การนำการสร้างแบบจำลองสารสนเทศอาคาร (BIM) ไปใช้จัดการความเสี่ยงในโครงการออกแบบและก่อสร้าง

นายเมอวีน เจน มาลวาร์

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IMPLEMENTING BUILDING INFORMATION MODELING (BIM) FOR CONSTRUCTION RISK MANAGEMENT IN DESIGN-BUILD PROJECTS

Mr. Mervyn Jan Malvar

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Civil Engineering
Department of Civil Engineering
Faculty of Engineering
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เมอวีน เจน มาลวาร์ : การนำการสร้างแบบจำลองสารสนเทศอาคาร (BIM)ไปใช้จัดการความเสี่ยงในโครงการออกแบบและก่อสร้าง (IMPLEMENTING BUILDING INFORMATION MODELING (BIM) FOR CONSTRUCTION RISK MANAGEMENT IN DESIGN-BUILD PROJECTS) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร วีระศักดิ์ ลิขิตเรืองศิลป์, 201 หน้า.

การสร้างแบบจำลองสารสนเทศอาคาร (Building Information Modeling, BIM) เป็นแนวคิดเชิงนวัตกรรมสำหรับการบริหารงานก่อสร้างซึ่งเป็นประโยชน์แก่ทุกฝ่ายภายในโครงการในหลากหลายแง่มุม รวมไปถึงการจัดการความเสี่ยงของโครงการ อย่างไรก็ตามยังมีการศึกษาที่จำกัดเกี่ยวกับความสัมพันธ์ระหว่างความเสี่ยงกับ BIM รวมถึงการนำ BIM ไปใช้จัดการความเสี่ยงโครงการก่อสร้าง โดยเฉพาะอย่างยิ่งในโครงการออกแบบและก่อสร้าง (Design-Build, DB) ซึ่งความเสี่ยงส่วนใหญ่ถูกส่งผ่านไปยังผู้รับจ้างก่อสร้าง งานวิจัยนี้นำเสนอการใช้ BIM (BIM Use) ที่เหมาะสมสำหรับจัดการความเสี่ยงต่าง ๆ ในงานก่อสร้าง ความเสี่ยงในโครงการออกแบบและก่อสร้างถูกรวบรวมจากเอกสารงานวิจัยในอดีต และถูกตรวจสอบความถูกต้องโดยการสัมภาษณ์เชิงลึกกับกลุ่มผู้เชี่ยวชาญทางด้าน BIM และโครงการออกแบบและก่อสร้าง นอกจากนั้นการใช้ BIM 30 ลักษณะได้ถูกระบุและทบทวนอย่างละเอียด กรอบความสัมพันธ์ระหว่างความเสี่ยงและการใช้ BIM ได้ถูกสร้างขึ้นโดยอาศัยลักษณะประจำ (attribute) ที่ร่วมกันของความเสี่ยงและการใช้ BIM ได้แก่ ปัจจัยเสี่ยง ความมุ่งหมายของการใช้ BIM วัฏจักรชีวิตของโครงการ องค์ประกอบของสิ่งปลูกสร้าง และกลุ่มคนซึ่งรับผิดชอบ กรอบที่นำเสนอประกอบด้วย 5 ขั้นตอนหลัก ได้แก่ (1) การกำหนดรายละเอียด (2) การวิเคราะห์ความมุ่งหมายของการใช้ BIM (3) การตรวจสอบความเสี่ยง (4) การคัดเลือกการใช้ BIM และ (5) การปรับเมทริกซ์ให้เป็นปัจจุบัน ผลวิจัยที่สำคัญคือเมทริกซ์ความสัมพันธ์ระหว่างความเสี่ยงและการใช้ BIM ซึ่งกำหนดการใช้ BIM ที่เป็นไปได้ทั้งหมดเพื่อจัดการความเสี่ยงต่าง ๆ ที่สำคัญในโครงการ แนวทางการใช้ BIMสำหรับจัดการความเสี่ยงได้ถูกสร้างขึ้น กรอบที่เสนอได้ถูกตรวจสอบความถูกต้องโดยประยุกต์ใช้ในกรณีศึกษา 3 ตัวอย่างซึ่งเป็นโครงการออกแบบและก่อสร้างที่ใช้ BIM ในประเทศฟิลิปปินส์ ปัจจัยที่สำคัญในการพิจารณาเลือกการใช้ BIM ที่เหมาะสมสำหรับจัดการความเสี่ยงถูกวิเคราะห์โดยอาศัยการใช้ BIM ที่ถูกนำไปใช้จริงในแต่ละกรณีศึกษาเปรียบเทียบกับการใช้ BIM ที่กรอบที่นำเสนอแนะนำ ปัจจัยดังกล่าวได้แก่ พื้นฐานการศึกษาและความสามารถของผู้รับจ้างก่อสร้าง ขนาดของโครงการ ต้นทุนในช่วงเริ่มต้นโครงการนำร่อง เส้นโค้งการเรียนรู้และความสนใจในการนำมาใช้ อินเทอร์เน็ต ความต้องการของลูกค้า การสนับสนุนของรัฐบาล และการบริหารองค์กร ผลการวิจัยสามารถใช้สำหรับสร้างระบบบนพื้นฐานของ BIM ที่สมบูรณ์สำหรับจัดการความเสี่ยงในงานก่อสร้างต่อไปในอนาคต

ภาควิชา วิศวกรรมโยธา	ลายมือชื่อนิสิต ....
สาขาวิชา วิศวกรรมโยธา	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
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KEYWORDS: BUILDING INFORMATION MODELING / RISK MANAGEMENT / PHILIPPINES / BIM BARRIERS / BIM IMPLEMENTATION / BIM USES / DESIGN-BUILD

MERVYN JAN MALVAR: IMPLEMENTING BUILDING INFORMATION MODELING (BIM) FOR CONSTRUCTION RISK MANAGEMENT IN DESIGN-BUILD PROJECTS. ADVISOR: ASSOC. PROF. VEERASAK LIKHITRUANGSILP, Ph.D., 201 pp.

