Identification of Workflow in Construction Projects in Cambodia

With and Without Building Information Modeling/ Models/ Management Approaches

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Abstract*—Cambodia's construction industry is overgrowing but faces challenges like cost overruns and delays. This study explores collaboration in construction projects involving project owners, designers, and contractors, including architecture, structure, mechanical, electrical, and plumbing disciplines. The semi-structured interviews were conducted with 16 participants, focusing on coordination, communication, and co-production. Two construction projects with and without Building Information Modeling (BIM) approaches were also observed. Our findings identified four workflow scenarios linked to different interaction actors' categories. The study demonstrated that the degree and timing of collaboration among project owners, designers, and contractors were the primary factors influencing the workflow scenarios in the Cambodian construction sector. Most participants were unfamiliar with BIM and did not apply it to their projects. Traditional project delivery methods remained prevalent, even in large-scale projects. Participants lacked a common language regarding BIM, hindering effective collaboration. It became evident that there was a lack of willingness to align knowledge and practices to enhance project value. To promote BIM collaboration within Cambodia's construction sector, we recommend the development of a centralized collaboration guideline tailored to architects, engineers, contractors, and project owners.

Keywords-collaboration; workflow; construction; Cambodia; BIM.

I. INTRODUCTION

This paper is an extension version of the COLLA 2023 conference paper [1], which added a research question: "How can we facilitate and support Building Information Modeling (BIM) enabled collaboration in Cambodia's construction sector?" To answer this, we extended experiments by observing two construction projects in Cambodia: one that BIM has not been used and one that BIM has been used. Moreover, we specifically explained our protocol.

The construction industry is pivotal in driving Cambodia's economic growth, contributing 9.1% to the country's total Gross Domestic Product (GDP) in 2018 [2]. Over the past few decades, the number of foreign investors, including those from China, South Korea, Japan, Europe, and America, has increased [3]. These investments have primarily targeted infrastructure development and urbanization, resulting in a remarkable construction sector expansion over the last [4][5].

However, despite this significant growth, many construction projects in Cambodia have grappled with poor cost management and project schedule performance [6]. It's worth noting that these challenges are not unique to Cambodia but are prevalent in contemporary construction projects worldwide [7]. The construction sector needs to improve its efficiency, which leads to decreased cost and improved project performance at various stages of the project life cycle.

Previous research has underscored the critical role of collaboration in ensuring the success of construction projects [8]. Meanwhile, effectively managing collaboration among various specialized actors involved in construction project development remains challenging [7]. To address these issues and improve the project performance, it is imperative to ascertain the current state of the collaborative process within the sector.

The three main parties driving construction development are the project owner, the designer, and the contractor, with a legal framework governing their interactions stated in the contract [9]. Architectural, civil, structural, mechanical, and electrical design are five essential disciplines in building design [10].

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This study is geared towards the collaborative process among project owners, designers, and contractors, focusing on the architectural, structural, and MEP disciplines across various phases of the construction project life cycle. Within the context of Cambodia's construction, this study aims to answer the following questions:

- What characterizes the interaction among Cambodian construction project owners, designers, and contractors?
- How do collaborative workflows and processes of these actors evolve throughout different phases of construction projects in Cambodia?
- Is BIM perceived by industry professionals as an alternative to overcome poor cost and schedule performance in the future?
- How can we facilitate and support BIM-enabled collaboration in Cambodia's construction sector?

Interviews and observations have been conducted to answer these multifaced questions. This article is structured into six parts. First, we introduce the Cambodian context, problem statement, research questions, and an outline of the article's content. The second section presents the specificity of the construction sector in Cambodia. The second section also delves into the existing literature, outlining the definitions and tools of collaboration, and the three components of collaborative work. The third section explains our data collection protocol, which encompasses semi-structured interviews and observation case studies. The fourth section presents results, including insights into the relationship among project owners, designers, and contractors, the four workflow scenarios, the balance of collaboration, problem-solving, and BIM experiences and perspectives. The fifth section discusses the results. We finish this paper with the conclusion of our research findings and further work in the last section.

II. Literature Review

This section demonstrates the existing knowledge, i.e., the specifics of Cambodia's construction context, including the construction contract, the project lifecycle phases, and the importance of adopting BIM. Moreover, this section presents the definition and components of collaboration.

A. *Specificity of the construction sector in Cambodia*

Bellowing is the information specific to the construction in Cambodia. However, finding this information is challenging due to limited resources and research gaps within this field.

1) *Construction contract in Cambodia*

The interaction, roles, and responsibilities of the owner, the designer, and the contractor are typically stated in the contract [9]. According to the contract agreement, the owners should expect the result, payment, and oversee the progress of the work. The structure of a construction contract in Cambodia is as follows:

Within the Cambodian context, the legal framework governing construction activities includes the adoption of a sub-decree on construction permits in 1997, as well as the Civil Code in 2007; and land law in 2001. However, it needs more explicit regulations of construction law and the establishment of a standardized construction contract. Without a locally standardized contract, Cambodian construction projects frequently turn to the International Federation of Consulting Engineers (FIDIC) standard, which was established by Belgium, France, and Switzerland [11].

FIDIC standards published in 1999 have four standard forms of contracts:

- Conditions of Contract for Construction recommended (1) for the project designed by the owner or engineer. The contractor builds the building following the design provided by the owner [12].
- Conditions of Contract for Plant and Design-build recommended (2) for "the provision of electrical and/or mechanical plants, and for the design and execution of building or engineering works" on a design/build basis. The contractor designs most or all the work [13].
- Conditions of Contract for EPC/Turnkey projects recommended for "a process or power plant, a factory or similar facility, an infrastructure project, or other types of development [14]."
  (i) a higher degree of certainty of final price and time is required.
  (ii) the contractor takes total responsibility for the design and execution of the project, with little involvement from the employer.
- Short form of Contract (3) recommended for building or engineering works, which is a small value (less than US$500,000) or short-term work (less than six months) [15][16].

In our study, we are interested in only the conditions of the contract for construction, conditions of the contract for plant and design-building, and the short form of the contract, which are recommended for building or engineering works. The definition of the contractual relationship between actors is the aim of these standards [17].

All contract standards have identified the tasks and responsibilities of three actors: employer (owner), engineer (designer), and contractor. We compare those contract standards based on the duties of actors, as shown in Table I.

- Contractors in (1) and (3) design only for extent specification. Otherwise, they design almost all the projects in (2).
- The requests for construction and environmental permits are the owners' responsibility.
- Providing instructions and requesting any requirement to the contractor is the owner's

responsibility in (2) and (3). Otherwise, it is the designer's responsibility in (1).

- There is the owner's representative who acts on behalf of the owners in (2) and (3)—otherwise, the designers who work on the owner's behalf in (1). On behalf of the owner, the owner's representative and designers have the authority to check, inspect the site, join decision-making, and make requests to the contractor on behalf of the owner.
- The contractor also executes and completes the project.

2) Construction project life cycle phase

In Cambodia, there is not a standardized national framework for delineating the phases of construction life cycle. Instead, individual companies, institutions, and universities often adopt the standard from United States (US) or Europe as a reference. Based on the interviews conducted (which will be discussed in the following section), we indicated that construction projects in Cambodia are typically structured into eight phases: initial, conceptual design, schematic design, permitting, tender, BID, construction, and post-construction. Thus, this part, we will illustrate the difference in nomenclature and the structure of the primary phase of the construction project life cycle between US, Europe, and Cambodia (Table II).

In traditional design-bid-build projects, the life cycle phases generally include project initiation, design, permitting, BID and award, construction, and commissioning and operation phase. In the initiation phase, they study the funding, environmental impact, and the potential of the project. The design phase is about conceptual design. Preliminary engineering is also a part of the design phase. It helps analyze and validate the project. From this phase, the owner can choose the option that meets their budget and requirements. Then, they detail the final design to request the permit. The detailed drawing and specifications are also submitted to the contractors' companies to bid. The selected contractor must complete the project as stated in the contract. The contractor must join in operation activities and commissioning when the construction phase is completed [18].

Naming these phrases may differ between countries, but the principal remains the same. For example, in Belgium, the design and construction phase of the project is divided into eight main sub-phases: preliminary studies (PRE), summary pre-project (APS), detailed pre-project (APD), construction of urban planning permit (PDU), construction of the contractor consultation (DCE), suit, development of works contracts (MDT), work execution (EXE), suit, and additional assignments phase (MSU) [19].

