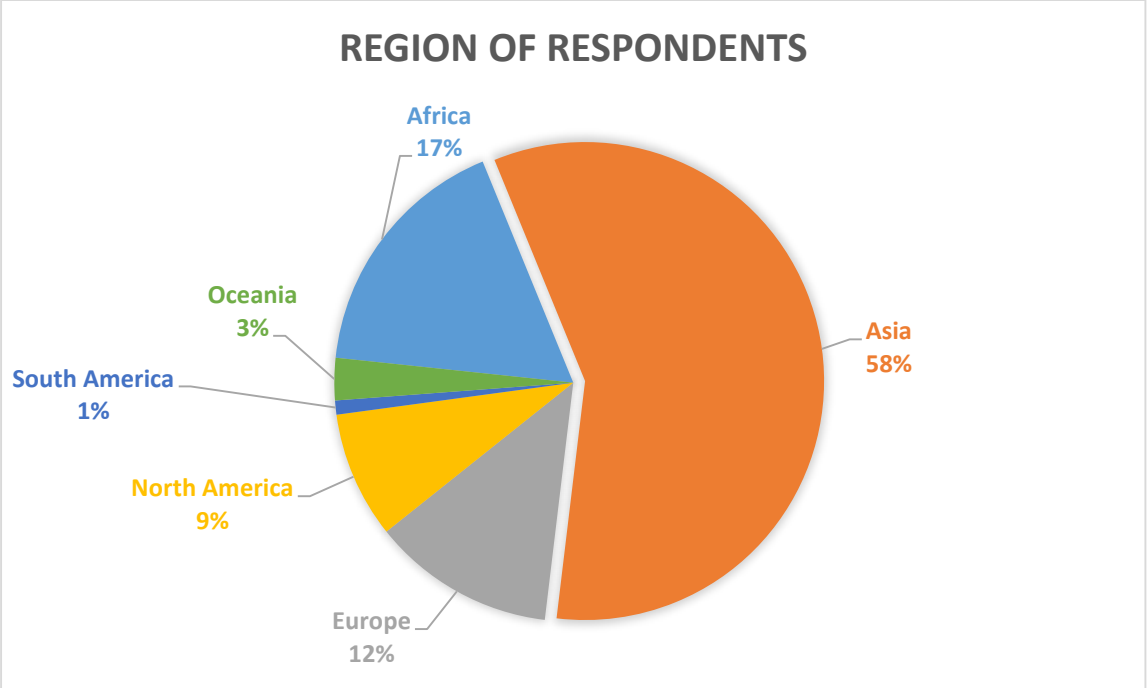

Figure 4.1: Regional Distribution of Respondents

Responses were then analyzed to get the most appropriate BIM role for each identified BIM task. Each role mentioned by the respondents was analyzed, and the frequency

with which it was identified was noted. The role with the highest frequency was selected for each task. Furthermore, for the tasks in which frequency difference between the roles was less, it was observed that which role was chosen from the literature for that tasks. As a result of the comparison, the appropriate role was selected for that task. Survey results are shown in the Table 4.2 below.

Table 4.2: BIM Roles identified through Survey

Task ID	Project Phases	BIM Tasks	Roles Identified through Survey	Percentage of People Responded for Identified Roles
T1	**Initiation**	Facilitate the development of a project BIM brief	BIM Manager (Design)	89%
T2		Define, complete and update the BIM execution plan	BIM Manager (Design)	74%
T3		Identify BIM standards	BIM Manager (Design)	81%
T4		Facilitate in the identification and implementation of BIM standards	Model Manager	69%
T5		Define project BIM protocols	BIM Coordinator (Design)	72%
T6		Establish project information requirement and information protocols	Information Manager (Design)	80%
T7		Coordinates BIM tasks in design discipline	BIM Coordinator (Design)	94%
T8		Provide guidelines to the team on agreed project rules	BIM Coordinator (Design)	85%
T9		Provide design guidelines to the team on project rules as agreed	Model Manager	70%
T10		Communicate BIM vision to the team	BIM Manager (Design)	68%