Building information modeling (BIM) is an innovative concept for construction management, which can benefit all stakeholders in several aspects, including project risk management. However, there have been limited studies about the relations between risk and BIM, as well as the implementation of BIM for construction risk management, particularly in design-build (DB) projects where most risks are transferred to the DB contractors. This research proposes BIM uses that are appropriate for managing different construction risks. A total of 20 DB project risks were compiled from past literature and verified through in-depth interviews with BIM and DB project experts, and 30 BIM uses were identified and reviewed thoroughly. A risk-BIM use framework was created based on the common attributes of risks and BIM uses, including risk factors, BIM use purposes, project lifecycle, facility elements, and responsible parties. The proposed framework consists of five main steps: (1) detail setting, (2) BIM use purpose analysis, (3) risk investigation, (4) BIM use filtering, and (5) matrix update. An important result is a risk-BIM use relation matrix, which provides all potential BIM uses to manage critical project risks. A guideline on utilizing BIM uses for risk management is elaborated. The proposed framework was verified through three case studies of BIM-adopted DB projects in the Philippines. The important factors considered in selecting the optimal BIM uses for risk management are analyzed based on the BIM uses each case study actually implements as compared with those suggested by the proposed framework. Such factors are educational background and capability of contractors, project size, upfront cost, pilot projects, learning curve and eagerness to adopt, internet, client demand, government support, and governing body. The results can be used to establish a comprehensive BIM-based system for managing construction risks.

Department:	Civil Engineering	Student's Signature	....
Field of Study:	Civil Engineering	Advisor's Signature	....
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CHAPTER 1
INTRODUCTION

1.1 Background

The Philippine economy is currently recognized as the fastest growing economy among the five largest in the ASEAN or ASEAN 5 (NSCB, 2013). The ASEAN 5 which includes Indonesia, Malaysia, Philippines, Singapore and Thailand, is expected to be the key growth drivers not only in Southeast Asia but also the Asia Pacific region. Figure 1.1 shows the annual PH, ASEAN and ASEAN 5 gross domestic product (GDP) growth from 2005-2012. In the Philippines, a 6.8% growth in the GDP was seen in 2012. In 2013, it grew to 7.6% wherein the second most contributor is the construction sector. The construction sector generated a growth of 17.4% in 2013 from 11.6% in 2012 (Cabiao, 2013). Improvement in the industry shows a lot of progress that affects the development of the country as a whole.

The Philippine construction industry has presented a myriad of opportunities. Most projects are a result of recent rehabilitation efforts due to tropical storms, private sector venturing to mining and plant projects, and the participation of the private sector in infrastructure projects. These contribute to the rapid economic growth in the Philippines. In addition, the ASEAN integration provides opportunities in the Southeast Asian market.

Technological advancement has been a catalyst of improvement in the recent years. Sharif (1997) said that technology-based strategic advancement of the different enterprises is the key for success in the global market. He concluded that the Philippine service companies need guidance for technological implementation and support from the government to compete with the global market. Therefore, keeping abreast with the latest technology and innovation like building information modeling (BIM) would affect the country's development, particularly the construction sector.

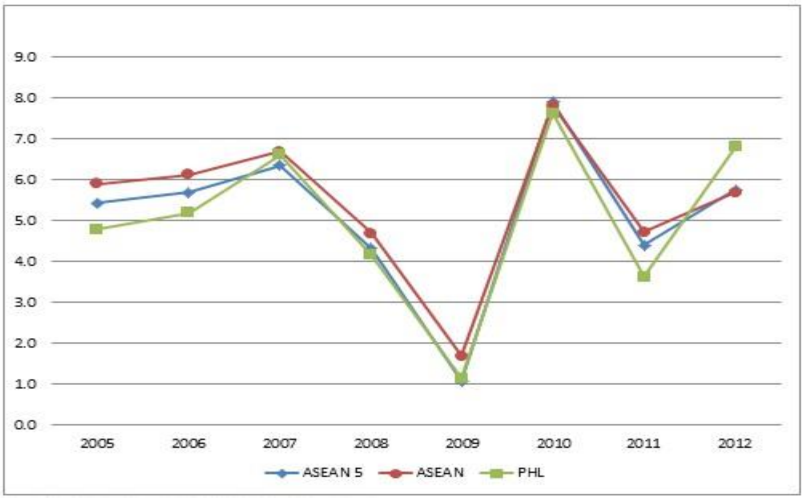

Figure 1.1 Annual PH, ASEAN and ASEAN 5 GDP Growth: 2005-2012 (NSCB, 2013)

The popularity of BIM has encouraged the academia, the industry, and the government of some nations to implement it. However, these implementation efforts experience barriers. BIM is not only a technological shift but it also changes the perspective of the design and construction teams (Porwal and Hewage, 2013). Currently the industry is undergoing a gradual transition to BIM due to the industry's fragmented nature (Reddy, 2012). Taylor and Bernstein (2009) have shown that BIM technologies were adopted more slowly in the AEC industry than its predecessor two-dimensional (2D) CAD. As a result, many countries have started implementing BIM over the last years and have been enjoying the benefits that the new technology offers. On the other hand, other countries have difficulty implementing BIM due to some impediments such as lack of technological development and reluctance to change.

1.2 Problem Statement

The complexity and uniqueness of construction projects expose each construction activities to uncertainty and risk. To minimize the adverse effects of risks on project objectives, risk management is enforced. Risk management is an aspect of project management used to proactively and systematically identify, assess, respond, and monitor risks (Smith, 2006, PMI, 2004). Moreover, employers usually implement design-build (DB) procurement to transfer most of the risks to the DB contracting party and to fast-track project delivery.

In recent years, BIM has become a well-known innovative concept and tool for construction management. The benefit of BIM for project management has been given emphasis by Bryde et al., (2013). Since risk management is an aspect of project management, BIM can be perceived beneficial for all aspects of project management (Bryde et al, 2013). However, there is still a lack in research with regard to BIM and risk management.

With the abundance in the development of applications and uses of BIM available nowadays, it becomes difficult for the project planning team to select which applications and BIM uses would benefit their projects. Owners and contractors are faced with the problem of identifying which BIM uses to implement based on their current needs. This is due to the lack of BIM experts especially in developing countries like the Philippines, combined with upfront costs, and other barriers in BIM implementation. With an industry that does not have enough experts, it therefore becomes difficult to identify which BIM uses are required to shift to the BIM paradigm.

The identification in which area to implement BIM in managing project risks remains distorted. Since risks are inevitable and are likely to deviate from the desired project objectives, being able to relate BIM with risks would direct it to the attention of BIM implementers in order to attend to their needs. The perception of identifying and selecting BIM uses should be driven by expected outputs and goals, not by the input which are essentially the required tools (Won et al., 2013). However, there has been a lack of study of how BIM can address risks in DB projects. Also, BIM research with regard to the Philippine context has been deficient despite its rapid growth and implementation.

1.3 Research Objective

This research explores the BIM uses that both owners and contractors can implement to manage their construction project risks. Thus, the objective of this research is to identify appropriate BIM uses for construction risk management.

