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BIM Roles and Responsibilities in Developing Countries: A Dedicated Matrix for Design-Bid-Build Projects

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Abstract: Building information modeling (BIM) through data-rich digital representation has revolutionized the architecture, engineering, and construction (AEC) industry. BIM implementation in the AEC industry has noticeably increased over the last decade. Various BIM roles have been discussed in the literature to ease the process of BIM implementation, but the BIM roles related to project delivery methods have not been standardized. Stimulated by this need, this study develops a BIM roles and responsibilities matrix (BIM-R&R) in the context of the design−bid−build (DBB) projects for developing countries. A comprehensive literature review has been conducted, followed by a questionnaire survey comprising 105 responses. The results were analyzed to formulate a BIM-R&R matrix, on which the expert opinion was obtained from the BIM experts. The proposed BIM-R&R matrix describes all the roles and their corresponding responsibilities required along the project life cycle phases of DBB projects. The incorporation of BIM roles in the DBB procurement process will aid in the efficient management of all information and data that may be lost due to the fragmented nature of DBB. BIM roles with enhanced communication and coordination will also help in reducing time and cost overruns while maintaining a high-quality product. This study helps the associated construction industry in its efforts to implement BIM on their projects by providing a method by which to assess which BIM roles are necessary. Moreover, it will provide project and construction managers with a clear understanding of the BIM roles in DBB projects.

Keywords: building information modeling (BIM); BIM roles; BIM responsibilities; roles and responsibilities matrix

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1. Introduction

The construction industry is characterized by uncertainty due to the intricate nature of its projects [1]. To deal with the increasing intricacy of construction projects, adopting new and emerging technologies, specifications, contracting, and delivery methods have become essential [2]. Building information modeling (BIM) is among such promising technological developments that have the potential to address the challenges of the construction industry [3]. BIM provides a set of technologies and solutions aimed at improving interorganizational collaboration [4], enhancing construction quality [3,5,6], safety [6,7], sustainability [5,6], and efficiency [6,8]. In addition, BIM results in increased productivity and better design, construction, and maintenance practices [4]. Overall, BIM is a process integrated with software that influences organizational practices [9]. Comprising all the graphical and non-graphical data, BIM ensures integrating information, data management,

simulations, and analysis efforts for enhanced coordination and communication among project members [10].

Recently, BIM implementation has noticeably increased in developed countries [11,12]. Compared to other countries, the US and the UK are leading BIM adoption [13]. The adoption rate of BIM in the UK was 13% in 2011 and has increased to 69% by 2019 [11]. BIM implementation in Singapore stands at 50% [14]. In Germany, the adoption rate of BIM has reached 90% [12]. To adopt and implement BIM, international BIM specifications like publicly available specifications [15] and international organization for standardization [16] have been developed to provide specific guidance on project delivery.

Similarly, the BIM knowledge and skills framework developed by the Australian Construction Industry Forum (ACIF) provides information on the necessary skills and education for BIM implementation [17]. Likewise, several guides have been created that define the key BIM roles required for successful BIM implementation [18–21]. As an example, the New Zealand BIM handbook incorporates the role of the BIM manager [20]. At the same time, BIM-Belgian Guide for the construction industry outlines the role of the BIM process manager and BIM discipline manager [18]. Similarly, Hong Kong BIM project specification indicates BIM project manager as an important role [19]. Furthermore, each guide has developed BIM roles according to their specific usage. However, no similar BIM role title is used in the abovementioned guides. Furthermore, an important role of the BIM modeler is also missing in these guides.

Despite being adopted rapidly in developed countries [22,23], developing countries' construction industry faces challenges in BIM implementation [5,22]. Among the major challenges involved, rigid traditional work processes [10,22,24], insufficient knowledge of work practices [10,25], and extensive financing in guidance and skill needed for BIM [10,22] are common. Another key challenge is the insufficient understanding of the BIM roles and responsibilities (BIM-R&R) in the construction industries of developing countries [3,10]. Consequently, developing countries are unaware of the relevant BIM-R&R on projects. Furthermore, most developing countries use traditional project delivery methods such as design-bid-build (DBB) instead of adopting new methods [26]. Traditional delivery methods make it harder to deploy BIM because BIM-R&Rs are not defined. Thus, standardization of BIM-R&R for DBB will help better understand 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 identify the appropriate BIM personnel for BIM-enabled projects. Consequently, this can be extended to other project types in developing countries.

Worldwide, BIM implementation has caused a change in customary project roles and positions [27]. For example, in BIM-based projects, the client needs to focus their efforts on establishing the BIM process and ways to use BIM while the contractor develops digital models by using BIM tools [28]. Similarly, the architect's role is also affected due to the use of lifecycle management principles in the design process [29]. Moreover, BIM deployment has also resulted in new work practices, roles, and responsibilities [30]. Accordingly, new roles such as BIM manager, BIM coordinator, model manager, BIM modeler, and BIM technicians have been created.

Several 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 by [31]. Sebastian [29] stressed the need for a model manager as the new role within a BIM project, to provide and maintain the technological solutions required for BIM process, manage the information flow, and help stakeholders to improve their information technology skills. Similarly, Bosch-Sijtsema and Gluch [32] discussed the roles and actions of the BIM coordinator and the BIM manager in the Swedish construction industry to support the use and implementation of BIM. Another corresponding study analyzed various online BIM jobs in which 35 different BIM-related job titles were found to have distinct responsibilities [33]. Furthermore, Davies et al. [34] explained how the BIM actor roles are defined in different BIM

guides and handbooks. Overall, the literature has been highly encouraging on establishing new positions such as BIM manager, BIM coordinator, BIM modeler, and BIM strategist [30]. These BIM actors can be part of the client, architect, and contractor firms [3,35]. BSI PAS [15] highlights multiple new roles and their responsibilities for information management, such as task information manager, task team manager, interface manager, and information originator. BIM roles are evolving [27], and numerous BIM titles are available nowadays in different countries [36]. This shows a difference in the development and definition of BIM roles in the industry across countries [30].