Task ID	Project Phases	BIM Tasks	Roles Identified through Survey	Percentage of People Responded for Identified Roles
T11		Establish asset information requirement & the process to maintain asset information model	Information Manager (Design)	57%
T12		Coordinate and organize BIM trainings and workshops	BIM Manager (Design)	50%
T13		Coordinate modelling standards among project team	Model Manager	75%
T14	**Planning & Design**	Manage all the graphical model development related tasks (i.e. setting design templates, classification of all spaces, creation of model geometry and specific BIM content) and non-graphical model development related tasks (i.e. adding parameters, pdf, URL to the model) in accordance with BIM execution plan	BIM Coordinator (Design)	50%
T15		Create, coordinate & extract design drawings from BIM models	BIM Modeler	73%
T16		Coordinates all technical discipline and trade specific BIM activity i.e tools, content, standards, requirements	BIM Coordinator (Design)	94%
T17		Lead the BIM documentation and analysis efforts of the internal project team	BIM Coordinator (Design)	88%
T18		Perform internal model reviews and interdisciplinary checks	Model Manager	75%
T19		Oversee the full integrated set of project models from all disciplines	BIM Manager (Design)	48%

Task ID	Project Phases	BIM Tasks	Roles Identified through Survey	Percentage of People Responded for Identified Roles
T20		Coordinate multidisciplinary tasks	BIM Coordinator (Design)	62%
T21		Assure assembling of merged models	BIM Coordinator (Design)	59%
T22		Assures and inspects, the functionality of merged models and the integration of the design models	Model Manager	77%
T23		Carry out clash detection & resolution activities	BIM Coordinator (Design)	64%
T24		Manage model transfer and version control	BIM Manager (Design)	85%
T25		Schedule, coordinate, and facilitate BIM meetings between the design and construction team as well as all design disciplines	BIM Manager (Design)	52%
T26		Participate and coordinate in internal BIM meetings	Model Manager	73%
T27		Prepare project outputs and revise them regarding QA and QC protocols	BIM Modeler	51%
T28		Assist in preparation of project outputs	BIM Manager (Design)	48%
T29		Coordinates with the construction BIM manager on the BIM execution plan	BIM Manager (Design)	92%
T30	**Construction**	Create BIM execution plan in coordination with design team	BIM Manager (Construction)	74%
T31		Establish software protocols for efficient BIM delivery	BIM Manager (Construction)	94%
T32		Coordinate software trainings	BIM Manager (Construction)	88%

Task ID	Project Phases	BIM Tasks	Roles Identified through Survey	Percentage of People Responded for Identified Roles
T33		Coordinate sub-contractor BIM development	BIM Manager (Construction)	88%
T34		Integrate and coordinate the construction schedule with developed models	BIM Manager (Construction)	87%
T35		Integrate 3D fabrication models with the updated design model to ensure compliance with design intent	BIM Manager (Construction)	52%
T36		Carry out clash detection & resolution activities	BIM Manager (Construction)	67%
T37		Schedule, coordinate, and facilitate BIM meetings between the design and construction team as well as all design disciplines	BIM Manager (Construction)	57%
T38		Update models for shop drawings development	BIM Coordinator (Construction)	84%
T39		Create construction and as built models	BIM Coordinator (Construction)	79%
T40		Prepare as built BIM	Model Manager	71%
T41		Coordinate data extraction sets	BIM Coordinator (Construction)	61%
T42		Coordinate model commissioning and data handover	BIM Manager (Construction)	91%
T43	**Monitoring & Control**	Implement and manage BIM process i.e. BIM execution plan	BIM Manager (Design & Construction)	57%
T44		Participate in the updating of the building information modeling plan	Model Manager	79%
T45		Ensure compliance with BIM execution plan	BIM Manager (Design & Construction)	52%
T46		Ensure compliance with standards	BIM Manager (Design)	66%

Task ID	Project Phases	BIM Tasks	Roles Identified through Survey	Percentage of People Responded for Identified Roles
T47		Ensure BIM protocols implementation	BIM Coordinator (Design)	74%
T48		Verify that all necessary configurations required for the seamless integration of design and construction model information have been implemented	BIM Manager (Design)	89%
T49		Ensure the accuracy of construction documents in accordance with discipline BIM modeling	BIM Modeler	85%
T50		Ensure BIM document management	BIM Manager (Design)	84%
T51		Ensure software installation, operation, and version control	BIM Manager (Design & Construction)	51%
T52		Ensure software operation	Model Manager	74%
T53		Develop & maintain graphical and non-graphical models in accordance with BIM execution plan	BIM Modeler	65%
T54		Monitor model production and updating	BIM Coordinator (Design & Construction)	65%
T55		Manage model production and updating	Model Manager	82%
T56		Brief, assist and coordinate with stakeholders	BIM Manager (Design & Construction)	61%
T57		Assist the project manager in coordination with stakeholders	Model Manager	74%
T58		Communicate/Coordinate BIM issues with other members	BIM Coordinator (Design & Construction)	63%