This research explores an approach of implementing BIM through investigating the risk management in DB projects. The identification of critical risks that stakeholders are exposed to leads to the requirement of BIM in their future projects. It therefore shows which BIM uses can help manage the owners' and contractors' risks in construction projects.

1.4 Research Scope

As DB and construction projects in particular are exposed to a lot of risks, the risks that were identified were only those that were critical in past studies. This research focuses on project risks and does not tackle IT-related risks, which are common in BIM-related studies.

The interview respondents are limited to owners, i.e., developers, and DB contractors, who are knowledgeable about BIM. In addition, the study will focus on DB projects, which is the most effective project delivery to integrate BIM (Bynum et al., 2013) and resolving technical risks (Ling et al., 2007). Hence, this research does not discuss the other project delivery methods. This research focuses on DB projects in the Philippines, particularly the new projects which include high rise buildings and plant projects.

This research does not intend to tackle risk management in detail. The output of risk assessment which will be the critical risks will lead to the ideal BIM uses that the organization can implement. Consequently, it is assumed that all risks identified are risks that the respondents want to mitigate. The focus of this study is on how to use BIM to address those identified risks by evaluating which are critical. Thus, other response strategies existing in literature such as risk avoidance, risk transfer and risk absorption will not be discussed.

The risk management processes discussed are risk identification, risk response, and risk monitoring. Risk assessment is not included because recent studies have proven that external numerical analysis is still conducted and is not in the BIM system (Kang et al., 2013).

This study will analyze some BIM uses that are available in most of the BIM tools. Therefore this does not intend to have bias on software or hardware as some specific BIM tools will be mentioned from time to time. Moreover, information exchanges, as part of the BIM execution plan (BEP), will not be elaborated in this thesis. Hence, an overview map of the whole BIM process in a project will not be discussed.

Lastly the recommendations on this research is to present common guidelines for implementing BIM in risk management process. Ergo, providing a detailed execution plan is outside the scope of this thesis.

1.5 Steps of Research

The summary of the steps of research are as follows:

Step 1: Understand Relevant Concepts and Investigate the Current State of Research in the Philippines. This step is to identify the relevant literature regarding risk management, BIM, and DB projects. In addition, risk identification based on previous DB projects was performed.

Step 2: Verify Identified Risks. This step is to verify the applicability of the identified risks in DB projects from literature to the Philippine context. This step also verifies BIM-manageable risks through in-depth interviews with DB project and BIM. The verification process includes the identification of attributes that are used for the framework development.

Step 3: Investigate Attributes of Each BIM Use. This step is to review the current BIM uses in literature. This involves identifying and defining of the attributes that are related to the risks, which are used for the framework development. Some of the attributes of BIM use considered are description, expected benefits, requirements, and processes.

Step 4: Develop the Risk-BIM Use Framework. This step is to develop a preliminary framework based on the established relationship between BIM and risk. The framework results to a risk-BIM use matrix, which determines the appropriate BIM uses to be implemented for the verified risks.

Step 5: Explicate Implementation of BIM for Risk Management. This step is to discuss how to implement each BIM use for project risk management based on the identified relationship with the project risk. It involves analysis based on the attributes of BIM use, which were investigated in the previous step.

Step 6: Verify the Framework through Case Studies of DB Projects in the Philippines. This step is to investigate three different case studies of early BIM adopters in the Philippines and how they use their current BIM uses in managing their risks. In addition, this step identifies factors to be considered when implementing the BIM uses for risk management.

Step 7: Draw Conclusions and State Limitations of the Research. This step is to report the findings, limitations, and recommendations of this research.

The detailed discussion of each step will be discussed in Chapter3.

1.6 Summary of Thesis

This thesis seeks to relate risks and BIM uses, and to present guidelines on how to utilize BIM uses for construction risk management. The following is a summary of the thesis.

- Chapter 2 presents a literature review on related concepts such as risk and risk management, BIM background, risk and BIM related research, and research gaps.
- Chapter 3 describes the research methodology adopted in this thesis including the conceptual and theoretical frameworks and respondents' profiles.
- Chapter 4 describes the background of DB projects in the Philippines and the perception why owners and contractors decide to implement that project delivery method.
- Chapter 5 describes the risks verified for DB projects in the Philippines including its attributes that are related to the BIM uses.

- Chapter 6 presents the current BIM uses available in literature at the time this research was written along with its attributes.
- Chapter 7 provides the developed framework and the main output of this thesis which is the risk-BIM use relation matrix, and demonstrated its application.
- Chapter 8 presents three case studies of early BIM implementers in the Philippines in the pre-construction, construction, and post-construction stages. This chapter also provides discussions and presents the factors identified by the author in selecting optimal BIM uses for risk management.
- Chapter 9 concludes the research, identifies the limitations, and suggests future implications concerning risks and BIM.

CHAPTER 2
LITERATURE REVIEW

Literature review was performed to comprehend the current information available with regard to relating BIM and risk management. The objectives are determining the current applications and uses of BIM in projects, identifying risks in DB projects and in terms of the Philippine context, and examining current publications relating risks and BIM.

This chapter consists of five sections. The first part discusses the overview of BIM. The second part overviews risk and its management. The third part reviews DB procurement and identifies risks related to it. The fourth part examines existing literature about project risks and BIM. The final section concludes this chapter and highlights important research gaps leading to the main objective of this thesis.

2.1 Overview of Building Information Modeling

BIM is one of the promising developments in the AEC industry (Kubba, 2012). It has changed the way contractors and designers do business for the early adopters. Until now it is still changing and developing and there is still much to learn about this technological development. It is very important to establish a correct foundation about the concept and theories relating to BIM.

Computer Aided Drafting (CAD) is different from BIM. According to Kubba (2012), BIM is not CAD nor is it intended to be. CAD is a shift from pen and paper and a documentation tool. CAD files are basic data consisting of lines, arcs, circles, time surfaces and solids that are purely graphical representations of building components. BIM is not just the 3D model of a facility but also a process where communication and collaboration among stakeholders are important.

2.1.1 Definition of BIM

Scholarly articles have given BIM definitions. According to Hardin (2009), BIM is a "virtual construction of a facility or structure that contains intelligent objects in a single source file that, when shared among project team members, intends to increase the amount of communication and collaboration." Another definition is by Eastman et al. (2011) wherein BIM is a modeling technology and associated set of processes to produce, communicate and analyze building models. Kubba (2012) said that BIM has gained widespread popularity but has failed to gain a consistent definition. He therefore consolidated the definitions given by various authors and came up with another definition quite similar and in the context. BIM is defined as an integrated process that allows architects, engineers, builders, owners and other stakeholders to explore a project's key physical and functional characteristics digitally-prior to construction. Kubba (2012) emphasized that BIM is the future and it is here now. The definition by Kubba is the definition of BIM utilized for this thesis.