Furthermore, BIM-professional roles are being implemented in the AEC industry as envisaged by [34]. However, these newly developed BIM-R&R are contrasting and indistinct, and the BIM professionals' role description needs to be standardized for holistic adoption [30]. This variation regarding BIM roles causes vagueness and confusion in project teams and organizations [34]. In an attempt to observe the changes that BIM brings in an organization in developing countries, such as the Brazilian construction industry, de Almeida and de Brito [37] indicates that for adopting new technology, a new BIM role such as a BIM manager should be appointed to avoid difficulty in its implementation. The Malaysian building industry's BIM project guide proposes appointing a BIM manager to handle and manage the associated information [38].

Similarly, Hafeez [39] discussed that no role and responsibilities are defined in the employer's information requirements (EIR) for construction projects in Qatar. Nevertheless, it can be observed from the abovementioned studies that the role of the BIM manager is primarily identified for developing countries, and the responsibilities of this role are yet to be defined. This helps conclude that the empirical research on BIM roles, tasks, and perceived responsibilities in the AEC industry is lacking in developing countries, particularly with the traditionally used project delivery methods.

To address this gap for developing economies, the present study aims to define the BIM-R&R in traditional project delivery methods, commonly used in most developing economies, i.e., DBB. Research objectives that form the basis of this research study are:

1. to identify and analyze the existing BIM-R&R for developing countries;
2. to determine the BIM-R&R for DBB projects in developing countries; and
3. to develop a matrix for the adoption of relevant BIM-R&R in developing countries.

This research paves the way for BIM adoption in developing countries by providing clarity for the developed BIM roles and their corresponding responsibilities on a project during its lifecycle. This study will help the associated construction industry in its efforts to implement BIM on their projects by assisting them in their practices. This study will provide the construction industry with a method to assess which BIM roles are necessary for projects. Moreover, it will give project and construction managers a clear understanding of the BIM roles on projects.

The BIM actor roles have been discussed in previous studies, either as a review or such roles are defined differently depending upon the industry, region, and country. Similarly, BIM guides are established by the developed economies in accordance with the particular BIM use by the relevant authority for the state or specific projects. Moreover, no study has empirically compiled all the roles employed in a project, nor has any study compiled BIM roles specific to a certain delivery method. Furthermore, no research has been conducted on BIM's role in developing countries. BIM is gaining interest in developing economies, but they lack the idea of roles and responsibilities associated with BIM. Thus, to close the gap, this study provides BIM-R&R for prevalent project delivery methods in developing countries, which speaks to the novelty of this study.

The rest of the paper is organized as follows. The importance of roles and responsibilities in the construction industry and the roles and responsibilities associated with BIM are discussed in light of the literature and past research in the following section. This is followed by the description of the methodology used, the demonstration of results from the questionnaire survey responses and validation, and the conclusion.

2. Literature Review

2.1. Importance of Roles and Responsibilities in the Construction Industry

Construction projects involve unique and complex processes [40]. Within a project, each activity necessitates a different level of managerial focus and skillsets [41]. The project's intricacy also increases due to the involvement of different parties and stakeholders who must effectively communicate to achieve the overall project objectives [42]. Thus, the complex construction project delivery comprises various disciplines and roles [29]. Similarly, distinct roles and responsibilities of the project teams are required at each phase of the project lifecycle [43]. A clear definition of the roles and duties of a project team is vital to avoid problems and conflicts and ensure project success through greater collaboration and openness [40,44]. Anantatmula [45] proposes that well-defined roles and responsibilities pave the way for building teamwork, managing conflicts, and improving project performance. According to Hoda and Murugesan [46], effective project team management requires understanding team members' roles and outlining responsibilities.

Studies show that clearly defined roles and responsibilities of the construction project team significantly impact project outcomes and performance [45,47]. This highlights that unclear roles and responsibilities can lead to conflicts and failure to meet the client's requirements, ultimately resulting in project failures [48]. Furthermore, Masengesho et al. [49] highlight the roles and responsibilities of project consultants in developing economies that influence the project's success or failure. Additionally, the project manager's role is important in achieving the project's success [50,51]. However, this role is still ambiguous in developing countries [52]. Thus, it is not surprising to see many projects failing in developing countries due to improper allocation and understanding of project roles and responsibilities.

2.2. Design-Bid-Build Project Delivery

The traditional delivery method, design-bid-build, typically entails a process whereby design and contractor teams enters into a separate contract with the client to carry out the design and construction work, respectively [53]. In DBB, each task is completed one after the other without any overlap [54]. By using the competitive bidding, DBB exhibits the better cost performance [55] and is preferred over other delivery methods because of its higher productivity and lower cost [56], and the client's desire to keep control of the project [55]. However, because of the fragmented approach of the design and construction phases, problems such as design and information issues, cost overruns, and poor project performance can be avoided by using BIM because all the project participants can easily share and reuse various information owing to BIM [57]. In addition, BIM has also helped in minimizing the design change orders and delivering better design [24].

2.3. Building Information Modelling in the Construction Industry

Organizations are increasingly turning toward BIM to improve project performance [28]. Due to its integrated design, construction, and maintenance approach, BIM provides simpler solutions to the complex nature of construction projects [58]. BIM incorporates multiple aspects, disciplines, and structures, making it favorable for most construction stakeholders [7,10]. By using a digital representation of a facility's physical and functional properties, BIM helps the users share and use design data and requirements between different software applications across a multidisciplinary team [4]. Due to the excessive information exchange between parties, BIM's support for collaboration has become an important requirement [59].

BIM provides easy sharing and reusing of different types of information between all project parties [57]. For example, the project team collects, manages, and documents graphical and non-graphical data through a single information source by using BIM [15]. Sharing the data in a central place makes the expected result clearer, concise, and understandable for all the team members [60]. Moreover, establishing collaborative practices on construction projects are likely to involve the coordination and integration of complex

information, procedures, and systems [61]. Therefore, BIM allows better communication among project stakeholders [32] and influences how they work and collaborate [59].

BIM has benefited developing economies by reducing design change orders and improving design [24]. Al-Ashmori at al. [62] highlighted increased productivity and efficiency as one of the important benefits of implementing BIM in Malaysia. Similarly, as [12] discussed, BIM adoption results in increased profit, reduced cost and time, and improved relationships between the client and customer.

2.4. BIM Roles and Responsibilities

BIM has infiltrated the practices of a large number of interdisciplinary professionals [63]. Studies acknowledge that BIM alters project team members' roles and responsibilities, including that of the client, designers, and contractors [28,29,63]. Another 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 [63]. Sebastian [29] also discussed that the BIM projects demand the continuous emergence of BIM roles for construction professionals and highlight the need to evolve the roles among clients, designers, and contractors.