In the PRE phase, the owners gather information about their project and define the requirements, including the project's characteristics, budget, etc. All that information must be provided to the architect to study. Then, the architect sketches three proposals to the owner. In APS phase, they summarize and search for more information from the PRE phase and develop the selected sketch. They also study energy performance choice, technical security, ventilation, and acoustics. APD is the phase of coordination structure and technical design. They choose the material, ventilation, etc., and calculate the PEB. The PDU phase is the registration for the environment, construction permit, and Energy Performance of Building (PEB) certificate. The DCE phase is the phase of preparing documents for contracts. MDT is a phase of analysis, choosing the contractor company, and signing the contract. In EXE phase, the site works start and follow the plans in the agreement. There are regular meetings and report submissions in the phase. The MSU phase is the final step to be completed [19].

TABLE I. COMPARISON OF THE RESPONSIBILITIES OF ACTORS IN STANDARD FORM: CONDITION CONTRACT FOR CONSTRUCTION, CONDITION CONTRACT FOR PLANT AND DESIGN-BUILD, AND SHORT FORM OF CONTRACT

Task	**Condition contract for construction** [12]	**Condition contract for plant and design-build** [13]	**Short form of contract** [15]
Designing the project	Owner/ designer	Contractor	Owner/ designer
Requesting construction and environmental permits	Owner	Owner	Owner
Giving the instruction	Designer	Owner	Owner
Designing to the extent specified in the contract	Contractor	Contractor	Contractor
Execution plan	Contractor	Contractor	Contractor
Completing the work (building)	Contractor	Contractor	Contractor
Submitting details of the arrangements and method, which the contractor proposes to adopt for the execution of the work	Contractor	Contractor	
Requesting details of the arrangements and method	Designer	Owner's representative	Owner's representative
Action on the owner's behalf under the contract: approval, check, certificate, consent, examination, inspection, instruction, notice, proposal, request, test	Designer	Owner's representative	Owner's representative

3) For construction 4.0 in Cambodia: towards Building Information Modeling, Models, Management (BIM)

In the 21st century, industrials have a remarkable evolution with the advent of Industries 4.0, driven by digital technology. This transformation has had a profonde impact across various industrial sectors. In the construction industry, often referred to as Construction 4.0, the goal is to promote the integration of advanced information and communication technologies into construction services. The aim is to enhance collaboration, productivity, and overall quality while minimizing project delays and costs. This approach also involve effectively managing complex construction projects their life cycle [20].

TABLE II. THE DIFFERENCE BETWEEN US, EUROPE, AND CAMBODIA PROJECT LIFE CYCLES PHASE NOMEMCLATURE

	US	Belgium	Cambodia
Phase	Initial	PRE	Initial
	Design	APS	Conceptual design
		APD	Schematic design
	Permitting	PDU	Permitting & Tender
	BID & award	DCE	BID
		MDT	
	Construction	EXE	Construction
	Post-construction	MSU	Post-construction

Moreover, Royal Government of Cambodia has issued the Rectangle Strategy-Phase IV for Growth, Employment, Equity, and Efficiency: Building the Foundation Toward Realizing the Cambodia Vision 2050. Within rectangle 2 (Economic Diversification) and slide 3 (preparing for the digital economy and the Industrial 4.0 revolution) express the purpose of the government developing forward the Industrial 4.0 as stated below [21]:

- “Developing and implementing a long-term strategic framework for digital economics.
- Further updating and implementing the Telecommunication and ICT Development Policy, the Master Plan for Information and Communication Technology, the Law on Telecommunications, and other relevant regulations, along with developing and implementing a long-term ICT strategic framework.
- Further strengthening and expanding the development of necessary supporting infrastructures.
- Promoting the establishment of a legal framework to support development.
- Developing education and training programs
- Developing entrepreneurship and digital ecosystem.”

Towards the Construction 4.0, BIM is presented as the most appropriate solution to enable the change and as the potential tool/method for solving the problems in the architecture, engineering, and construction industry [22]. It profoundly impacts how project stakeholders collaborate and share information throughout a building’s lifecycle [23].

Numerous sources define BIM. The National BIM Standard-United States defines Building Information Modeling as “a digital representation of physical and functional characteristics of a facility forming a reliable basis for decisions during its life-cycle; defined as an existing from earliest conception to demolition [24].” International standard (ISO 19650-1: 2018) defines BIM as the “use of a shared digital representation of a built asset to facilitate design, construction, and operation processes to form a reliable basis for decisions [25].”

The letters “B” and “I” represent the civil construction or infrastructures (Building) and the information, respectively, which represents the real added value of this methodology in the context of 3D modeling. Otherwise, “M” has been given many definitions. BIM (modeling) is a process of creating models; BIM (models) is the model, which obtains the data and information for building; BIM (management) is the process of information management on the one hand and collaboration management on the other [26]. These three Ms complete the meaning of BIM and reflect the complexity of the resulting collaborative process and data sharing between the various actors and protagonists of the project throughout the life cycle of the building.

Rezaei and Sistani [27] found that professionals in the construction sector are confidential with hand drawing and 2D/3D CAD software, especially AutoCAD software. Otherwise, they lack BIM-based skills and knowledge [27][28], even as most companies in the United States and Europe actively promote BIM adoption.

Meanwhile, there remains a lack of studies on the factor facilitating or hindering BIM adoption within Cambodia’s Architecture, Engineering, and Construction (AEC) sector. Previous study demonstrated that project visualization and schedule performance are the most significant drivers factors, while significant industry resistance to change remains a considerable challenge [29].

In the broader Asian context, studies focusing the key barriers of BIM adoption, including those in China, Vietnam, and Malaysia, have highlighted the importance of BIM legal, regulation, and standards [30][31][32][33][34][35][36][37][38]. Additionally, the important BIM guideline encompass technology, return on investment, and implementation [31][37][39][40]. A study by Liu, 2022 presents the hierarchical structure and level partitioning of BIM adoption barriers for small and medium-sized fire protection enterprise in China [33]. This study highlights root barriers, including lack of external support from local government and a deficiency of BIM laws and regulations applicable to the fire protection industry. It also identifies a lack of client demand, and internal issues (i.e., training culture), software and technology-based barriers, insufficient knowledge and experience in applying BIM, and external guidance barriers such as pilot and standard. Remarkably, in China, the BIM adoption rate has surged from 5% in 2014 to 23.6% in 2019, following the government’s promoted BIM policies in 2015 [41]. This rate is expected to further rise if BIM

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becomes mandatory for national construction projects, increasing client demand.

Many countries have conducted extensive research to customize guidelines or references for their national setting. As previously mentioned, fostering collaborative culture among project teams is vital for successful BIM implementation [28]. Therefore, imperative for us to gain a comprehensive understanding of the collaborative processes within Cambodia's construction sector. This knowledge will enable us to better prepare for change, overcome significant inertia, and promote the adoption of Construction 4.0.

B. "Collaboration": Many defenition and tools

Several definitions are given for Collaboration. Some speak of collective activity in general, and others propose differentiating them in terms of collaboration or cooperation. Both collaboration and cooperation are inter-organizational. Nevertheless, we refer to the definition of collaboration as the relationship with a common goal. In contrast, cooperation refers to "relationship among participants in a project, which does not commonly relate by vision or mission, resulting in separated project organization with independent structures, where the project culture is based on control and coordination to solve problems independently to maximize the value of the own organization [42]."

In our case, we borrow the definition of Wood and Gray (1991), who describe collaboration as an interactive process of a group of actors that work together to make joint decision-making on a problem domain [43] by sharing their vision, information, and process via interacting, communicating, exchanging, coordinating, and approving in order to meet their common goal [44]. In the construction management domain, "collaboration" is defined as "a central element of success throughout the lifecycle of construction project [45][46]." Schöttle et al. [42] stated that the factors to reaching a successful collaboration are "trust, communication, commitment, knowledge, sharing, and information exchange [42]." Moreover, "the project-based nature of the Architect, Engineer, and construction industry requires collaboration, or at a minimum some form of negotiated interaction [47]."

Table III shows the supported system variant of place and time which was originally presented by DeSanctis and Gallupe [48].

TABLE III. GROUP DECISION-SUPPORTED SYSTEM [48]

	Synchronous	**Asynchronous**
Same place	Face-to-face meetings and discussion aids	Team meeting rooms and discussion areas
Different place	Voice/ video conferences, virtual meeting rooms, shared applications	Messaging systems, e.g., e-mail, multi-user editors and collaborative writing tools, workflow systems

C. Three components of collaborative work

We base ourselves on Ellis's model [49], which is also used by many researchers [50][51] because it permits us to understand collaborative works through three components: "Coordination", "Communication", and "Co-production".