2.1.2 Benefits and Barriers in Adopting BIM

The added value of BIM for collaborative processes has been acknowledged in theory and practice. Increased in effectiveness and efficiency, reduced time and errors, and improved quality are some of the common added values (Sebastian and van Berlo, 2010). McGraw-Hill (2012a) has been conducting an on-going study for the benefits of BIM since 2009 and highlighted the long and short-term benefits of BIM. The long-term benefits include repeated business with clients, reduced overall project duration, increased profits, reduced construction cost and fewer disputes while the short benefits include reduced errors, added marking strategy, reduced rework, offered new services, reduced cycle time of specific workflows, and added more staff (McGraw-Hill, 2012a).

In spite of the benefits perceived in adopting BIM, it is still doubted by some practitioners. Even though BIM is expected to deliver many benefits and the costs are not significantly higher than traditional or alternative management approaches, there are still many reasons that impede widespread adoption. It was emphasized by Kubba (2012) that organizations are taking a wait-and-see approach in which they are seeking clear evidence for a return on the investment of implementing BIM.

Eadie et al. (2013) analyzed the BIM implementation throughout the UK construction project lifecycle. Along with discovering the financial benefits of BIM and examination of BIM usage at various lifecycle stages, they also analyzed why stakeholders did not implement BIM. Some of the reasons were:

- Lack of expertise within the project team and organizations
- Lack of client demand
- Cultural resistance
- High investment cost
- Lack of additional project finance to support BIM
- Resistance at operational level
- Reluctance of team members to share information
- Lack of immediate benefits and
- Legal issues around ownership of the model

The literature has presented a wide variety of benefits perceived when implementing BIM. These benefits generally contribute to the easement of managing risks which will be discussed in the succeeding sections. Although these benefits exist, barriers of BIM adoption are still prevalent. These barriers may have been discovered in other countries; however, they are still relevant to the Philippine construction industry and any country in general. Similar to South Korea before (McGraw-Hill, 2012b), the Philippines encounters the same challenges during the time this thesis was written due to the infancy of BIM adoption. Thus, it is noteworthy to examine these barriers to properly address them and streamline implementation.

2.1.3 Benefits of BIM in Project Management

Exploration of BIM for project management was given emphasis after Allison (2010) as stated in (Bryde et al., 2013). The potential benefits for project management, although coming from a software vendor's standpoint from Allison (2010), is currently being explored. Some of the potential benefits were organizing schedule and budget, working well with design teams, limiting request for information (RFIs) and change orders, managing subcontractors, optimizing owner's experience and satisfaction, having efficient project closeout and better profit margin, and catalyzing organizational growth.

Theoretically, BIM can also be beneficial for the management of construction projects aside from its geometric modelling benefits. (Bryde et al., 2013) explored the extent of using BIM for project management. A total of 35 construction projects that utilized BIM were explored which were contextually analyzed according to a set of project management success criteria according to PMBOK knowledge areas (PMI, 2004) . Cost reduction and control through the project lifecycle were the most frequently reported benefit among the cases. Other benefits include time reduction and control, communication improvement, coordination improvement, quality increase or control, negative risk reduction, scope clarification, organization improvement, and software issues.

From the 35 cases studies by Bryde et al. (2013), 6 cases discussed about the context of risk management through negative risk reduction. These cases provided a positive impact in terms of the contribution of BIM to risk management. However, the description of the benefit of BIM for risk still has ambiguity. The limited instances in the cases provided by Bryde et al. (2013) supplemented by a lack of literature regarding the benefit of BIM for risk management signify a need for exploration in this topic.

2.1.4 BIM Uses

The term "BIM uses" was initiated by Kreider et al. (2010) in their study of identifying perceived benefits and frequency of implementation of twenty five uses of BIM in construction projects in the US. BIM use was defined as "a method of applying BIM during a facility's life cycle to achieve one or more specific objectives" (Kreider et al., 2010). The same definition was adopted for this thesis and similar researchers regarding BIM applications and uses. The same list of BIM uses was adopted in the Computer Integrated Construction Research Group (CICRP) of the Pennsylvania State University

(Penn State) Project Planning Guide (CICRP, 2011). The Penn State Project Planning Guide classified the 25 BIM uses according to project lifecycle as shown on Figure 2.1.

Taylor and Bernstein (2009) investigated the paradigm trajectories of BIM practice. They identified four paradigms of BIM practice as shown in Figure 2.2. Visualization is the first paradigm wherein the initial adopters perceive the primary role of BIM tools as enhancing visualization and as an initial approach to using BIM on projects. The next paradigm is coordination. After evolving beyond the visualization paradigm, firms use BIM to improve coordination of work within the firm and with other project stakeholders. The coordination paradigm is the stage where firms have difficulties on moving to the next. The extent to which firms do coordination is from within the firm and/or sharing files with other project members. The third paradigm is analysis. Firms that share files with other firms on projects such as fabricators and suppliers are considered in the analysis paradigm. This paradigm includes analysis of impact of design changes on cost, access and egress patterns in situations of fire, analyze lighting scenarios and optimization of natural light, thermal and air flow analysis. The last paradigm is supply chain integration. This paradigm uses the model created to design the building to be used to order or manufacture materials for the building. With increasing project experience, the BIM practice in a firm evolves cumulatively from visualization, to coordination, to analysis, and to supply chain integration. Similar to BIM uses, these paradigms represent the state of application of BIM depending on the BIM practice of a particular firm.