Task ID	Project Phases	BIM Tasks	Roles Identified through Survey	Percentage of People Responded for Identified Roles
T59		Manage the BIM resources (hardware, software, and people)	BIM Manager (Construction)	89%
T60		Ensure building information models are used appropriately to test design requirements / criteria	BIM Manager (Design)	80%
T61		Perform and manage the QA and QC of models	BIM Coordinator (Design)	51%
T62		Looks after design discipline based QA and QC of models	Model Manager	81%
T63		Coordinate update of as built conditions in the final model deliverable	BIM Manager (Construction)	93%
T64		Adhere to the projects BIM deliverables and their submission	Model Manager	79%
T65		Ensure final BIM deliverable requirements are achieved	BIM Manager (Design)	93%
T66		Maintain local file transfers, control of access rights, and compilation of information from smaller models of other members	Model Manager	77%
T67		Manage digital outputs, data transmission, and archiving	BIM Manager (Design)	54%
T68		Facilitate, plan, and manage interoperability issues	Model Manager	78%
T69		Manage interoperability issues	BIM Coordinator (Design)	79%
T70		Enable integration and coordination of information within information model	Information Manager (Design & Construction)	66%

Task ID	Project Phases	BIM Tasks	Roles Identified through Survey	Percentage of People Responded for Identified Roles
T71		Coordinate to assure completeness of interoperability information	BIM Manager (Design & Construction)	60%
T72		Ensure interoperability information is provided for milestone submittals	BIM Manager (Design)	61%
T73		Liaise with the client's facilities management department to determine specific data and file exchange requirements	BIM Manager (Design)	95%
T74		Maintain exchange information requirements	Information Manager (Construction)	81%
T75		Initiate and implement the project information plan and asset information plan	Information Manager (Design)	85%
T76		Enable reliable information exchange through a common data environment	Information Manager (Design)	85%
T77		Manage the processes and procedures for information exchange on projects	Information Manager (Design)	84%
T78		Ensure that the information exchanged between the different stakeholders corresponds to the rules fixed by the contract	BIM Manager (Design)	92%
T79		Archive the project information model	Information Manager (Construction)	85%
T80	**Operation & Maintenance**	Ensure information and model availability for operation and maintenance	BIM Coordinator (Construction)	91%
T81		Identify assets (model and physical) and the foreseeable trigger events	Information Manager (Construction)	87%

Task ID	Project Phases	BIM Tasks	Roles Identified through Survey	Percentage of People Responded for Identified Roles
		for which information should be managed		
T82		Capture lessons learnt for future projects	Information Manager (Construction)	80%

4.3 PROPOSED BIM-R&R MATRIX

The data collected from the survey was used to develop a matrix for implementing BIM roles and responsibilities on a BIM-based DBB project. To do this, research articles were explored to get an idea of how a process map for implementing BIM roles and responsibilities can be developed. This was done to identify the key groups and relate them to the tasks present in the project lifecycle phases of BIM. It was found that three project focus groups i.e., Process, People, and Technology (PPT) are widely accepted and help improve the overall organizational efforts (Javaid & Iqbal, 2017; Prodan, 2015; Nadim & Goulding, 2011). The implementation of new technologies requires considerable changes in the construction process. Therefore, it becomes crucial to define the process and to hire and train the right people (Arayici et al., 2011). Dawood & Vukovic (2015) also used PPT to classify BIM information flow during the whole project lifecycle processes. Davies et al. (2017) in their study, also used PPT and categorized the BIM activities in them. These articles assist in getting an idea about how the groups of PPT can be used to classify BIM tasks.

Following this, a BIM Roles and Responsibilities matrix named BIM-R&R matrix is developed along the project lifecycle phases using the PPT groups as shown in Figure 4.2. While categorizing the tasks, it was ensured that all the tasks were placed in the correct PPT group. The distinct groups along which BIM tasks are classified are

represented both horizontally and vertically. Project lifecycle phases are shown horizontally while focus groups are shown vertically. BIM tasks are grouped in between the vertical and horizontal categories. Different color combinations are used to distinguish between different BIM personnel to whom BIM tasks are assigned i.e., BIM manager (Design), BIM manager (Construction), BIM coordinator (Design), BIM coordinator (Construction), Information manager (Design), Information manager (Construction), Model manager, and BIM modeler. The task number represents the tasks presented in Figure4.2, while the coloring represents the BIM person responsible for performing them. For example, T1 represents tasks number for 'Facilitate the development of a project BIM brief,' and its color 'light yellow' shows that the BIM manager (Design) will perform this task. Some tasks were assigned to more than one BIM professional and were placed in succession to eliminate confusion.