In addition to evolving with technology, new BIM-R&R have also been established within the construction industry [3]. Jacobsson and Merschbrock [6] state that the appearance of formal BIM professional roles was among the preliminary and noticeable changes observed due to the initiation of BIM. Owing to the increasing adoption of BIM within the construction industry, numerous BIM-related roles have emerged, such as BIM manager (VDC manager), BIM facilitator, BIM coordinator, BIM project manager, design team BIM manager/construction BIM manager, project model manager, BIM process manager, BIM lead coordinator, BIM discipline manager [34]. However, [64] states that the BIM manager, BIM coordinator and BIM modeler roles are considered as the three most important BIM roles required on a BIM-based project, in addition to the numerous BIM roles available. These newly formed roles and responsibilities ensure the organization's transformation to BIM-based methods and BIM-enabled projects [3].

The US Veterans Affairs BIM Guide [21] defines BIM manager and discipline BIM coordinator's responsibilities. It indicates that these roles are at the core of every BIM project. Similarly, the Singaporean BIM guide [65] emphasizes that two BIM professional roles, BIM manager and BIM coordinator, are recognized for facilitating the BIM process during the design and construction phases. The Norwegian Home Builders' Association acknowledges the BIM coordinator as a key BIM role [66]. BSI PAS [15] defines the roles of task information manager, task team manager, interface manager, and information originator for BIM-based information management. Furthermore, the information manager role is also mandated in the Construction Industry Council BIM protocol. Information management is important in the level 2 BIM process [67]. Similarly, BIM roles of BIM manager, BIM coordinator, and BIM modeler are also recognized by [42] for improving the stakeholders' relationship. Furthermore, Bilge and Yaman [68] explained the significance of information management in BIM and integrated project delivery (IPD) real estate projects. The authors defined the extended responsibilities of the information manager and information coordinator along the project lifecycle.

Though widely focused these days, BIM roles may not be as clear as needed so far. For example, Mathews [36] claimed that the industry is confused about the meaning and interpretation of three BIM roles, i.e., BIM manager, BIM coordinator, and BIM technician. Similarly, Davies et al. [34] studied how 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, which causes confusion. Other studies show that BIM manager and BIM coordinator roles are blurred, and their tasks are comparable [27,30,32]. Likewise, Zanni et al. [69] indicates that clash detection will be the responsibility of either the BIM manager or BIM coordinator, creating tensions between these roles. Jacobsson and Merschbrock [6] highlight that the BIM coordinator

is mainly responsible for clash detection. However, Davies et al. [34] states that the BIM coordinator role is secondary and is led by the BIM manager.

Similarly, whether the BIM coordinator acts as a third party or comes from a design or construction firm, the unique and dedicated role in managing BIM projects is becoming necessary for most projects [59]. Furthermore, Wang et al. [42] noticed that the responsibilities of a BIM modeler are comparable to those of a BIM coordinator. In the information management domain, Bosch-Sijtsema [70] states that BIM facilitators manage the information and communication flow. However, Jacobsson and Merschbrock [6] state that the BIM coordinator is mainly responsible for managing information and communication flows. In comparison, BIM documents emphasize that the information manager is required for information-related activities [15,67]. Thus, there exists a fair confusion between the responsibilities of different BIM roles.

Different interpretations of identical roles are visible depending on the standards followed in each scenario [34]. With the increase in BIM-based projects, BIM-based roles and titles have also increased, which has resulted in increased nomenclature. However, there is still an ambiguity in the industry about the meaning and description of the discussed BIM roles. With so many different positions held by the diverse participants, it has become very important to define BIM roles for successful BIM implementation in the AEC industry [34].

This confusion around the BIM roles may further jeopardize the developing countries' construction industry, where stakeholders' clashes and imbalanced responsibilities assignments are common. Moreover, the lack of awareness regarding BIM-R&R in developing countries further adds to the adversities of the failures of BIM-based projects. The increase in BIM-based projects in developing economies necessitates a thorough understanding of the BIM roles. Therefore, BIM roles and responsibilities must be studied and investigated in the context of developing countries providing impetus to this study.

3. Research Methodology

A three-step process has been adopted in this study, as displayed in Figure 1. The subsequent sections thoroughly explain the research methodology.

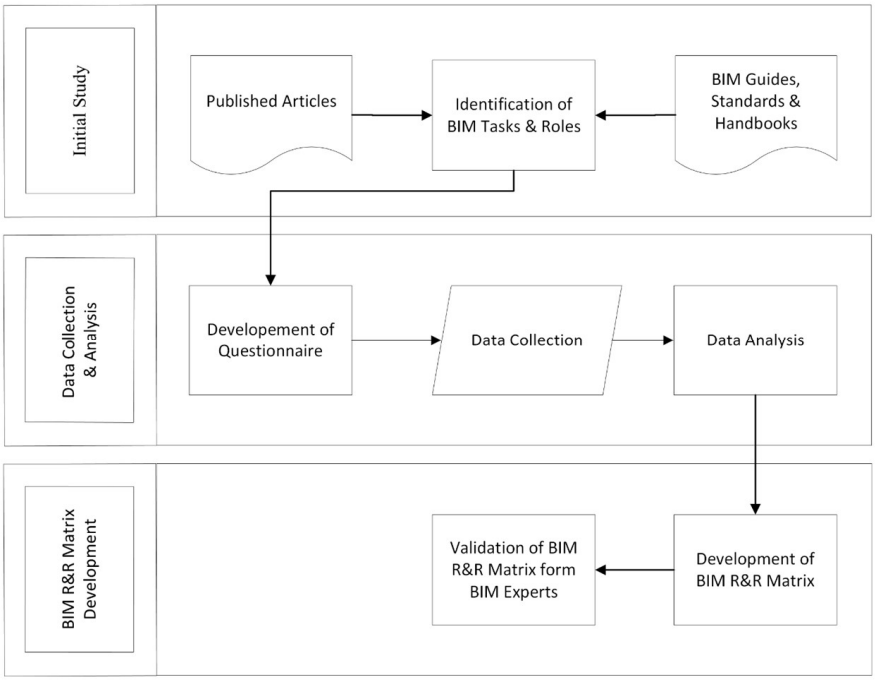

Figure 1. Research methodology.