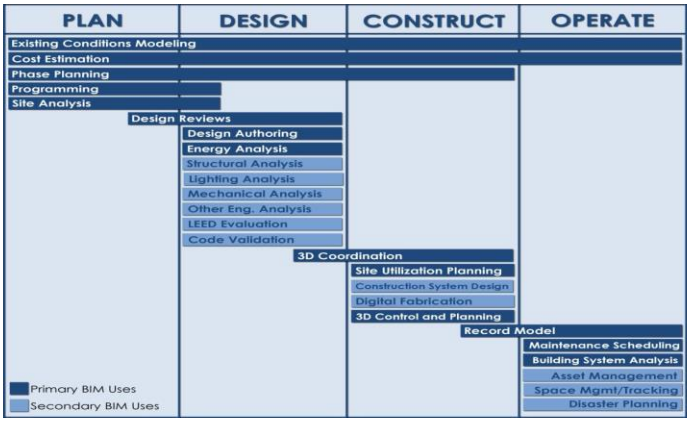

Figure 2.1 BIM uses in the building lifecycle (CICRP, 2011)

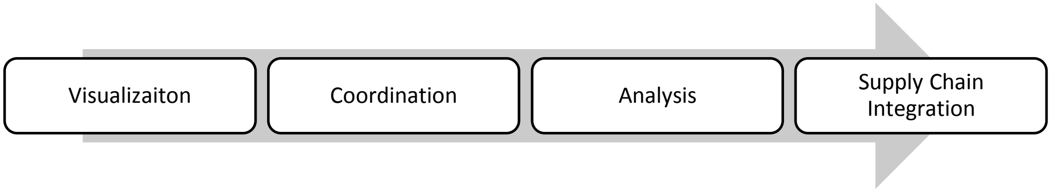

Figure 2.2 Paradigm trajectories of BIM practice (Taylor and Bernstein, 2009)

Ku and Taiebat (2011) investigated the current level of BIM implementation and capabilities in construction firms. They examined the areas of BIM implementation and highlighted the areas that are needed immediately, in the near future, and in the far future as their main goal is to determine the capabilities of fresh graduates in terms of BIM use. The authors found out 14 implementation areas which includes 4D scheduling, performance optimization, model based estimating, productivity optimization, environmental analysis, safety, alternative development, constructability, visualization, database information management, sustainability, cost control, facility management and site planning. Their findings correspond with Taylor and Bernstein (2009) in which the immediate BIM knowledge demands constructability and visualization. The near future requires model based estimating and cost control whereas environmental analysis and facility management are required in the far future. These implementation areas highlighted by Ku and Taiebat (2011) showed the current BIM uses practiced by construction firms.

Eastman et al. (2011, p. 203) discussed about the BIM uses that the designer can use when adopting BIM. They investigated the uses in three stages namely: (1) conceptual design, (2) use of BIM for design and analysis, and (3) developing construction-level information. Conceptual design involves development and refinement of the building (Eastman et al., 2011). In this stage, it specifies the project in terms of spatial area, functions, types of construction and basic assessment of the building use and cost viability. In this stage, space validation, preliminary circulation and security assessment, preliminary energy analysis and preliminary cost estimate can be performed. The building system design and analysis includes multi-disciplinary analyses like structural, mechanical, lighting, and etc. This also includes analysis of conformance to building code requirements and regulations. Cost estimation can also be done wherein value engineering can be carried out while the designers are designing. The consideration of alternatives with the automatic generation of bill of quantities makes it easier to make better use of client’s resources. Lastly, developing construction-level information includes building systems layout that help systems, particularly MEP systems in confined spaces, to be properly laid out and detect clashes. The ability of BIM tools to automatically generate and produce drawings and other relative documents are seen as an advantage. The design review is also useful in developing construction-level information since it enables multiple professional designers and detailers to collaborate and discuss feedback, advice or changes especially when it comes to complex projects.

Recently, Kreider and Messner (2013) introduced a classification system, which can be used as an alternative to the BIM uses (Kreider et al., 2010, CICRP, 2011) stated previously. Aside from classifying BIM uses by a facility's phase, the system also considers the purpose of implementing BIM. It is noteworthy that BIM does not alter the purpose, but only influences the means, which the purpose can be achieved (Kreider and Messner, 2013). Figure 2.3 shows the purpose classification by Kreider and Messner (2013). Their work, in relation to AIA Document G202-2013: Project Building Information Modeling Protocol Form (AIA, 2013), established a framework which describes the attributes of BIM uses. These attributes include discipline, facility element, facility phase, and level of development; all of which are to be discussed in the succeeding sections.

Since the emergence of BIM in the literature and practice, many uses and applications have been found. In relation with this study’s scope, it is particular to determine which areas of BIM implementation can be used by the designers to be able to show how to mitigate the risks that owners are most concerned with.

Gather	Generate	Analyze	Communicate	Realize
•Qualify •Monitor •Capture •Quantify	•Prescribe •Size •Arrange	•Coordinate •Forecast •Validate	•Visualize •Draw •Transform •Document	•Fabricate •Assemble •Control •Regulate

Figure 2.3 BIM use purpose classification (Kreider and Messner, 2013)

2.1.4.1 Facility Element

The facility element describes the elements in the facility to which the BIM use will be utilized for (Kreider and Messner, 2013). The facility element breakdown can be referred from OmniClass Table 21: Elements (OmniClass, 2012a) which include: (1) substructure, (2) shell, (3) interiors, (4) services, (5) equipment and furnishings, (6) special construction and demolition, and (7) site work. Any other element breakdown could be used; however, for this thesis the OmniClass Table 21 was used and adopted.

2.1.4.2 Facility Phase

The facility phase designates the phase in the project lifecycle when the BIM use will be utilized (Kreider and Messner, 2013). The facility phase depends on how the project team breaks down the stages of the project lifecycle. However, it is suggested to utilize a universally known breakdown of the phases (Kreider and Messner, 2013) such as OmniClass Table 31: Phases (OmniClass, 2012b), which is used in this thesis.

2.1.4.3 Discipline

Also referred as the “responsible party” for the BIM use, the discipline describes the entity responsible for using such BIM use (Kreider and Messner, 2013). The responsible party also authors the element called “model element author (MEA)” as described in AIA Document G202-2013 (AIA, 2013). The reliance on information by project participants depends on the level of development established by the MEA (AIA, 2013).

2.1.4.4 Level of Development

The level of development (LOD) identifies the specific minimum content requirements of each modeled element (AIA, 2013) and the level of granularity to which an element is developed (Kreider and Messner, 2013). AIA Document G202-2013 specifies five levels of development while BIMForum’s Level of Development Specification has six (BIMForum, 2013). For this thesis, the BIMForum specification will be utilized since AIA Document G202-2013 adopted it as well and has minimal differences. Table 2.1 shows the description of LOD.

There are many issues which the LOD is able to address. First, as the design procedure progresses from concept to exact description, there was no simple way to allocate a model element. Thus, it leads to the second issue which is misinterpretation of the precision of the modeling of the element. The third issue is when there is misunderstanding of the information provided by the model author. In other words, sometimes the conceptual dimensions are measured precisely. Lastly, for collaborative environments where there are multi-disciplinary authors involved in a project, the knowledge of when information will be available is addressed by the development of the LOD Specification (BIMForum, 2013).