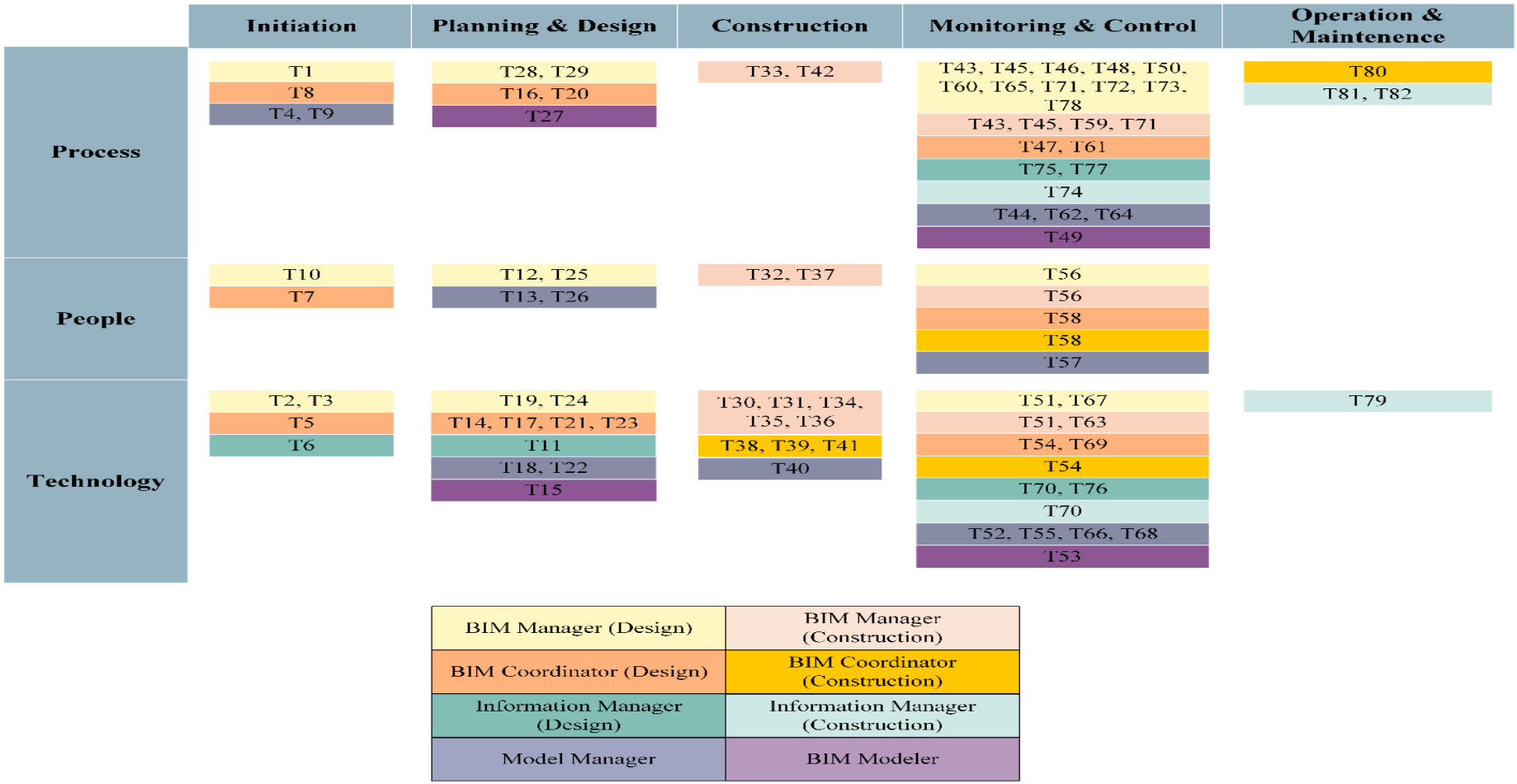

Figure 4.2: Proposed BIM-R&R matrix

4.4 VALIDATION OF THE MATRIX THROUGH EXPERT OPINION

To determine the applicability of the proposed matrix, three experts from the industry with BIM experience were contacted to validate the proposed matrix. Due to the length of the matrix, it was not feasible to conduct interviews. Experts have to critically analyze the placement of each task in project phases as well as in PPT. Because of the large number of tasks, the experts were sent a pdf file. The main idea was to ensure the reliability of the validation achieved. Thus, the construction industry experts having significant experience and an in-depth understanding of BIM were contacted. The experts approached were informed about the study in detail and accepted it to validate the matrix. After receiving their consent to validate the matrix, the pdf file was provided to them to give their opinion on it. Table 4. 3 shows the demographics of the experts.

Table 4. 3: Demographics of Experts for Validating the Matrix

Demographics of respondents	**Expert 1**	**Expert 2**	**Expert 3**
Organization Type	Architect	Architect	Contractor
Country of Organization	France	Lebanon	Qatar
Role in organization	BIM Manager	BIM Manager	BIM Manager
Year of experience with BIM	9-12	6-9	3-6

All of the experts agreed on the placement of the tasks in the project phases and PPT and no changes were recommended. Likewise, they also agreed on the roles for each

task assigned through questionnaire responses. However, a few concerns were raised that are discussed below.

One of the concerns raised by the experts was that no modeling-related BIM modeler task is present in the construction phase. The modeling-related tasks of the BIM modeler are present in the monitoring and control phase of the matrix. However, it should be noted that the monitoring and control phase responsibilities must be carried out during both the planning and construction phases of the project's lifetime. So the task placed initially is correct and its placement should not be changed.

Furthermore, one of the respondents argued that they have only three roles for BIM Management i.e., Model manager, BIM coordinator, and BIM manager. Therefore, the role of the Information manager does not exist and its tasks can be delegated to the BIM manager. However, it is to be noted that the roles identified in this study are the result of a thorough review of the existing literature, and BIM publications stress the importance of having an information manager in charge of all information related tasks as supported by relevant studies in different countries of the world (CIC, 2018; PAS 1192-2, 2013). Such requirements are more pronounced in developed countries where information management is considered to be a high priority task. Therefore, to have a holistic matrix, such a position is retained in the current study.