Coordination is how the work is structured [52]. The coordinative activities manage the task for actors to perform and the relationship between the actors to complete the tasks [53].

Communication is about exchanging information and sharing knowledge [54] to ensure that all actors get a common referential [46]. The information can be transmitted in different forms, e.g., verbal, written [54]. However, the development of technologies has supported communication, including "the electronic communication system (mail systems, facsimile transfer, voice and video conferencing) and shared workspace systems (virtual meeting rooms, remote screen sharing and electronically aided intelligent whiteboards (shared application) [54]."

Co-production is the action related to creating or realizing the project design or building [53][55]. Those actions can be an action of a single actor or multi actors [55]. This concept also includes the decision-making of problem-solving.

BIM capability supports all three components of collaboration. BIM actively facilities co-productive activities. For example, it enables actors to collaborate closely with other disciplinary actors. Model-based collaboration within BIM includes the interchange of models or part-models through both proprietary formats "(e.g., between Revit Architecture and Revit Structure through the .RVT file format) and non-proprietary formats (e.g., between ArchiCAD and Tekla using the IFC file format) [23]."

Furthermore, BIM enhances coordination through software tools like Navisworks and BIM collab, etc. These tools streamline the coordination of various project aspects.

BIM also supports communication activities, both asynchronous and synchronous. Actors can leave the comments, highlight issues, and engage in discussions based on information shared through software platforms, i.e., BIM collab, etc., thus fostering effective communication among project stakeholders, regardless of geographical distance.

Hence, the Cambodian construction context needs national common references, including standard contracts, a clear workflow of the project lifecycle, and BIM implantation guidelines. Moreover, the research on these references needs to be improved; a few studies demonstrate the current construction situation. Our research aims to fill this gap and significantly contribute to knowledge in this field.

III. PROTOCOL

This section provides how the study was successfully conducted through interviews and observations. The semi-structured interviews process encompassed two steps

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approach. The first step involved interviewing employees to establish the relation of actor's categories, while the second step aimed to validate the collaborative activities and workflow within each project phase. Additionally, observation of construction project/company in Cambodia were conducted to identify practical issues.

A. *Semi-structured interviewing*

We employed qualitative research via semi-structured interviews to gather participants' thoughts, feelings, and perspectives. This data allowed us to collect detailed problems in the participants' practice. The framework for these interview were based on the Ellis's model: coordination, communication, and co-production (Cf. II.C.) [49].

We structured the semi-structured interviews around five themes:

- Presentation project and company: participants described the projects they have been involved in and their company's role in those projects.
- Coordination: participants answered questions about their roles and responsibilities in the project. We defined the participants' tasks (individual and overlapping tasks) and participants' roles. They mentioned how the work was structured and their interactions with other actors to complete the tasks.
- Communication: participants explained the communication methods and tools for teams. Participants described the procedure of sharing understanding, knowledge, and information.
- Co-production: we focused on the action that actors produced tasks or projects, especially the method and tools they used.
- BIM experience and perspective: we asked the participants a straightforward question to see their first expression. The question is "Have you ever heard of BIM?" If so, participants explained their experiences and perspective.

In total, we conducted semi-structured interviews with sixteen participants for approximately fourteen hours, divided into two steps.

In the first step, we interviewed eight participants from three disciplines: architecture, structure, and MEP. These participants work in different companies and play various roles, including MEP engineers, architects, and structural engineers (Table IV).

In the second step is the interviews of an additional eight participants (Table IV). The section of participants in the 2nd step were based on the outcome of the initial interview, aimed at gaining a more understanding of workflow scenarios. These eight participants were selected from management level, including free-lancer architects, MEP manager, CEO of contractor company, general manager, CEO of architecture company, BIM modeler and coordinator. These participants addressed the same five thematic areas but were required to provide a holistic account of the entire process, from design to construction phase.

The number of participants is indeed restricted. However, qualitative research typically required a sample size of five to twenty-five samples are sufficient [56], and our sample of 16 participants is considered acceptable. We know that this size could limit our research, but our work has allowed us to trace specific trends in the collaboration sector, illuminate the collaboration process and the workflow, and address the specificity of the construction sector in Cambodia, all with the aim of preparing for the BIM implementation.

TABLE IV. PARTICIPANTS' INFORMATION OF SEMI-STRUCTURED INTERVIEWS

No	Role	Company
		1st step
1	MEP engineer 1	Contractor
2	MEP engineer 2	Contractor
3	Architect 1	Owner
4	Architect 2	Designer
		Sub-contractor (finishing)
5	Architect 3	Contractor
6	Architect 4	Owner
7	Structural Engineer 1	Owner
8	Structural Engineer 2	Owner
		2nd step
9	Architect 5	Free lancer
10	Architect 6	Free lancer
11	Architect 7	BIM modeler & coordinator
12	MEP engineer 3	MEP manager
13	Structural engineer 3	CEO of contractor company
14	Structure engineer 4	General manager
15	Architect 8	Involved both local and standard project
16	Architect 9	CEO of Architecture company

B. *Case study: Observation the construction projects in Cambodia*

In addition to our interview data, we complemented our research with field observations of construction project/company in Cambodia. These observations cover both projects without and with BIM deliverables.

1) *Construction project without BIM deliverables*

We received permission from Panhchaksela Construction company to conduct site visits to the Ly Vouch Leng Condo project in Phnom Penh, Cambodia. This high-rise condominium building consists of 30 floors and covers an area of 1 150m2. The stakeholder structure during our observation is illustrated in Fig. 1, which included project manager, site manager, MEP contractor, and structural consultant teams. At the time of our observation, the construction phase has been ongoing for two months with an expected completion date in 2024.

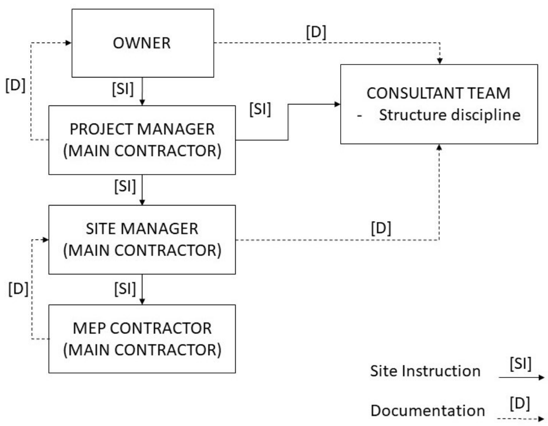

Figure 1. Stakeholder's structure.

2) Construction project with BIM deliverables

Our study concerning BIM implementation in construction project aims to address the question of how we facilitate and support BIM-enabled collaboration in Cambodia's construction sector. To gather insights into this aspect, we engaged with Shanghai Baoye (Cambodia) CO., LTD (SBCC), a Chinese construction company that has been established in Cambodia since 2016. SBCC has an extensive experience, having participated in high-rise construction more than 25 projects in Cambodia, including those in Phnom Penh, Sihanoukville, Siem Reap, Kampot, Koh Kong, and other locations.

The presence of a company utilizing BIM in Cambodia is a positive indication. We conducted a questionnaire survey with a BIM engineer from SBCC, who was part of the project management team. The question covered various aspects, including information about the respondent, the company's details, project specifics, BIM standards and protocols, BIM deliverables method, roles and responsibilities within the BIM process, workflow, dataflow, communication methods, BIM software usage at different project stages, and the engineer's perspectives. To overcome language barriers, interviews were conducted following a questionnaire.

IV. Results

The research results are demonstrated in the following.

A. Actor relationship

The findings from first step semi-structured interviews indicated a clear correlation between project tasks and roles actors. Subsequently, we categorized the participants into four distinct categories, each contingent on the relationship among project owners, designers, and contractors. These categories are summarized as follows:

1) Category 1

The owner separated the contract between the designer and the contractor. Participants who were involved with this project said that "[…] the foreign company provided the architectural plan […]"; and a local architect provided the finishing plan.