3.1. Identification of BIM Tasks and Roles

To address the research gap and identify the BIM-based roles and responsibilities, a two-step literature review was carried out. In the first step, the BIM guides, standards, and handbooks were searched online on Google & Microsoft Bing search engines by using the keywords "BIM guides", "BIM standards", "BIM Handbooks" and "National BIM guides/standards/handbooks" until the present. The idea was to gather the maximum data possible for the study. This resulted in a total of 52 retrieved BIM guides/handbooks. As a screening step, their introduction and contents were read to identify the roles and responsibilities within, reducing it to 29 relevant documents. In the second step, published articles were searched online by using keywords including "Building Information Modelling", "BIM", "BIM roles", "BIM responsibilities", "BIM professional roles" and "BIM tasks" by using the ASCE, Web of Science, and Scopus libraries, Science Direct, Google Scholar, Taylor and Francis Online, and Emerald Insight following [55,71]. The search strings were formalized by combining the word "construction" with the Boolean operators AND/OR. The research publications only in the English language were considered in this study. Initially, 113 papers were retrieved related to BIM roles in the construction industry from 2010 to 2022, out of which 48 duplicated papers were eliminated and were counted only once. Furthermore, 25 papers were removed that were not related to BIM roles and responsibilities and focused on other aspects of BIM roles such as competencies, leaving 37 papers focused on BIM roles. To extract the most relevant papers, the keywords mentioned above were used in the search string of articles to look up the discussion regarding BIM roles and tasks. The papers having information about BIM-R&R were scrutinized and accessed individually, which resulted in the 26 shortlisted articles being analyzed further. Therefore, 29 BIM guides and 26 shortlisted research papers resulted in 55 relevant documents utilized in this study as shown in Figure 2.

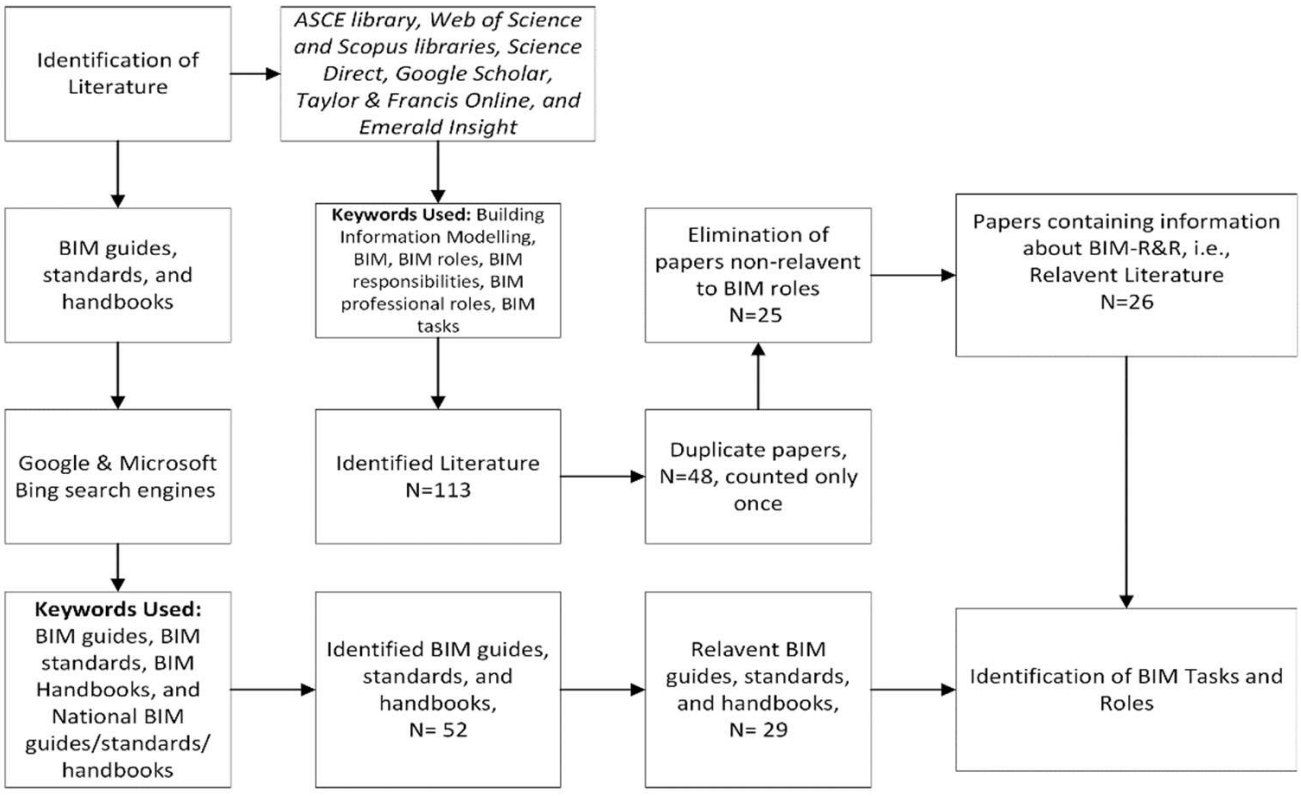

Figure 2. Identification of BIM tasks and roles though literature.

The BIM-based tasks and their roles were extracted from the BIM documents and the published articles and then scrutinized in two steps. In the first step, extracted tasks

were arranged alongside the project lifecycle phases used in BIM-based projects: initiation, planning and design, construction, monitoring and control, and operation and maintenance as envisaged by multiple BIM studies [9,72–75]. As a result, 555 BIM-based tasks were identified in five project phases. Upon scrutiny, the identical tasks were merged, resulting in 125 shortlisted BIM tasks. Depending on their significance, these BIM tasks were then classified into primary and secondary tasks. The primary category contained more exclusive tasks in terms of BIM and was performed by BIM personnel. Whereas the tasks and roles that are part of the project phases, even without BIM implementation, were placed in the secondary category. This exercise identified 82 BIM tasks in the primary category and 43 tasks in the secondary category.

In the second step, BIM roles were identified for each corresponding task depending on their frequency of appearance in the shortlisted documents. A maximum of the top three roles was selected for a task. The same role was selected for the tasks where only one role was mentioned in the literature. However, the most frequently used (top three) roles were chosen for the tasks with multiple roles. It was observed that approximately 50 tasks have only one role identified. This was because the tasks have only appeared once in the literature, or only one role has appeared frequently 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. Consequently, the BIM roles were separated for the design and construction phases considering the DBB project delivery method. All the selected roles and primary tasks formed the basis for the questionnaire development, as shown in Table 1.