Level of Development vs. Level of Detail

The two LODs which are level of development and level of detail did not vary much previously. Initially, the level of detail was introduced by Vico Software to help address cost estimation issues. It was then adopted by AIA in their BIM protocol *E202-2008 Building Information Modeling Protocol* (BIMForum, 2013).

To understand the two similar terms, BIMForum (2013) separated the definitions which are generally related to each other. On one hand, level of detail addresses *how much* detail is included in the model element. On the other hand, level of development is the degree to which project stakeholders can rely on the information when using the model. Thus, in terms of input, process, and output, level of detail is the input of the element during the design process while level of development defines the usable output.

Level of detail and level of development are greatly related in each other. Before the use of the term *level of development*, level of detail was used to determine the amount of information needed. In relation with this study's scope, the level of development (LOD) as specified in BIMForum (2013) will be used.

Table 2.1 shows that the LOD progresses along with the project lifecycle. The availability of information relied upon by project members depends on the level of development. The LOD therefore specifies the information available in clarity during the project lifecycle. All of the elements of BIM uses are interrelated and varies upon how the BIM use is utilized.

2.1.4.5 BIM Use Selection

The Penn State Project Planning Guide (CICRP, 2011) developed a methodology in their BIM Use Selection Worksheet which identifies BIM uses required for their projects. A total of five steps were elaborated which were: (1) identify potential BIM uses; (2) identify responsible parties; (3) rate the capability of each party; (4) identify additional value and risk associated with each use; (5) determine whether or not to implement each BIM use.

Table 2.1 LOD explanation and example

LOD	Explanation	Example [light fixture as explained in BIMForum (2013)]
100	Conceptual level wherein the elements are not yet modeled; however, area-based cost can be extracted	Cost per area attached to floor slabs
200	Elements are presented as generic items in the system with approximate dimensions	Generic light fixture with approximate size, shape and location
300	Elements are presented as a specific item with exact dimensions	Type of light fixture with specific size, shape and location
350	Elements are presented as a specific item with exact dimensions and interface with other building elements	Exact details with brand and model number with specific size, shape and location
400	LOD 350 which includes detail on fabrication, assembly and installation.	LOD 350 with special mounting details (e.g. in a decorative soffit)
500	Actual representations as built in the site	

CICRP (2011) provided a straightforward approach which can be adopted easily; however, has difficulty when non-experts are planning to adopt BIM. To be specific, the first step, which is identifying potential BIM uses, would require deep knowledge about BIM uses which would be difficult for those planning to adopt BIM. The need for such catalyst to identify appropriate BIM uses for the project is thus needed.

2.2 Overview of Risk Management

This section presents the definition of risks and risk management from literature. It starts with highlighting the use of the term risk in this thesis followed by the steps of the risk management framework that were used in the study.

2.2.1 Risk, Uncertainty and Certainty

Decision-making takes place in an environment where there are certainties, risks, and uncertainties. The basic distinction between the three is that risk is considered to have quantifiable attributes, uncertainty cannot be quantified (Raftery, 1994) while certainty exists when one can specify exactly the outcome (Flanagan and Norman, 1993). Risk and uncertainty describe situations where the result of a particular event is likely to deviate from the estimate or forecast value (Raftery, 1994).

Generally, risks can be understood in two different ways: the outcome can be better (upside risk) or worse (downside risk) than expected. According to ICE (2005), risks are defined as “a threat (or opportunity) which could affect adversely (or favorably) achievement of the objectives of an investment.” Given the definitions of risk, it is important to understand that risk doesn’t not only mean on the negative side, rather, also exploits positive effects and opportunities.

The definitions of risk give its essential attribute as an event that affects an outcome. The probability of that event to occur depends on the factors (i.e., risk factors) in which, has adverse outcomes (i.e., risk outcomes) (ICE, 2005). The relationship of risk factor, risk event, and risk outcome is presented in Figure 2.4. The breakdown of risk to these important entities is required since managing the factors would provide a rectifying effect in reducing the overall probability of the risk event to happen.

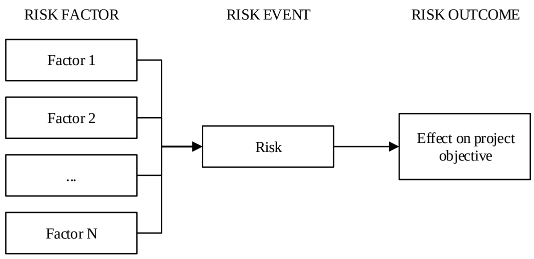

Figure 2.4 Risk factor, event, and outcome relationship

2.2.2 Risk Management

Risk management can be defined as both a cycle and systematic process of identifying, analyzing and responding to the risks (Raftery, 1994). The process of risk management is broken into systematic steps of dealing with risk. These steps usually include risk identification, risk classification, risk analysis and risk response (Flanagan and Norman, 1993). Generally, risk management process follow those steps and have led to the development of frameworks and internationally recognized standards. For this thesis, a generic risk management step was adopted from Smith (2005) as shown in Figure 2.5.

2.2.3 Overview of DB Procurement

This section discusses the overview of DB procurement and the identified risks from literature. It starts with defining DB procurement. Then DB is compared with the traditional project delivery design-bid-build (DBB). Finally, the initial risks identified for DB projects were listed.

2.2.4 Definition of DB Procurement

One of the emerging construction contracting nowadays is DB. In this type of procurement, the owner contracts with a single entity to provide the entire project (Jervis and Levin, 1988). The single entity called the design builder is either a general contractor providing design services or a partnership of two or more construction and design teams. The typical contractual relationship is shown in Figure 2.6.

2.2.4.1 Comparison with Traditional Project Delivery

This type of procurement is advantageous as compared to the traditional design-DBB. DB projects allows fast-track of design and construction on a project therefore having a great opportunity to have fast project delivery (Ling and Kerh, 2004, Jervis and Levin, 1988). In terms of quality on one hand, DB projects have lesser defects; on the other hand, DBB projects have better quality building elements (Ling and Kerh, 2004). Songer and Molenaar (1997) stated that success in DB projects have the criteria of staying on budget, conforming to user’s expectations and staying on schedule.

DB procurement also has disadvantages. (Jervis and Levin, 1988) stated that the biggest disadvantage is the owner’s inability to precisely define the project. Due to the lack of precise contractual drawings and specifications, change orders are common problems in this type of project. This was backed up by Songer and Molenaar (1997) by stating that definition and understanding of the project scope is the most important element in DB projects. For the contractor, they are more faced with liabilities since they are both in-charge of design and construction (Jervis and Levin, 1988). Therefore, these issues should be looked upon in DB projects.