2) Category 2

The owner owned a company that has a full-package team: designer and constructor. He could be a real estate agent or own a company with many campuses. Thus, the owner used the same design for his many projects. The architect participant stated, "I design […], but I had to respect the previous project reference or guideline"; "I kept its style, function, similar size, and then I suited it in the new terrain." Projects could be banks, coffee shops, stores, factories, or a uniform residential building like Borey. The architect proposed and discussed the new architectural plan with the owner. The architectural plan must respect the standard of the previous project.

3) Category 3

The owner owned the full package of the design team. The contractor company built the project by follow up and participating in discussions from owner or his representative in construction phase.

4) Category 4

The owner hired a design-build company to oversee the project.

B. Workflow

Based on the data gathered from both step of semi-structured interviews, we have identified four workflow scenarios that defined in eight phases (referred to as phase in Cambodia). These phases are initial, conceptual design, schematic design, tender design, permitting, BID, construction, and post-construction (Fig. 2).

We illustrated Fig. 2 to provide a visual comparison of these four workflow scenarios across the project life cycle. Additionally, the tools and methods employed for communication, coordination, and co-production are depicted.

1) Scenario 1

In this scenario, the architect proposed the concept design corresponding to the owner's requirements. The structural and MEP consultants also supported and advised on the design. They here had a role in giving ideas, critiquing, and predicting future technical problems. As the owner's representatives, they also participated in accepting or rejecting the architect's proposal. If the owner requests, the architect modifies his proposal until the owner approves it. Otherwise, the presence of consultants here was only in some cases. They did not participate in the conceptual design phase for some projects presented as shown in Fig. 3.

Schematic design phase, structural and MEP designers proposed the structural and MEP design, respectively. Then,

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they submitted those plans to the architect, who overlayed them and identified the clashes. The architect, structural engineer, and MEP engineer discussed solving those clashes. They modified those plans until these three parties, and the owner approved.

Then, the architect, structural engineer, and MEP engineer detailed their plans. They also must list material quantities in detail and submit them to the owner. The owner gave these tender documents to many contractors for studies. Those contractors' companies applied their proposal attached with cost estimates, build method, schedule, etc. Then, the owner chose a company to be a contractor.

In the construction phase, the contractor submitted the progress report to the owner or consultant and completed the work mentioned in the contract.

2) Scenario 2

The architect proposed the conceptual architecture under the support of the structure and MEP engineer. If the owner rejects the proposal, it must repeat it. If the owner accepts the proposal, it moves to schematic design.

Structure and MEP engineers designed the structure and MEP plan, respectively. The architect had a role in overlapping the three plans. Then, the architect, owner, structure, and MEP engineer discussed solving the clashes or technical problems between those three discipline plans.

After the approval of the schematic design, the architect, structural, and MEP engineer provided detailed drawings for the building.

3) Scenario C

The workflow in the conceptual and schematic design phase is the same as in scenario B. The difference is the designer from the owner teams. The tender, construction, and post-construction workflow is the same as in scenario A.

4) Scenario D

An architect designs conceptual design. The Schematic Design phase is the same as in scenario A. The workflow of the tender, construction and post-construction phases is the same as in scenario B. But the contractors who designed and built the structure and MEP.

C. Collaborative work: a balance between communication, coordination, and co-production

The participant stated, "architect is remote, and we do the videoconference. The participant added, "[…] we sent questions via e-mail and got a response one week later." In Cambodia, actors mostly communicate via social media in routine work, such as Telegram, WhatsApp, WeChat, etc., and in the form of voices, text, videos, and pictures. The architect shared all plans in Dropbox. If there were any updates, he sent us an e-mail with the link for access to a modified plan.

They discussed it face-to-face. It can be a formal or informal meeting. A face-to-face meeting is better than a distant meeting to solve the critical situation [54]. Not only Computer-Aided (CAD) but actors also printed to make a discussion during the meetings. Workers preferred hard copies compared to soft copies. After getting the agreement, they updated the plan. The participant said, "[…] after discussion, I made a cloud in red color on layout and made a note, e.g., 3rd-floor modification on the layout plan." Other actors received the updated information.

In the construction phase, they discussed daily with the internal team (MEP management team, subcontractor) and finishing team, rarely with an architect. The structure team works more often with an architect. One participant mentioned using DWG Fast view application to demonstrate 2D plans. It also allows him to use AutoCAD to verify its dimensions and take notes by smartphone.

D. Problem-solving

The issues on-site have been resolved through stakeholder discussions, which encompass both formal and informal meetings. These regular meetings are held bi-weekly and are attended by key participants, including the project manager, site manager, MEP contractor, and structural consultant teams. The project management team represents the owner's interests and is responsible for guiding the project towards meeting its planning and cost targets. The site manager plays a pivotal role in troubleshooting and ensuring the progress of the work aligns with the project's success criteria. The consultant teams act as proxies for the owner to ensure the contractor adheres to the owner's requirements.

The primary objective of these meetings is to provide progress reports on the work, address challenges related to retaining wall installation, and seek solutions. The meetings typically last for approximately 35 minutes.

This process is depicted as a recurring cycle in Fig. 4. The meetings commence with progress reports and the introduction of challenges. The project manager and site manager propose solutions, initiating discussions. As the highest-ranking authority in the cooperative hierarchy, the project manager makes final decisions. Participants with specialized knowledge share their expertise with others. The information disseminated after each meeting includes proposals, opinions, and problem-solving strategies.

Verbal communication serves as the primary method of interaction during these meetings, complemented by hand-drawn diagrams and hard copies of plans to facilitate discussions.

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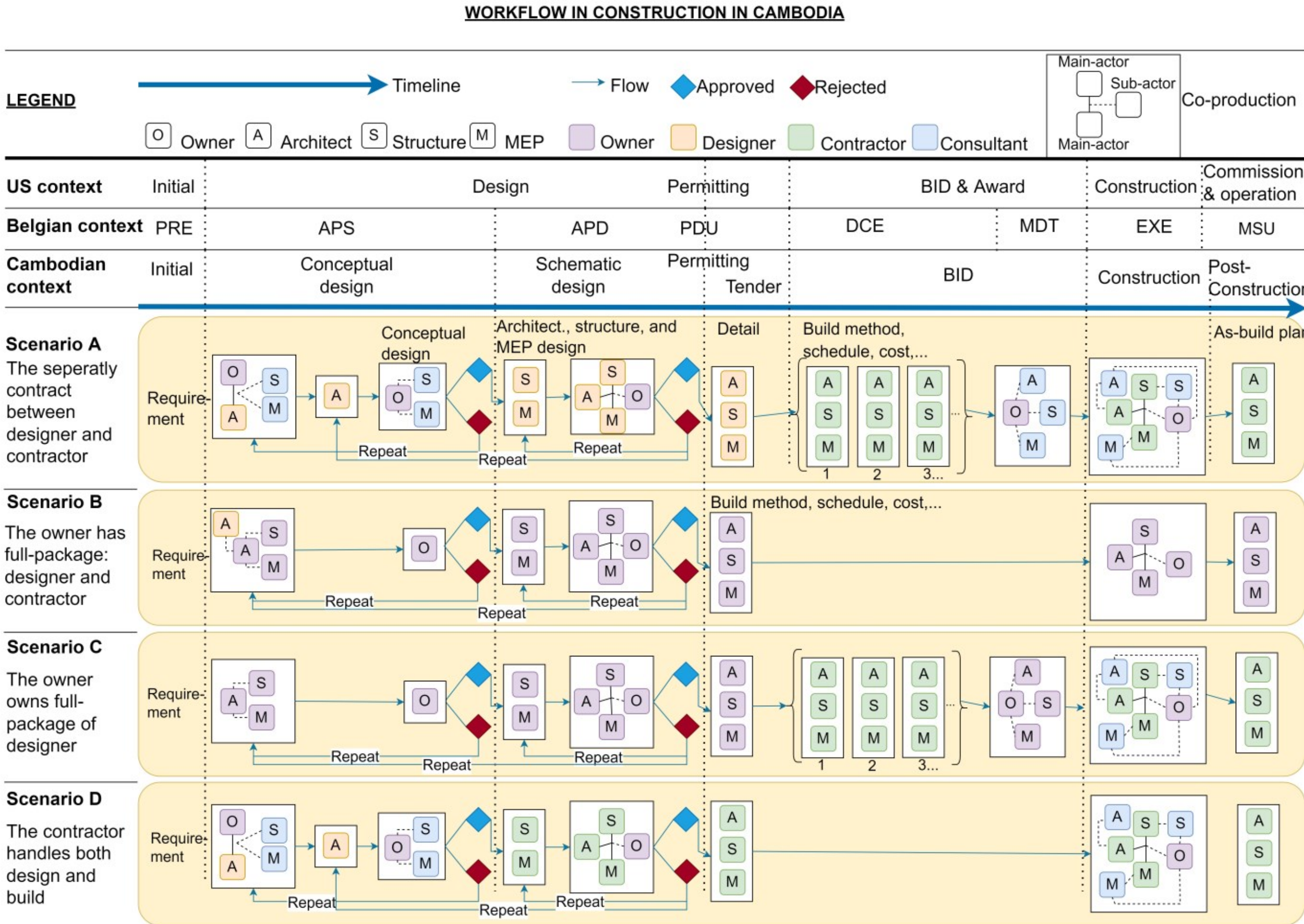

Figure 2. Four workflow scenarios in construction in Cambodia [1].