Table 1. Identified BIM tasks and roles.

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected Refs
T1	Initiation	Facilitate the development of a project BIM brief	BIM manager (design)	[20]
T2		Define, complete and update the BIM execution plan	BIM manager (design), BIM coordinator (design)	[3,76]
T3		Identify BIM standards	BIM manager (design), BIM coordinator (design)	[3,77]
T4		Facilitate the identification and implementation of BIM standards	Model manager	[35]
T5		Define project BIM protocols	BIM coordinator (design), BIM facilitator (design)	[3,78]
T6		Establish project information requirement and information protocols	Information manager (design)	[68]
T7		Coordinate BIM tasks in design discipline	BIM coordinator (design)	[34]
T8		Provide guidelines to the team on agreed project rules	BIM coordinator (design)	[34]
T9		Provide design guidelines to the team on project rules as agreed	Model manager	[79]
T10		Communicate BIM vision to the team	BIM manager (design)	[80]
T11	Planning & Design	Establish asset information requirements and the process to maintain the asset information model	Information manager (design)	[68]
T12		Coordinate and organize BIM training and workshops	BIM manager (design), BIM coordinator (design), BIM facilitator (design)	[32,81]

Table 1. *Cont.*

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected Refs
T13	Planning & Design	Coordinate modeling standards among the project team	Model manager	[79]
T14		Manage all the graphical model development related tasks and non-graphical model development related tasks in accordance with BIM execution plan	BIM manager (design), BIM coordinator (design), BIM facilitator (design)	[30,77]
T15		Create, coordinate & extract design drawings from BIM models	Model manager, BIM modeler	[35]
T16		Coordinate all technical discipline and trade-specific BIM activity, i.e., tools, content, standards, requirements	BIM coordinator (design)	[76,81]
T17		Lead the BIM documentation and analysis efforts of the internal project team	BIM coordinator (design)	[21,82]
T18		Perform internal model reviews and interdisciplinary checks	Model manager	[35]
T19		Oversee the fully integrated set of project models from all disciplines	BIM manager (design), BIM coordinator (design)	[42,83]
T20		Coordinate multidisciplinary tasks	BIM manager (design), BIM coordinator (design), Model manager	[77,84]
T21		Assure assembling of merged models	BIM manager (design), BIM coordinator (design), BIM facilitator (design)	[78,85]
T22		Assure and inspect the functionality of merged models and the integration of the design models	Model manager	[79]
T23		Carry out clash detection and resolution activities	BIM manager (design), BIM coordinator (design), Model manager	[84,86]
T24		Manage model transfer and version control	BIM manager (design)	[20]
T25		Schedule, coordinate, and facilitate BIM meetings for the design and construction team as well as all design disciplines	BIM manager (design), BIM coordinator (design)	[66,77]
T26		Participate and coordinate in internal BIM meetings	Model manager	[79]
T27		Prepare project outputs and revise them regarding quality assurance (QA) and quality control (QC) protocols	Model manager, BIM modeler	[87]
T28		Assist in the preparation of project outputs	BIM manager (design), Information manager (design)	[34,67]
T29		Coordinate with the construction manager on the BIM execution plan	BIM manager (design)	[84]

Table 1. *Cont.*

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected Refs
T30	Construction	Create BIM execution plan in coordination with the design team	BIM manager (construction), BIM coordinator (construction)	[82,88]
T31		Establish software protocols for efficient BIM delivery	BIM manager (construction)	[21,77]
T32		Coordinate software training	BIM manager (construction)	[21,77]
T33		Coordinate sub-contractor BIM development	BIM manager (construction)	[82]
T34		Integrate and coordinate the construction schedule with developed models	BIM manager (construction)	[84]
T35		Integrate 3D fabrication models with the updated design model to ensure compliance with the design intent	BIM manager (construction), BIM facilitator (construction)	[78,82]
T36		Carry out clash detection and resolution activities	BIM manager (construction)	[82,84]
T37		Schedule, coordinate, and facilitate BIM meetings for the design and construction team and all design disciplines	BIM manager (construction), BIM coordinator (construction), BIM facilitator (construction)	[77,89]
T38		Update models for shop drawings development	BIM coordinator (construction)	[82,89]
T39		Create construction and as-built models	BIM coordinator (construction)	[65]
T40		Prepare as-built BIM	Model manager	[29]
T41		Coordinate data extraction sets	BIM manager (construction), BIM facilitator (construction)	[77,78]
T42		Coordinate model commissioning and data handover	BIM manager (construction)	[82]
T43	Monitoring & Control	Implement and manage the BIM process, i.e., the BIM execution plan	BIM manager (design), BIM manager (construction), BIM manager (design and construction)	[35,84]
T44		Participate in the updating of the BIM plan	Model manager	[79]
T45		Ensure compliance with the BIM execution plan	BIM manager (design and construction), BIM coordinator (design and construction)	[34,77]
T46		Ensure compliance with standards	BIM manager (design), BIM coordinator (design), Task information manager	[15,87]
T47		Ensure BIM protocols implementation	BIM coordinator (design), Information manager (design)	[3,67]
T48		Verify that all necessary configurations required for the seamless integration of design and construction model information have been implemented	BIM manager (design)	[77,82]
T49		Ensure the accuracy of construction documents in accordance with discipline BIM modeling	BIM modeler	[89]
T50		Ensure document management	BIM manager (design)	[21,34]