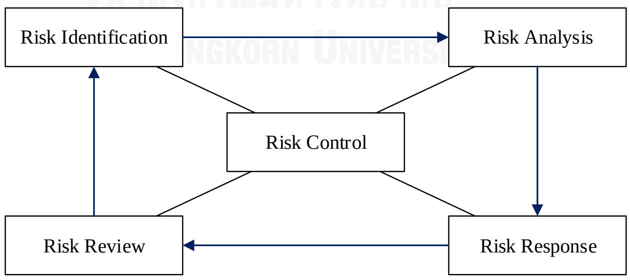

Figure 2.5 Generic risk management step

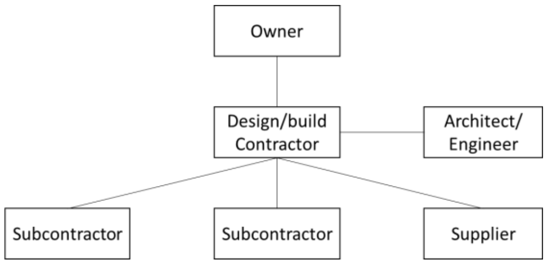

Figure 2.6 Typical DB contractual relationship

Interestingly, Lam et al. (2008) identified critical factors for success in DB projects. Aside from three important aspects of time, cost and quality stated by Songer and Molenaar (1997), highlighted that project nature, effecting project management and adopting of innovative methods are critical success factors. Although the three also reflect on time, cost and quality aspects of the project, the importance of innovation was considered an important element in the success. In terms of innovation, Lam et al. (2008) highlighted value management and partnering as important. Value management helps eliminate cost without the added value and partnering enhances collaboration among the DB team since they are geared towards the same goals. Building information modeling, which in nature is innovative, has highlighted the benefits of value management and increased collaboration.

2.2.5 Risks in DB

Ling et al. (2007) investigated the benefits of innovation in the client's perspective. According to Zaltman et al. (1973) as quoted by Ling et al. (2007), the general process model consists of two main stages: Initiation and Implementation. The initiation stage includes knowledge about the innovation, formation of attitude towards innovation, and evaluation. The implementation stage begins with the decision to adopt the innovation followed by application of it. Ling et al. (2007) found out that in the implementation stage, innovation is beneficial if they are intended to solve technical difficulties in the projects. Therefore, it is important to focus on the technical risks which can be managed by implementing innovation such as BIM.

In the study of Tsai and Yang (2010), risk assessment from the clients' perspective was done to aid the need of clients in choosing the right project delivery system. The authors compared DBB and DB project delivery systems from the viewpoint of risk management and as per project lifecycle. They determined from literature the risks encountered for both project delivery systems and had a total of 106 risks classified into 62 items and 11 groups. They analyzed the significance ranking of the risks and their effect over the project lifecycle (i.e., proposal surveying, scheme designing, procurement contracting, and construction receiving). The analysis with respect to project lifecycle was significant since the amount of risk also varies with developing project stages. All risks identified were the same for both project delivery systems; however, the results showed different critical risks as well as varying order of critical risks as the project progresses. Upon knowing the significant risks and the change of priority with respect to project stages, the clients can select the appropriate project delivery.

In relation to this study’s scope, the critical risks identified by Tsai and Yang (2010) are shown in Table 2.2.

Table 2.2 Critical risks in DB projects (Tsai & Yang, 2010)

Classification	Risk no	Risk description
Natural Phenomenon	1	Rainfall
Economics/Finance	2	Increased material cost
	3	Exchange rate fluctuation
	4	Difficulty of financing
	5	Strong competitor
Politics/Society	6	Change of laws
	7	Bribery/corruption
	8	Interference of illegal parties
	9	Rigid bureaucracy
Contract	10	Unequal contractual provisions
	11	Defect warranty
	12	Misjudged cost estimation
Construction	13	New technology implementation
	14	Too high quality standard
	15	Inadequate procurement planning
Job site	16	Incompetent planning
	17	Incompetent coordinator
Client	18	Unreasonable demand
	19	Reliance on architect/consultant

	20	Difficulty in choosing business dealer
Designer	21	Constructability
	22	Vague drawing specifications
	23	Frequent design change
	24	Lack of fair stance
Contractor	25	Stringent contractual terms
	26	Deficit contracting
	27	Short of manpower or experience
	28	Local jobsite particularity
	29	Erroneous allocation of human resource
	30	Lack of trustworthy support by contractor
	31	Low working morale

Ling and Poh (2008) investigated the problems encountered by DB project owners in Singapore as shown in Table 2.3. They explored the risks of owners with respect to key stages of DB procurement namely tender preparation, tender evaluation, design, and construction stage. During tender preparation, the authors claim that owners lacked knowledge and experience in preparing tenders and also lack required manpower and legal advice. It is important to note that tender preparation is the most critical element in the DB project success (Songer and Molenaar, 1997). In the tender evaluation stage, lack of evaluation system, uncertainty in selecting the tenderer, and the uncertainty if the DB contractor would give value for money. In the design stage, communication within stakeholders as well as approving design and drawings are usually allocated to the owner. Lastly in the construction stage, delays in commencing work due to government regulations, uncertainty in contractor's method statements and shop drawings as well as difficulty in the frequency of checking on the contractor are seen as problems faced by the owners. Based on the various problems stated by the owners, it is noteworthy that problems occur in different stages of the DB projects.

Table 2.3 Risks faced by owners in DB projects in Singapore (Ling and Poh, 2008)

Design-build Key Stages	Risk No.	Risk Type
Tender Preparation	1.1	Owners lack knowledge and experience
	1.2	Owners lack relevant manpower and resources
	1.3	Owners lack legal advice and assistance
	1.4	Communication with end users to meet their requirements is lacking
	1.5	Insufficient time to prepare tender documents
	1.6	Information to draft tender documents is lacking
	1.7	Level of information to be provided in tender document is uncertain
	1.8	Scope of works is uncertain
Tender Evaluation	2.1	Owners lack knowledge and experience to evaluate tender
	2.2	A well-established tender evaluation system is lacking
	2.3	Too many proposals to evaluate
	2.4	Insufficient time to evaluate tenders
	2.5	Owner unsure if selected contractor is appropriate
	2.6	Owner unsure if selected contractor would give value for money
Design Stage	3.1	Contractor's detailed design does not meet owner's expectations
	3.2	Contractor submits claims for items not clearly stated in the tender documents
	3.3	Contractor's consultants are not competent
	3.4	Contractor's consultants, subcontractors and supliers are not participating in technical discussions with owners
	3.5	Insufficient communication between owner and contractor's consultants, subcontractors and suppliers
	3.6	Owners need to bear more risks in approving design and drawings
Construction Stage	4.1	Delays in commencing work because under-estimated time needed to obtain statutory approvals
	4.2	Owners unsure if contractor's method statements or shop drawings are adequate
	4.3	Owners unsure of the extent they should check on contractors
	4.4	Low price certainty for owners because of more change orders