E. BIM experiences and perspectives

From semi-structured interviews conducted with a sample of sixteen participants, it emerged that eleven of them used to hear or know BIM. Among these, two individuals had received formal BIM training provided by their companies, while an additional four had acquired their knowledge through online or self-guided learning resources such as YouTube. These findings underscore the existing limitations in BIM training, highlighting a potential area for improvement, particularly within the context of universities and educational institutions.

Interestingly, only one participant reported having practical experience with BIM in real application, indicating a lack of BIM implementation within the Cambodian construction industry. One stated, “Our team utilized BIM for quantity and cost estimation, design planification during in Bidding phase.” Furthermore, among the sixteen participants, one was engaged in BIM modeling (architecture) and served as a BIM coordinator. This individual had undergone company-sponsored BIM training and emphasized the considerable benefits of BIM, particularly in terms of reducing rework and minimizing wastage of time. They also acknowledged the challenges associated with transitioning from traditional software to BIM, emphasizing the need for additional expertise to address the difficulties encountered.

One architecture company expressed an interest in adopting BIM but voiced concerns about the associated expenses and time required to train their staff. Additionally, they indicated that their decision would be contingent upon project owner requirements. Another participant acknowledged the advantages of BIM in construction but admitted to needing more time for learning. Due to the limited familiarity with BIM among collaborators, this individual found it necessary to export BIM models to DWG format each time they shared documents with their partners.

Shanghai Baoye (Cambodia) CO., LTD stands as a pioneering entity in the widespread adoption of Building Information Modeling (BIM) across numerous projects in Cambodia, contributing significantly to developing professionals in this field. SBCC has been actively engaged in these endeavors, assuming roles as bidders, general contractors, and sub-contractors.

A BIM engineer affiliated with SBCC has diligently provided insights through our questionnaires. She/he outlined the utilization of several standards, including BS1192 (collaborative production, management & exchange of AEC information), PAS1192-2 (information management using BIM - capital delivery phase), PAS1192-3 (information management using BIM - operational phase), BS8536 (soft landing - handover & post occupancy evaluation), and PAS 1192-2:2013 (information management).

BIM engineer has specified that BIM has been used for tasks such as building performance analysis and design/draw MEP coordinate. It is important to clarify that the reference to "Building Performance Analysis" does not exclusively entail the analysis, evaluation, or simulation of building performance parameters, which encompass aspects like energy efficiency, occupant comfort, and environmental impact. To eliminate any ambiguity, we conducted an in-depth interview to extract more precise information.

She/he described the communication question in general. Effective communication within the team is characterized by several principals:

- Team members prioritize communication by ensuring that everyone has an opportunity to both speak and listen simultaneously during discussions. This fosters inclusivity and active engagement.
- Communication is primarily conducted through face-to-face interactions, emphasizing the use of both verbal expressions and gestures to convey information. This robust approach enhances clarity and mutual understanding.
- Team members establish direct links with one another, promoting open communication channels not solely reliant on communication through a team leader. This reflects a culture of respect and equality within the team.
- Team communication goals encompass both formal and informal interactions, allowing team members to engage in discussions not limited to official team meetings. This flexibility encourages diverse forms of collaboration and knowledge exchange.
- Team members regularly venture outside the team to explore external resources and gather information. This information is subsequently shared with the team, avoiding unnecessary duplication of efforts and promoting resourcefulness.

In summary, these communication practices underscore the importance of inclusive, clear, respectful, and resourceful communication within the team, contributing to effective collaboration and knowledge sharing.

The software tools are employed for various purposes within the project workflow. These software tools can be categorized as follows:

- Programing: Microsoft office, WPS (Writer, Presentation, Spreadsheets), Adobe Photoshop.
- Designing: Revit (Architect, Structural, MEP Template), AutoCAD, 3D studio max, CAD MEP, ArchiCAD, Lumion,
- Analysis: AutoCAD Civil 3D, Autodesk, Steps software.
- Management: Microsoft Project, Synchro, Asite, BIM technologies, Autodesk Naviworks, Takeoff Cubicost (QS), Review: AutoCAD, Autodesk Design Review, PDF, Second life.
- Review: AutoCAD, Autodesk Design Review, PDF, Second life.

Fig. 5 illustrates the BIM workflow implemented by Shanghai Baoye (Cambodia), as outlined below:

The project owner provided 2D plans to the contractor company. The BIM team's responsibility generated geometrically precise 3D models from 2D Computer-Aided Design (CAD) plans. The primary software utilized for modeling is Revit. Within the SBCC BIM modeling workflow, modeling tasks are distributed among BIM team members based on floor levels or towers; the partial models are then combined.

A team member assumes the role of clash detection overseer. This individual exports architectural, structural, and MEP models from .rvt to .nwd format for clash detection purposes.. All identified clashes are screenshotted and reported in .doc format. This report is then submitted to the project owner for review and feedback. Subsequently, the BIM team undertakes corrective actions and revises the information or models as deemed necessary after discussion.

The BIM models serve various purposes, including utilization in the bidding and/or construction phase. The BIM models are subject to two distinct modes of export:

- Quantitative analysis and cost estimation: BIM models play an integral role in conducting meticulous quantity and cost estimations pertinent to the construction endeavor. To facilitate this process, BIM models are exported from the .rvt (Revit) format to the Industry Foundation Classes (IFC) format. These IFC-formatted models are subsequently imported into the Take-off Cubicost software. The utilization of Take-off Cubicost software allows for precise cost estimations, thus aiding in financial planning and budgeting for the project.
- Construction planning and execution: the BIM models are pivotal in orchestrating comprehensive construction planning and execution strategies. Furthermore, BIM technology extends to the creation of various visual assets (e.g., video, image, etc.) and generation comprehensive documentation pertinent to on-site construction.

Based on the questionnaire and interview, the following conclusion can be drawn:

- **Roles in the BIM process:** the BIM process at SBCC involves two distinct roles: BIM modelers and BIM coordinators. BIM modelers are responsible for creating precise geometrically accurate models. BIM coordinators are responsible for supervising the BIM modelers, ensuring model accuracy, and conducting clash detection checks.

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- **BIM utilization at SBCC**: SBCC leverages BIM for various purposes, encompassing 3D BIM for modeling and documentation, 4D BIM for planification, and 5D BIM for cost estimation.
- **Lack of BIM procedure protocol:** notably, there is currently no documented BIM procedure protocol in place at SBCC. This suggests a potential area for improvement in formalizing and standardizing their BIM processes.
- **Challenges in BIM questionnaire:** the effectiveness of BIM-related questionnaires appears to be hampered by language and comprehension gaps among the participants. This highlights the importance of clear communication and common understanding when collecting BIM-related information.
- **BIM workflow:** the BIM workflow was drawn and submitted to Shanghai Baoye (Cambodia) company, and after review, it received approval.

This conclusion provides insights into the organizational structure and BIM practices, emphasizing the need for formalized procedures and improved communication strategies for BIM-related activities.

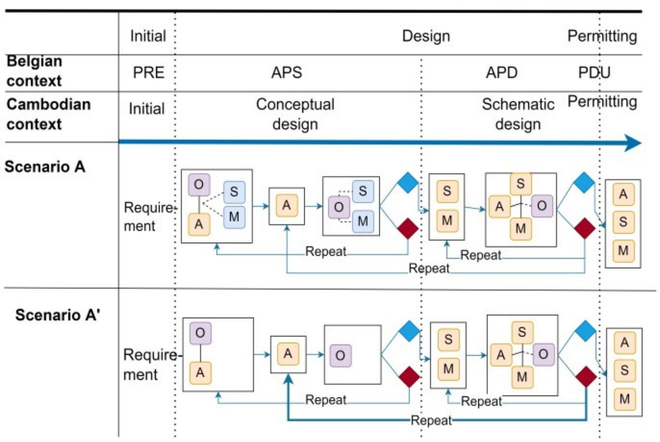

Figure 3. Scenario A in the conceptual design phase [1].