4.2 DISCUSSION

This study presents a matrix aimed at defining BIM roles and responsibilities for DBB construction projects in developing countries. The study highlights that the BIM roles have been developed without uniformity over the past years due to the development of multiple BIM guides, whereas no study has been conducted for applying BIM roles and responsibilities on a DBB project in developing countries. To develop roles for DBB projects, the survey responses in the current study show that certain roles need to be

bifurcated between design and construction teams, where the roles of BIM manager, BIM coordinator, and Information manager are prevalent. The survey results indicate that BIM manager (Design), BIM manager (Construction), BIM coordinator (Design), BIM coordinator (Construction), Information manager (Design), Information manager (Construction), Model manager, and BIM modeler are the key roles on a BIM project for implementing BIM-based activities.

According to the survey results, the BIM managers for design and construction have different roles, respectively, depending on the project phase and the party they represent. The matrix shows that most of the tasks related to planning and design fall under the responsibility of the BIM manager (Design) while the tasks related to execution fall under the responsibility of the BIM manager (Construction). Thus, the BIM manager (Design) and BIM manager (Construction) are responsible for certain important managerial tasks such as defining, completing, and updating the BIM execution plan (T2) and creating BIM execution plan in coordination with the design team (T31), respectively. These findings can be verified from the BIM guide (NATSPEC, 2016), which makes the BIM manager for the design team responsible for defining the BIM Execution Plan (BEP) for all of the planning, design, and supervision activities related to a project. On the other hand, (FIU, 2014) assigns the creation of the BEP for the construction phase of the project to the BIM manager (Construction) who is responsible for overseeing all aspects of construction. This shows the harmony of the obtained responses with the published sources. Similarly, some important technical tasks for BIM manager (Design) and (Construction) include overseeing the full integrated set of project models from all disciplines (T20) and integrating and coordinating the construction schedule with developed models (T35) respectively. Most of the technical tasks are identical to the tasks defined in various BIM guides, and

articles that fall under the responsibility of BIM managers (Barison & Santos, 2019; FIU, 2014; Wu & Issa, 2014). However, the survey responses clarify this confusion by correctly assigning the tasks to the BIM manager of design and construction teams.