Table 1. *Cont.*

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected Refs
T51	Monitoring & Control	Ensure software installation, operation, and version control	BIM manager (design and construction), BIM facilitator (design and construction)	[21,34]
T52		Ensure software operation	Model manager	[87]
T53		Develop & maintain graphical and non-graphical models in accordance with the BIM execution plan	BIM modeler	[59,90]
T54		Monitor model production and updating	BIM coordinator (design and construction), BIM facilitator (design and construction)	[6,91]
T55		Manage model production and updating	Model manager	[35,90]
T56		Brief, assist, and coordinate with stakeholders	BIM manager (design and construction), BIM coordinator (design and construction)	[20,42]
T57		Assist in coordination with stakeholders	Model manager	[29]
T58		Communicate/Coordinate BIM issues with other members	BIM manager (design and construction), BIM coordinator (design and construction)	[20,92]
T59		Manage the BIM resources (hardware, software, and people)	BIM manager (construction)	[35]
T60		Ensure BIM is used appropriately to test design requirements/criteria	BIM manager (design), BIM facilitator (design)	[78,82]
T61		Perform and manage the QA and QC of models	BIM manager (design), BIM coordinator (design)	[34,93]
T62		Look after design discipline-based QA and QC of models	Model manager	[79]
T63		Coordinate update of as-built conditions in the final model deliverable	BIM manager (construction)	[21,91]
T64		Adhere to the projects BIM deliverables and their submission	Model manager	[90]
T65		Ensure final BIM deliverable requirements are achieved	BIM manager (design)	[21,77]
T66		Maintain local file transfers, control of access lefts, and compilation of information from smaller models of other members	Model manager	[35]
T67		Manage digital outputs, data transmission, and archiving	BIM manager (design), Information manager (design), Model manager	[94]
T68		Facilitate, plan, and manage interoperability issues	Model manager	[29,35]
T69		Manage interoperability issues	BIM coordinator (design), BIM facilitator (design)	[6,70]
T70		Enable integration and coordination of information within the information model	Information manager (design), Information manager (construction), Information manager (design and construction)	[15]

Table 1. *Cont.*

Task ID	Project Phases	BIM Tasks	Top Roles from Literature	Selected Refs
T71	Monitoring & Control	Coordinate to assure completeness of interoperability information	BIM manager (design), BIM manager (construction), BIM manager (design and construction)	[21,77]
T72		Ensure interoperability information is provided for milestone submittals	BIM manager (design), BIM facilitator (design)	[21,91]
T73		Liaise with the client's facilities management department to determine specific data and file exchange requirements	BIM manager (design)	[76]
T74		Maintain exchange information requirements	Information manager (construction)	[68]
T75		Initiate and implement the project information plan and asset information plan	Information manager (design)	[68]
T76		Enable reliable information exchange through a common data environment	Information manager (design)	[68]
T77		Manage the processes and procedures for information exchange on projects	Information manager (design)	[68]
T78		Ensure that the information exchanged between the different stakeholders corresponds to the rules fixed by the contract	BIM manager (design)	[18]
T79	Operation & Maintenance	Archive the project information model	Information manager (construction)	[68]
T80		Ensure information and model availability for operation and maintenance	BIM coordinator (construction)	[66]
T81		Identify assets (model and physical) and the foreseeable trigger events for which information should be managed	Information manager (construction)	[68]
T82		Capture lessons learned for future projects	Information manager (construction)	[68]

3.2. Data Collection and Primary Analysis

Data in this research were collected through a questionnaire that was developed by using the identified BIM tasks and their relevant roles from both the published articles and BIM guides. The questionnaire aimed to identify BIM roles for the BIM-based tasks in construction projects using the DBB project delivery method in developing countries.

The questionnaire has two sections. The first section inquires about the respondent's demographic and organizational information, such as their role, country of organization, designation, and experience. The second section identifies the most appropriate BIM role for each BIM task. For the tasks where more than one role was identified from the literature, respondents were asked to choose from the given roles or to mention any other role. However, for the tasks for which only one role was identified through the literature, an option was given to either select the same role or to mention another deemed appropriate by the respondents. Thus, the respondents had a choice in selecting the role for each task. The questionnaire was circulated in the construction industry of developing and developed economies. The reason for approaching both developed and developing countries is that developed countries are more experienced in implementing BIM and have a better understanding of the BIM process. Furthermore, DBB methods are still used for some projects in developed countries, so their opinion is relevant. It was also important to get

the point of view from developing countries, as they have begun implementing BIM in line with the main aim of this study. The targeted respondents from the construction industry include BIM managers, project and construction managers, BIM coordinators, and BIM modelers.

Additionally, employees from the consultant and contractor firms were approached with a minimum of three years of BIM experience for more credible responses. The questionnaire was circulated online via official organizational emails and professional networks such as LinkedIn for four months between July 2021 and October 2021. As a result, 105 valid responses were obtained from the 200 professionals contacted to fill the questionnaire, yielding a response rate of 52 percent.

Following the statistics mentioned by [95], a sample size of 105 responses was considered adequate to represent a population of 200 million. The demographic information of the respondents is mentioned in Table 2.

Table 2. Demographic information of respondents.

Demographic Variables		Numbers	Percentage (%)
Organization type	Client	5	5
	Design consultant	39	37
	Supervisory consultant	3	3
	Contractor	28	27
	Architect	18	17
	Other	12	11
Role in organization	Project manager	2	2
	Construction manager	3	3
	BIM manager	43	41
	BIM modeler	21	20
	BIM coordinator	28	27
	Other	8	7
Year of experience with BIM	1–3	28	27
	3–6	32	31
	6–9	23	21
	9–12	10	10
	Above 12	12	11

The highest number of responses were received from Asia (58%), as shown in Figure 3. Moreover, the maximum number of responses were received from India in the Asian continent. Similarly, the top countries from the continents where the majority of responses were obtained are Egypt from Africa (corner of Africa and Asia), France from Europe, Canada from North America, Ecuador from South America, and Australia from Oceania. According to the findings of the [96] study, BIM adoption in Asia is perceived to be comparable to that of any other developed continent, which confirms the higher response rate from Asia in this study.

It can be clearly seen in Table 2 that most of the respondents were working with consultants (40%), followed by the contractor organizations (27%) as they are the primary stakeholders and are more familiar with implementing BIM. Moreover, BIM manager (41%) and BIM coordinator (27%) were the key BIM positions held by these respondents. Thus, the respondents held important BIM positions in their respective organizations. Furthermore, 34% of the respondents worked in technical BIM jobs like BIM modeler and management jobs such as project manager and construction manager. Furthermore, 83% of the respondents had less than 10 years of experience. The main reason is that BIM is a relatively new technology gaining experience with time [97]. Consequently, most of the direct BIM experience is expected to be limited [55].