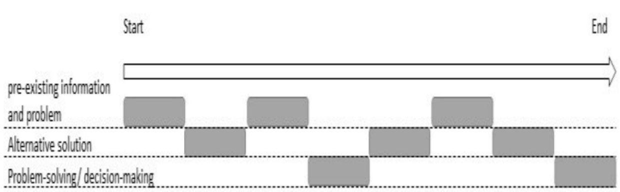

Figure 4. Action in the meeting.

V. Discussion

In Scenarios A and D, the project will be challenged with many technical problems in the schematic design phase if there is no participation of structural and MEP engineers in the concept design phase. Engineers will request the architect to make many changes affecting the conception design that due to wasting time and design costs. Otherwise, with the collaboration of other disciplines, the conceptual design will easily convince the owner to accept, reducing design error, time, and cost. The architect, structural engineer, and MEP engineer participated in the project since the early design phase in Scenarios B and C. As the claim of [41], the actors tend to isolate working, which is the roadblock to BIM collaboration. Thus, the collaborative culture in our scenarios is a good sight of the construction sector in Cambodia to influence BIM collaboration.

The similarity and differences between our workflow scenarios and the workflow we assumed from the FIDIC contracts were figured out. Scenario A and C are comparable to (1). In condition contract for construction, the designer or owner design almost the whole project. At the same time, the designer also brings this action in Scenario A, and the owner completes this task in scenario C. In scenario A and C, the contractor specified the design and completed the works as mentioned in (1).

In Scenario D, the designer designed only the conceptual design. The contractor designed in the schematic design phase. At the same time, the contractor designed almost the whole project in (2). The contractor in Scenario D also handled the work after the design phase, such as giving instructions, specifying design, method, execution, and completing the project, as mentioned in (2). In Scenario B, the owner handles everything by himself. We cannot find a similarity between Scenario B with any case in FIDIC contracts.

Cambodia's construction sector still uses CAD as the main tool to complete projects, as Rezaei and Sistani claimed [40]. Overall, actors are familiar with traditional project delivery methods. They are used to the problem and resistant to change. The participant stated, "normally, we had to re-model, re-check, and re-work. I don't think other tools can reduce it." Nevertheless, the participants who had experience with BIM practice or BIM training strongly believe that the waste from poor cost and schedule performance will be reduced by BIM adoption.

The BIM-based processed in the BID phase (Fig. 6). The contractor modeled BIM models in different disciplines based on the final designs that were provided. The contractor also extended the specific details. He coordinated the BIM-Models collaboration, identified the clashes and co-produced multi-disciplinary model via visualization. Moreover, he estimated the cost and scheduled performance in the further execution works. In our participant's case, the contractor volunteered using BIM by put a lot of effort and had a strong commitment into fighting the barrier of adoption BIM in Cambodia's construction project: "strong industry resistance to change [37]."

A questionnaire survey method was employed for data collection, with participants providing response independently. However, our find revealed significant knowledge gaps among participants and researcher, which is a challenge of research on BIM in Cambodia due to the limited common language, knowledge, and understanding. For example, while eleven out of sixteen respondents had heard of BIM, they were unable to provide an accurate definition. Remarkably, BIM was often equated with Revit, indicating a need for clarification. Furthermore, as mentioned in the results section, respondents associated Building Performance Analysis more with the modelling process than its energy, structural, and environmental aspects. Given these challenges, it became evident that questionnaires alone were insufficient, and interviews would be a more effective means of data collection.

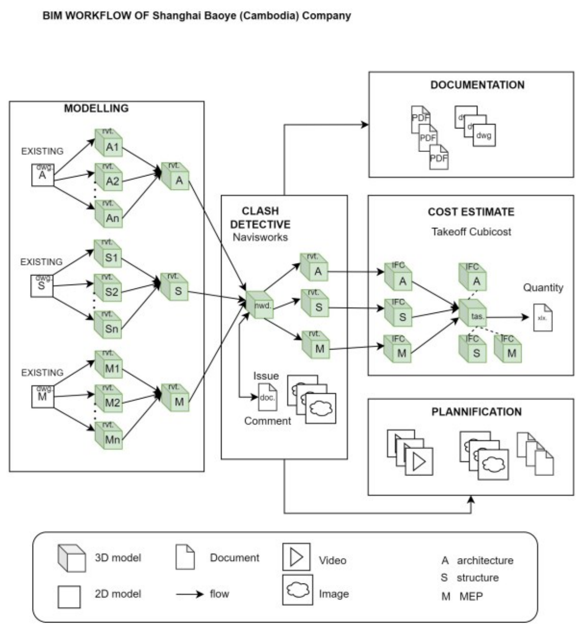

Figure 5. BIM workflow of Shanghai Baoye (Cambodia) Company.

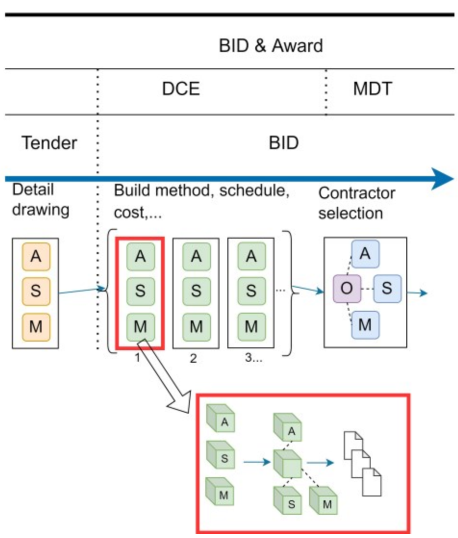

Figure 6. Workflow of BIM modeling in a project in Cambodia [1].

The research of Schöttle et al. [42] has identified trust, communication, commitment, knowledge sharing, and information exchange, are the factors to succeed collaboration. However, these factors are dependent on a shared language, common knowledge, and mutual understanding. Herbert Clark's psycholinguistic research emphasizes the importance of common ground for effective communication [54]. In the context of Cambodia's AEC industry, achieving such a common reference is essential.

To address the challenges faced in Cambodia's AEC sector and enhance BIM adaptation, several recommendations are proposed:

- **Establish common reference and guideline:** Developing a common reference and guidelines specific to the Cambodian context is vital to fostering collaboration and ensuring data centralization for future urbanization projects.
- **Promoting BIM education:** Promoting BIM courses within architecture, engineering, and construction universities is essential to equip future professionals with the necessary skills and knowledge. The companies have a willingness to use BIM by starting from training their staff. Yet, it takes a lot of time and effort. In United States, the companies prefer to employ candidate with BIM skills rather than those who lack BIM knowledge [40].
- **Regulatory framework:** Introducing government or owner requirements for BIM adoption can incentivize AEC companies to transition towards BIM-based practices. Additionally, establishing contractual standards that accommodate multidisciplinary organizational structures is crucial. The architecture company's owner said, "I'll accept to move to a BIM-based model if it is the governments or owners' requirement." Moreover, it also required contractual standards that support multidisciplinary actors' organizational structures [40].

The workflow scenarios describe the relationship of actors depending on the type of each scenario and program of construction. However, the current descriptions lack precision in elucidating the specificities behind these relationships. The limited sample size of 16 interviewees and observations from 2 construction projects prevents generalization to the broader context of Cambodia. It is crucial to explore the complexities and have a more comprehensive understanding.

VI. Conclusion

The empirical findings presented in this study provide valuable into the construction sector, particularly in the context of Cambodia. The research sheds light on factors that can contribute to the successful execution of construction projects in the region.

A. Finding

The research found four workflow scenarios. The main factor differs these scenarios in the Cambodian construction sector is the degree and timing of collaboration built between the owner(s), designers, and contractor(s). The study also underscore that traditional approaches still dominate project delivery in Cambodia, even for large-scale projects.