There were also instances where a certain task is defined as the responsibility of differing BIM personnel in the literature. For example, the literature suggests a task for assisting in preparing project outputs to be the responsibility of the BIM manager (Davies et al., 2017) or Information manager (CIC, 2013). Since the responses are provided for DBB projects which bifurcates the responsibilities of the consultant and the contractor, the responses obtained are also valuable to negate this confusion. Accordingly, most respondents believe it to be the responsibility of the BIM manager (Design), which seems logical since the BIM manager will be in a more commanding position to lead this task. Although the decision of task assignment to different roles lies with the project stakeholders, the results of this survey will help the stakeholders assign the roles with more clarity on their projects.

In this study, information management tasks are also bifurcated into the Information manager (Design) and the Information manager (Construction). According to (Davies et al., 2017), the Information manager is responsible for the information requirements of the project. This is reflected in the findings of the present study as the Information manager (Design) and the Information manager (Construction) are declared responsible for the information requirements of projects in their respective phase. Furthermore, the results also show that the Information manager (Construction) is responsible for archiving the project information models besides maintaining the information requirements during execution. This result also coincided with the literature, as (Bilge & Yaman, 2021) mention this task in their study to be among the fundamental responsibility of the Information manager at the end of the project.

The survey results reveal that the BIM coordinator (Design) is mostly responsible for managing graphical and non-graphical activities (T15) along with clash detection of models (T24). According to (VA, 2010), the BIM coordinator is in charge of these tasks, which aligns with our survey results. Further, the task of a BIM coordinator (Construction) includes the creation of construction and as-built models (T43). (BCA, 2013), while describing the roles of BIM coordinator (Construction), states that the BIM coordinator (Construction) is responsible for these activities thus supporting the findings of the current study.

In accordance with the literature, a Model manager is responsible for conducting interdisciplinary checks and dealing with internal model reviews and interoperability issues that may arise (Sebastian, 2011). This is also supported by the results of the survey, which show broad agreement among respondents.

Further, according to (Barison & Santos, 2019; Joseph, 2011; Wang et al., 2020), the tasks such as model development and construction drawing development are the responsibility of the BIM modeler, corresponding with the survey results.

Additionally, due to the human resource challenges which might be financial or resource availability, it may be considered that some BIM roles identified in this study can be merged with the existing roles on the construction project. It is not recommended for the top pier of the BIM manager as it is the sole responsibility of the BIM manager to manage the entire BIM process but other identified roles can be merged considering that they have BIM knowledge.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Worldwide BIM implementation has not only caused a change in traditional project roles and responsibilities but also has created new BIM roles on BIM-based projects. With the increase in BIM implementation in the AEC industry multiple BIM roles have been created to address the BIM process. To systematize the contrasting and indistinct BIM roles and responsibilities description, this research investigated how BIM roles are defined in the literature and policy documents. This study highlights the BIM roles that are required for successfully implementing BIM on DBB projects, which will help developing countries in better understanding the BIM roles and BIM implementation. This study identifies the BIM-based tasks and their roles through the detailed literature review of published research and BIM guides. The BIM tasks were then distributed among the project lifecycle phases i.e., initiation, planning and design, construction, monitoring and control, and operation and maintenance. Insights on what BIM tasks are performed by which BIM roles along the project lifecycle phases were gained through the questionnaire survey. The BIM roles identified through this study are BIM manager (Design), BIM manager (Construction), BIM coordinator (Design), BIM coordinator (Construction), Information manager (Design), Information manager (Construction), Model manager, BIM modeler. The BIM tasks were further categorized in three project focus groups i.e., Process, People, and Technology (PPT), and afterward, a BIM-R&R matrix was developed with respect to the analyzed BIM roles and their tasks. The proposed matrix will explain all the BIM roles and responsibilities along with the project life cycle phases.

5.2 LIMITATIONS AND FURTHER RESEARCH

The current study is based on the BIM roles and responsibilities for the Design Bid Build project delivery method only. However, other project delivery methods could be used for further research. Moreover, from a worldwide viewpoint, it is important to standardize the BIM roles and responsibilities for the Design-Build project delivery method.

This study examined BIM guides and articles along with survey data. Further, researchers can conduct detailed interviews with the field BIM practitioners of the developing economies to get more realistic results.

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