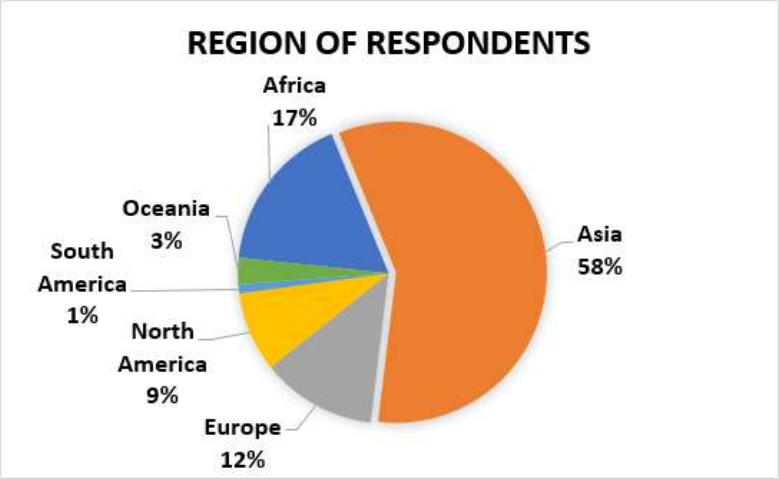

Figure 3. Demographic information of respondents.

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.

4. Matrix Development for BIM Roles and Responsibilities (BIM-R&R)

The collected data was used to develop a matrix for implementing BIM-R&R 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-R&R can be developed. This was done to identify the key groups and relate them to the tasks 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 [98–100]. 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 [101]. Dawood and Vukovic [102] also used PPT to classify BIM information flow during the project lifecycle processes. Davies et al. [34] also used the same categorization to classify the BIM activities. These articles assist in getting an idea about how the groups of PPT can be used to classify BIM tasks. A detailed overview of the PPT groups, project participants, and tasks associated with different project phases is provided in the Supplementary excel sheet attached as Supplementary Data to this article.

Following this, a BIM-R&R matrix is developed along the project lifecycle phases by using the PPT groups, as shown in Figure 4. 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 horizontally and vertically. Project lifecycle phases are shown horizontally, and focus groups are shown vertically. BIM tasks are grouped between the vertical and horizontal categories. Different color combinations are used to distinguish between different BIM personnel to whom BIM tasks are assigned. These include 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 Table 1, whereas the coloring represents the BIM person responsible for performing these tasks. For example, T1 represents task 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.

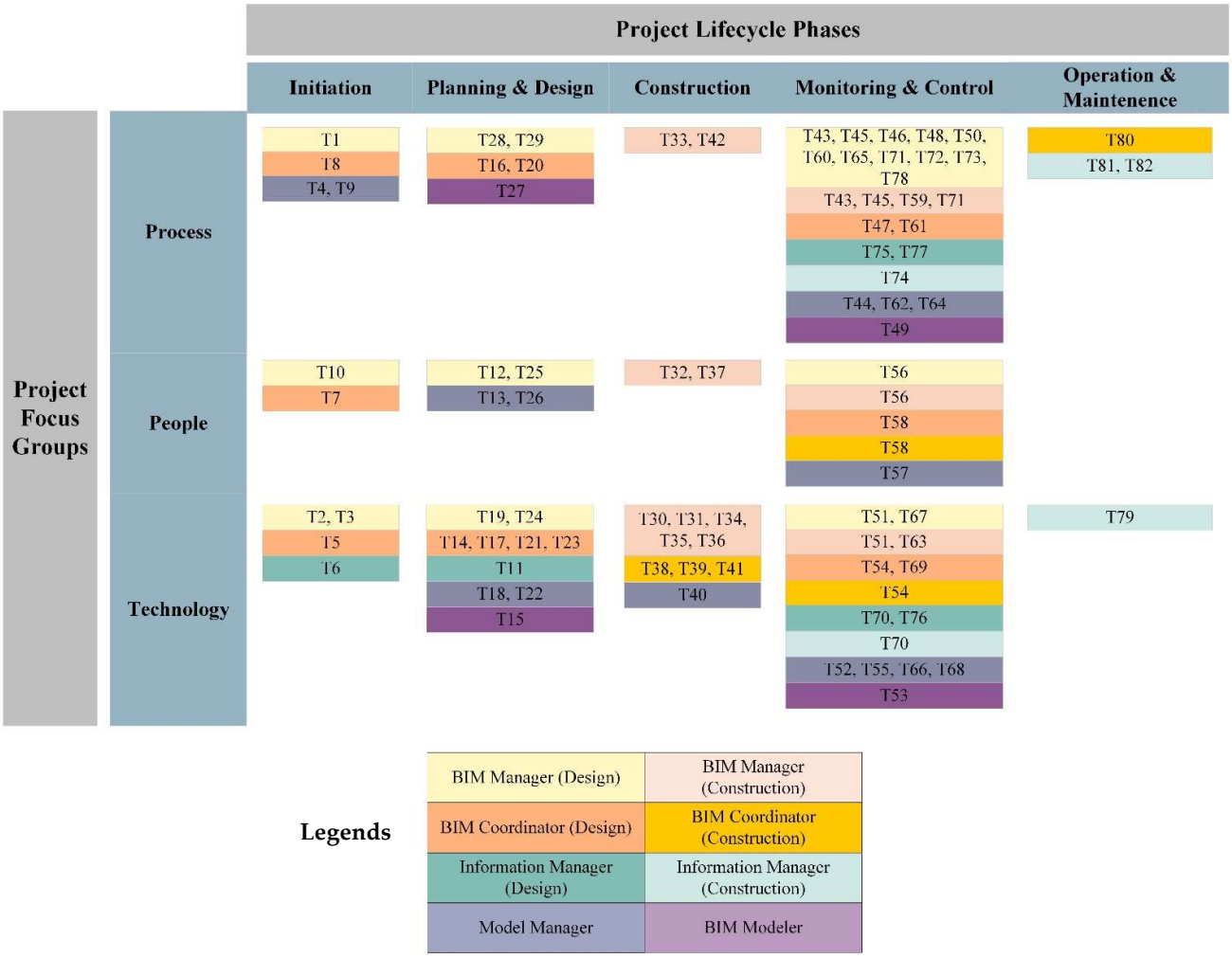

Figure 4. Proposed BIM-R&R matrix. Please note the different colors correspond to the color of the BIM roles and responsibilities provided in the legend section under the matrix.