BIM has not yet gained widespread traction in Cambodia. The experts involved in large projects strongly believe that BIM can influence their project to be more productive. Yet, they still resistance to change. Its adoption requires enhanced motivation, training, and practical implementation, with a particular emphasis on government support by establishing the guidelines and regulations framework. This reference shall identify the accurate tasks, duties, and interactions of actors involved in the project. These guides will serve as a light to aiding the industry stakeholders in the successful implementation of BIM in their projects. Furthermore, the standards should align with the vision for a new project delivery approach, such as BIM, capable of addressing cost and schedule performance challenges and fostering more efficient project outcomes. The adoption of BIM in Cambodia necessitates a focus on human resource development. New roles, including BIM modelers, BIM coordinators, and BIM managers, will play pivotal roles in the BIM process.

B. Further work

Given the small number of samples, this research seeks to deliver valuable insights within its boundaries. Despite the modest sample size, the study aims to provide an understanding by recognizing its limitations and highlight the significance of the findings within the given resource constraints. While the findings are based on a smaller cohort, they contribute meaningfully to the existing knowledge in the field, laying the groupwork for future research with a more extensive participant. Future research should aim to expand the sample size to further validate and build upon the current findings. This broader approach will enable a more comprehensive exploration of the collaboration sector and the intricacies of workflow in the construction industry, facilitating a deeper understanding.

Furthermore, further research should concentrate on evaluating the impact BIM adoption within the Cambodian context. This assessment will provide valuable insights into the effectiveness of BIM in enhancing project outcomes, efficiency, and productivity in this specific regional context.

It is imperative to embark on the development of guidelines aimed at facilitating the integration of BIM practices into Cambodia's construction sector. These guidelines will serve as a critical roadmap for industry stakeholders, paving the way for the adoption of more efficient and technologically advanced methodologies. This objective can be achieved by conducting an extensive review of existing BIM guidelines and standards from a global perspective. Notably, the study should encompass Asian countries such as China, South Korea, and Japan, given their significant role as foreign investors in Cambodia. Additionally, European nations, including Belgium and France, which are pivotal members of the International Federation of Consulting Engineers (FIDIC) contract that finds extensive use in Cambodia, should be considered.

Moreover, the examination of BIM guidelines from leading BIM practitioners such as the United Kingdom and Luxembourg, renowned for their advancements in BIM technology, will provide invaluable insights.

These efforts will play a pivotal role in advancing the industry towards heightened efficiency and technological sophistication, ensuring alignment with global best practices in BIM implementation.

Acknowledgment

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Reference

[1] K. Keth, S. Ben Rajeb, and V. Han, "Collaborative Works in Construction Projects in Cambodia Toward a Workflow Scenario Identification," in *Proc. 13th In. Conf. on Advanced Collaborative Networks, Systems and Applications (COLLA 2023)*, Mar 2023, pp. 8-16. ISSN: 2308-4227, ISBN: 978-1-68558-063-6. [online]. Available: https://www.thinkmind.org/index.php?view=instance&instance=COLLA+2023

[2] National Bank of Cambodia, NBC: Annual Report 2018. [Online]. Available: https://www.nbc.gov.kh/

[3] S. Bodach, "Partnership Ready Cambodia : The construction sector Current situation," Internationale Zusammenarbeit (GIZ) GmbH, Eschborn, Nov. 2019.

[4] S. Durdyev, M. Omarov, and S. Ismail, "Causes of delay in residential construction projects in Cambodia," *Cogent Eng.*, vol. 4, no. 1, 2017, doi: 10.1080/23311916.2017.1291117.

[5] Y. Kang, Z. Jin, C. Hyun, and H. Park, "Construction Management Functions for Developing Countries: Case of Cambodia," *J. Manag. Eng.*, vol. 34, no. 3, pp. 1-9, 2018, doi: 10.1061/(asce)me.1943-5479.0000609.

[6] *Cambodia Industrial Development Policy 2015-2025: Market Orientation and Enabling Environment for Industrial Development*, Royal Government of Cambodia: Council of Ministers, Phnom Penh, Cambodia, 2015.

[7] G. Wu, X. Zhao, and J. Zuo, "Effects of inter-organizational conflicts on construction project added value in China," *Int. J.*

Confl. Manag., vol. 28, no. 5, pp. 695–723, 2017, doi: 10.1108/IJCMA-03-2017-0025.

[8] S. Hamidah, A. Rahman, I. Rohani, and N. Faisol, "The Importance of Collaboration in Construction Industry from Contractors' Perspectives," *Procedia-Soc. Behav. Sci.*, vol. 129, pp. 414–421, 2014, doi: 10.1016/j.sbspro.2014.03.695.

[9] D. W. Halpin and B. A. Senior, Construction Management, 4th ed. U.S., John Wiley & Sons, Inc., 2010.

[10] V. Peansupap and R. Ly, "Evaluating the Impact Level of Design Errors in Structural and Other Building Components in Building Construction Projects in Cambodia," *Procedia Eng.*, vol. 123, pp. 370–378, 2015, doi: 10.1016/j.proeng.2015.10.049.

[11] S. S. Karkala, "Construction Contracts in Cambodia," Construction-property.com, https://construction-property.com/construction-contracts-in-cambodia/ (accessed Nov. 23, 2022).

[12] *Conditions of Contract for Construction*, 1st ed, FIDIC, ISBN: 2-88432-022-9, 1999.

[13] *Plant and Design-Build*, 1st ed, FIDIC, ISBN: 2-88432-023, 1999.

[14] *Conditions of Contract for EPC / Turnkey Projects*, FIDIC, ISBN: 2-88432-021-0, 1999.

[15] *Short Form of Contract*, 1st ed, FIDIC, ISBN: 2-884320245, 1999.

[16] *The FIDIC Contracts Guide: conditions of contract for construction, conditions of contract for plant and design-build, conditions of contract for EPC/Turnkey projects*, 1st ed. FIDIC, 2000.

[17] C. Fellowes, "Introduction to FIDIC contracts," 2012. [Online]. Available: https://www.mayerbrown.com/en/perspectives-events/publications/2012/12/introduction-to-fidic-contracts (assessed Nov. 24, 2023)

[18] K. Shadan and G. Fleming, "Construction Project Management Handbook," Federal Transit Administration, Washington, No. 0015, Mar. 2012.

[19] *L'architecte et Ses Missions [Architect and his Missions]*, Order des Architects, Belgium, 2020.

[20] R. Maskuriy, A. Selamat, K. N. Ali, P. Maresova, and O. Krejcar, "Industry 4 . 0 for the Construction Industry — How Ready Is the Industry ?," *Appl. Sci.*, vol. 9, no. 14, p. 1-26, 2019, [Online]. Available: https://doi.org/10.3390/app9142819

[21] *Rectangular Strategy for Growth, Employment, Equity and Efficiency: Building the Foundation Toward Realizing the Cambodia Vision 2050, Phase IV of the Royal Government of Cambodia of the Sixth Legislature of the National Assembly*, Royal Government of Cambodia, Phnom Penh, Cambodia, 2018, [Online]. Available: https://www.mcs.gov.kh/?p=14985

[22] C. Eastman, P. Teicholz, R. Sacks, and K. Liston, BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Architects, Engineers, Contractors, and Fabricators, vol. 53, no. 9. John Wiley & Sons, Inc., Hoboken, New Jersey, 2008.

[23] B. Succar, "Building Information Modelling Maturity Matrix," in Handbook of Research on Building Information Modeling and Construction Informations: Concepts and Technologies, Hershey, PA, USA: Information Science Reference, IGI Publishing, 2010, pp. 65–103.

[24] "Frequently asked questions about the National HR Standards Project," nationalbimstandard.org. https://www.nationalbimstandard.org/faqs#faq1 (accessed Dec. 06, 2022).

[25] R. Matos, F. Rodrigues, H. Rodrigues, and A. Costa, "Building condition assessment supported by Building Information Modelling," *J. Build. Eng.*, vol. 38, p. 1–12, 2021, doi: 10.1016/j.jobe.2021.102186.

[26] "Modeling, Model, and Management: the three M's of BIM and the right BIM tools," biblus.accasoftware.com. https://biblus.accasoftware.com/en/modeling-model-and-management-the-three-ms-of-bim-and-the-right-bim-tools/ (accessed Nov. 23, 2022).

[27] A. Rezaei and N. S. Sistani, "BIM Implementation in Developing Countries," in proc. *10th Int. Congr. Adv. Civ. Eng.*, Ankara, Turkey, 17-19 Oct., 2012,

[28] M. Oraee et al., "Collaboration barriers in BIM-based construction networks: A conceptual model," *Int. J. Proj. Manag.*, vol. 37, no. 6, pp. 839–854, 2019, doi: 10.1016/j.ijproman.2019.05.004.

[29] S. Durdyev, J. Mbachu, D. Thurnell, L. Zhao, and M. R. Hosseini, "BIM Adoption in the Cambodian Construction Industry: Key Drivers and Barriers," *ISPRS Int. J. Geo-Information*, vol. 10, no. 4, pp. 1–14, 2021, doi: 10.3390/ijgi10040215.

[30] T. Tan, K. Chen, F. Xue, and W. Lu, "Barriers to Building Information Modeling (BIM) implementation in China's prefabricated construction: An interpretive structural modeling (ISM) approach," *J. Clean. Prod.*, vol. 219, pp. 949–959, 2019, doi: 10.1016/j.jclepro.2019.02.141.

[31] Y. Zhou, Y. Yang, and J.-B. Yang, "Barriers to BIM implementation strategies in China," *Eng. Constr. Archit. Manag.*, vol. 26, no. 3, pp. 554–574, 2018, doi: 10.1108/ECAM-04-2018-0158.

[32] L. Ma, R. Lovregilo, W. Yi, T. Yiu, and M. Shan, "Barriers and strategies for building information modelling implementation : a comparative study between New Zealand and China," *Int. J. Constr. Manag.*, vol. 23, no. 12, pp. 2067–2076, 2023, doi: 10.1080/15623599.2022.2040076.

[33] H. Liu, R. Zhang, H. Zhang, H. Jiang, and Q. Ju, "Identification and Analysis of Key Barriers of BIM Application for Small- and Medium-Sized Fire Protection Enterprises," *J. Environ. Public Health*, vol. 2022, no. 9, p. 1–19, 2022, doi: https://doi.org/10.1155/2022/9240224.

[34] Q. To, T. Huong, E. C. W. Lou, and N. Le Hoai, "Enhancing BIM Diffusion through Pilot Projects in," *Eng. J.*, vol. 25, no. 7, pp. 167–176, 2021, doi: 10.4186/ej.2021.25.7.167.

[35] T. Nguyen and D. Nguyen, "Barriers in BIM Adoption and the Legal Considerations in Vietnam," *Int. J. Sustain. Constr. Eng. Technol.*, vol. 12, no. 1, pp. 283–295, 2021, doi: https://doi.org/10.30880/ijscet.2021.12.01.027.

[36] T. Dao and P. Chen, "Critical Success Factors and a Contractual Framework for Construction Projects Adopting Building Information Modeling in Vietnam," *Int. J. Civ. Eng.*, vol. 19, pp. 85–102, 2021, doi: 10.1007/s40999-020-00542-3.

[37] N. Akmal, A. Ismail, M. Nazareth, and M. Yousof, "BIM Adoption in Managing Construction Risks Amongst Malaysian Quantity Surveyors : Current Practice and Challenges," *Int. J. Sustain. Constr. Eng. Technol.*, vol. 12, no. 3, pp. 166–175, 2021, doi: https://doi.org/10.30880/ijscet.2021.12.03.017.

[38] M. Harris, A. I. C. Ani, A. . Haron, and A. . Husain, "The way forward for Building Information Modelling (BIM) for contractors in Malaysia," *Malaysian Constr. Res. J.*, vol. 15, no. 2, pp. 1–9, 2014, [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85053321777&partnerID=40&md5=053350fad7faf849dd7cb4efb28179c7

[39] Q. To, T. Huong, P. L. Quang, and N. Le Hoai, "Applying Bim and Related Technologies for Maintenance and Quality Management of Construction Assets in Vietnam," *Int. J. Sustain. Constr. Eng. Technol.*, vol. 12, no. 5, pp. 125–135, 2021, doi: https://doi.org/10.30880/ijscet.2021.12.05.013

[40] W. Syazwani, M. Abdullah, S. Ismail, and R. Takim, "Technology-Organisation-Environment Framework for Building Information Modelling (BIM) Adoption Challenges for Contractor's Organisations in Malaysia Journal," *J. Comput. Theor. Nanosci.,* vol. 16, no. 5, pp. 2282–2288, 2019, doi: 10.1166/jctn.2019.7885.

[41] M. Taib, H. Quanhua, and N. Taib, "Building Information Modelling (BIM) Adoption for Cost Engineering Consultant: Case Study of Southern China," *J. Adv. Res. Appl. Sci. Eng. Technol.*, vol. 29, no. 3, pp. 21–36, 2023, doi: https://doi.org/10.37934/araset.29.3.2136

[42] A. Schöttle, S. Haghsheno, and F. Gehbauer, "Defining cooperation and collaboration in the context of lean construction," in *Proc. 22nd Annu. Conf. Int. Gr. Lean Constr. Underst. Improv. Proj. Based Prod. IGLC 2014*, vol. 49, no. 0, pp. 1269–1280, 2014.

[43] D. J. Wood and B. Gray, "Toward a Comprehensive Theory of Collaboration," *J. Appl. Behav. Sci.,* vol. 27, no. 2, pp. 139–162, 1991, doi: 10.1177/0021886391272001.

[44] M. Ilich, B. Becerik, and B. Aultman, "Online collaboration: why aren't we using our tools? Publication," *Publ. of Architectural Eng. Inst. Constr. Inst. ASCE*, vol. 6, p. 10, 2006, doi: 10.1007/s00766-016-0254-6.

[45] M. Oraee, M. R. Hosseini, E. Papadonikolaki, R. Palliyaguru, and M. Arashpour, "Collaboration in BIM-based construction networks: A bibliometric-qualitative literature review," *Int. J. Proj. Manag.*, vol. 35, no. 7, pp. 1288–1301, 2017, doi: 10.1016/j.ijproman.2017.07.001.

[46] F. Détienne, M. Baker, and J. M. Burkhardt, "Perspectives on quality of collaboration in design," *CoDesign*, vol. 8, no. 4, pp. 197–199, 2012, doi: 10.1080/15710882.2012.742350.

[47] E. A. Poirier, D. Forgues, and S. Staub-French, "Understanding the impact of BIM on collaboration: a Canadian case study," *Build. Res. Inf.*, vol. 45, no. 6, pp. 681–695, 2017, doi: 10.1080/09613218.2017.1324724.

[48] G. DeSanctis and R. B. Gallupe, "Foundation for the Study of Group Decision Support Systems.," *Manage. Sci.*, vol. 33, no. 5, pp. 589–609, 1987, doi: 10.1287/mnsc.33.5.589.

[49] C. Ellis and J. Wainer, "A conceptual model of groupware," *in Proc. 1994 ACM Conf. Comput. Support. Coop. Work. CSCW 1994*, no. January 1999, pp. 79–88, 1994, doi: 10.1145/192844.192878.

[50] X. Calixte, S. Ben Rajeb, and P. Leclercq, "Traçabilité de l'usage des outils de conception dans un processus collaboratif [Traceability of the use of design tools in a collaborative process]," in *Proc. SHS Web Conf.*, vol. 47, pp. 1–12, 2018, doi: 10.1051/shsconf/20184701004.

[51] N. Gasmallah, M. Oussalah, and A. Amirat, "Towards a classification for software architecture evolution studies," in *Proc. Conf. Francoph. sur les Archit. Logicielles, CAL 2016*, no. August, pp. 42–51, 2016, doi: 10.3199/JESA.45.1-n.

[52] X. Calixte, G. Gronier, S. Ben Rajeb, and P. Leclercq, "Impact des outils numériques de communication et d'échanges d'information dans les processus de conception collaborative [Impact of digital communication and information exchange tools in collaborative design processes]," 01 Dessign'11, pp. 1–14, 2018.

[53] P. E. Weiseth, B. E. Munkvold, B. Tvedte, and S. Larsen, "The wheel of collaboration tools: A typology for analysis within a holistic framework," in *Proc. ACM Conf. Comput. Support. Coop. Work. CSCW*, pp. 239–248, 2006, doi: 10.1145/1180875.1180913.

[54] J. Clarkson and C. Eckert, Design process improvement: A review of current practice, 2005.

[55] X. Calixte, "Les outils dans l'activité collective médiatisée en conception : traçabilité des usages au sein du processus de conception architecturale [Tools in mediated collective activity in design: traceability of uses within the architectural design process]," Ph.D. dissertation, School of Poly., Univ. Liège and Univ. Libre de Bruxelles, Belgium, 2021.

[56] J. W. Creswell, Qualitative inquiry and research design: Choosing among five approaches. Sage Publications, Inc., 1998.