5. Results

This paper presents a matrix to define BIM-R&R 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. In contrast, no study has been conducted for applying BIM-R&R to 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, wherein the roles of BIM manager, BIM coordinator, and information manager are prevalent. The survey results indicate that the 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.

6. Discussion

According to the results, the BIM managers for design and construction have different roles, 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), whereas 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 the BIM execution

plan in coordination with the design team (T31), respectively. These findings can be verified from [76,103], which outlines the BIM manager (design) responsible for defining the BIM Execution Plan (BEP) for all the planning, design, and supervision activities related to a project. On the other hand, Florida International University (FIU) [84] assigns the BEP creation for the project's construction phase to the BIM manager (construction), who oversees all aspects of construction. This shows the harmony of the obtained responses with the published sources.

Similarly, some important technical tasks for BIM managers (design) and (construction) include overseeing the fully integrated set of project models from all disciplines (T20) and integrating and coordinating the construction schedule with developed models (T34), respectively. Most of the technical tasks are identical to the tasks defined in various BIM guides and articles that fall under the responsibility of the BIM manager [31,83,84,104]. The results of the current study clarify this confusion by correctly assigning the tasks to the BIM manager of the design and construction teams.

There were also instances in which 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 [34] or information manager [105]. Because the responses are provided for DBB projects which bifurcates the responsibilities of the consultant and the contractor, this confusion is also negated. Accordingly, most respondents believe it to be the responsibility of the BIM manager (design), which seems logical because 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, this survey will help the stakeholders assign the roles with more clarity on their projects.

In this study, information management tasks are also divided between the Information manager (design) and the information manager (construction). According to [34], 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 in addition to maintaining the information requirements during execution. This result also coincided with the literature, as Bilge and Yaman [68] mentioned this task to be among the fundamental responsibility of the information manager at the end of the project.

The results further 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 [21,69], the BIM coordinator is in charge of these tasks, which aligns with the current study's results. Furthermore, the task of a BIM coordinator (construction) includes the creation of construction and as-built models (T43). Building and Construction Authority (BCA) [65] while describing the roles of the BIM coordinator (construction), states that the BIM coordinator (construction) is responsible for these activities, thus supporting the findings of the current study.

According to the literature, a model manager is responsible for conducting interdisciplinary checks and dealing with internal model reviews and possible interoperability issues [29]. This is also supported by the survey results, which show broad agreement among respondents. Furthermore, according to [35,42,89], the tasks such as model development and construction drawing development are the responsibility of the BIM modeler, corresponding to the survey results.

Furthermore, the CIC BIM protocol suggests that the information manager be in charge of assisting in the preparation of project outputs [105]. The respondents, however, contrarily believe it to be the responsibility of the BIM manager (design). This makes sense as the task will be more effectively led by the BIM manager. Additionally, the roles for information management are also suggested by PAS as being crucial for the project [15]. This study

includes the information manager role as well, but due to the DBB's bifurcated nature, it is divided into the Information manager (design) and the information manager (construction).

Furthermore, it is observed that in contrast to the literature of developed economies, where multiple roles such as BIM manager, BIM coordinator, and information coordinator are identified for tasks such as define, complete, and update the BIM execution plan (T2), the respondents of the study clearly choose BIM manager (design) for this job in developing countries. Similarly, for the task of carrying out clash detection and resolution activities (T23), the literature identifies BIM manager, BIM coordinator, and model manager, whereas survey respondents select BIM coordinator (design) for DBB projects in developing countries. Thus, apart from the differences in BIM roles for a task, the study clearly identifies BIM roles needed for DBB projects in developing economies.

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 role of the BIM manager, as it is the sole responsibility of the BIM manager to manage the entire BIM process. However, other identified roles can be merged, considering that the person in this role has BIM knowledge.

6.1. 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 by using the triangulation technique. 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. Due to a large number of tasks, the experts were sent a PDF file. The 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 the intention of validating the matrix. After receiving their consent to validate the matrix, the PDF file was provided to them to give their opinion on it. Accordingly, an expert from one developed and two developing countries are engaged in the validation. Table 3 shows the demographics of the consulted experts.

Table 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 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 the questionnaire's 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. Consequently, the initial task is correct, and its placement was not changed.

Similarly, 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 information manager role 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 [15,67]. Such requirements are more pronounced in developed countries where information management is considered a high-priority task. Therefore, such a position is retained in the current study to have a holistic matrix. Moreover, one respondent recommended the representation of the proposed BIM-R&R in the form of a matrix. The said BIM-R&R matrix is developed to address this suggestion, and its expansion is provided in the Supplementary File with this article.

6.2. Study Implications and Contributions

This study has proposed a BIM-R&R matrix that will explain all the BIM roles and responsibilities required for the DBB project delivery methods along the project life cycle phases of BIM in construction projects of developing countries. The BIM-R&R matrix will help with 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 BIM-based project. Moreover, the BIM-R&R matrix will eventually help in identifying the right and appropriate BIM personnel for BIM-enabled projects. Furthermore, this matrix will assist managers in training their employees for the required role, if necessary.

7. 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 developed economies, multiple BIM roles have been created to address the BIM process. To systematize the contrasting and indistinct BIM-R&R description, this research investigated how BIM roles are defined in the literature and policy documents. This study highlights the BIM roles required for successfully implementing BIM on DBB projects, which will help developing countries better understand the BIM roles and implementation. Insights on what BIM tasks are performed by which BIM roles were gained through the questionnaire survey.

The survey results help selects appropriate BIM roles for the BIM tasks. 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, and BIM modeler.

The current study humbly attempts to uplift the BIM implementation status in developing countries by providing a definition and matrix to assign tasks to different BIM experts and roles in DBB projects. It will help the relevant construction and project managers assign tasks, duties, and responsibilities to the BIM professionals and achieve more stakeholders' satisfaction through transparent, clearer, and well-defined information-sharing mechanisms.

The current study is limited by its number of respondents, more focus on developing countries, and a single type of project delivery (DBB). In the future, this can be extended to include other more advanced and collaborative project types such as public–private partnerships, alliances, and joint ventures. In addition, this study examined BIM guides and articles along with survey data. Furthermore, researchers can conduct detailed interviews with the field BIM practitioners of developing economies to get more precise results.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/buildings12101752/s1. The attached Excel sheet provides the detailed BIM-R&R matrix representing the proposed BIM-based roles and their corresponding responsibilities.

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