The works of Tsai and Yang (2010) and Ling and Poh (2008) showed the importance of including the project stages in specifying the owner's risks in DB projects. It is important to consider risks that are associated with respect to project phases. A project phase has no finite number of phases because of many terminologies used by various authors as mentioned earlier in Section 2.1.3.2. It can be as simple as planning, designing, construction and operation to a more detailed one which is pre-feasibility, feasibility, design, contract/procurement, implementation, commissioning, hand-over and operation (Smith, 2006). As projects have various phases, risks being dynamic in nature are exposed to changes during the span of the project (Smith, 2006). Thus, it is important to identify the risks that may occur according to project phases.

In 2004, Oztas and Okmen (2004) investigated the applicability of risk analysis process in examining the schedule and cost factors of fixed-price DB construction projects in Turkey. Their research involved a case study of a design and construction of a 3-storey police station which was completed in 2001. The risk assessment with respect to the DB contractor was performed by Monte Carlo simulation using Crystal Ball™ for both schedule and cost modeling. In terms of the said aspects, overruns were experienced due to lack of risk management from the tender stage. The results showed that the planned schedule was too risky, i.e., the plan was 131 days but completed in 190 and simulated at 160. The cost of 84.5 billion Turkish Lira (TL) from the bid was impossible since the simulation showed at 0% risk was 105B TL while the actual payment was 130.1B TL. The authors concluded that DB projects are very risky especially for inexperienced contractors in this type of procurement. The summary of the risks identified are shown in Table 2.4.

Adnan et al. (2008) explored the risks in DB projects in Malaysia and suggested ways on how to mitigate them. The authors encountered 8 critical risks with their explanations as seen in Table 2.5. It was found that out of the 10 companies the authors interviewed, only 7 do formal risk management and all had a consensus that it's needed for DB projects. It was also found that changes of design, interference of employer's consultant, variations with changes in design criteria, conflict of interest, lack of employer's brief, force majeure, social disorder and employer caused delays are the critical risk factors in D&B projects in Malaysia.

Ogunsanmi et al. (2011) investigated if the various risks in design and build projects in Nigeria and if those risks can be clustered to groups of cost, time and quality using discriminant analysis technique. The authors identified risks through literature and found out risks that are similar to construction projects as seen in Table 2.6.

Table 2.4 Risk factors in DB projects in Turkey (Oztas and Okmen, 2004)

Risk no.	Risk description	Type	Impact	Consequence
1	Changes in quantity/scope of work	Speculative	Project	Duration, cost
2	Design changes	Pure	Project	Duration
3	Delay in design	Pure	Project	Duration
4	Third party delays and default	Pure	Project	Duration
5	Bureaucratic problems	Pure	Project	Duration, cost
6	Exceptionally inclement weather	Pure	Project	Duration
7	Owner delays (unable to get approvals, lack of payment, delayed progress payments	Pure	Company	Duration, cost
8	Difficulties/delays in availability of materials, equipment and labor	Pure	Project	Duration, cost
9	Inadequate quality of work and need for correction	Pure	Project	Duration, cost
10	Unforeseen ground conditions	Pure	Project	Duration, cost
11	Inflation	Speculative	Environmental	Cost
12	Exchange rate fluctuation/devaluation	Speculative	Environmental	Cost
13	Accidents	Pure	Project	Duration, cost
14	Inadequate specifications	Pure	Project	Duration, cost

Table 2.5 Risk factors in DB projects in Malaysia (Adnan et al., 2008)

Risk no.	Risk description	Explanation
1	Time overrun	This risk is affected by change in design, construction method, technical, environmental and government caused delays, force majeure
2	Cost overrun	Due to lack of details on owner's needs in the inception stage, change in design and specifications, professional fees for consultant
3	Delay caused by the owner or the government	Insufficient owner info, ill-conceived scheme of client requirement, changes of employer requirement, significant changes to original design, delay in approval, client initiated changes during construction, social disorder
4	Overlapping of roles	Interruption from client's consultants regarding design, correction, method and specification
5	Difficulty in adhering/following instructions	Inappropriate selection of designer, difficulty in accepting instructions from a contractor, inflexibility of consultants
6	Lack in employer brief	Employer brief which is not detailed enough, changes during the construction
7	Conflict of interest	Clients catering to contractor's suggestion in the case of negotiated contracts
8	Variation to changes in design criteria	Deviation from the original design

Table 2.6 Risk factors in DB projects in Nigeria (Ogunsanmi et al., 2011)

Risk No.	Risk Description	Effect		
		Time	Cost	Quality
1	Changes in quantity/scope of work	✓	✓	
2	Inflation		✓	
3	Exchange rate fluctuation/devaluation		✓	
4	Owner and contractor experience	✓	✓	✓
5	Contract and award method	✓	✓	✓
6	Differing site conditions	✓	✓	✓
7	Constructability of design	✓	✓	✓
8	Quality control and assurance		✓	✓
9	Owner delays (lack of payment, delayed progress)	✓	✓	
10	Errors or omissions revealed during construction	✓	✓	✓
11	Government acts and regulations	✓	✓	
12	Financial failure	✓	✓	
13	Warranty of facility performance		✓	✓
14	Inadequate specifications	✓	✓	✓
15	Bureaucratic problems	✓	✓	
16	Difficulties/delays in availability of materials, equipment and labor	✓	✓	
17	Construction defect	✓	✓	✓
18	Safety and accidents	✓	✓	
19	Catastrophes	✓	✓	✓
20	Permits and approvals	✓		
21	Site access/right of way	✓		
22	Design changes	✓		

23	Delay in design/redesign over budget	✓		
24	Exceptional in element weather	✓		
25	Third party delay and default	✓		

The risks identified in Table 2.6 are initially grouped according to a risk breakdown of natural phenomenon, economics and finance, political, contract, construction, safety, designer and contractor. Those risks were then grouped to either affect the project cost, time, and quality. The discriminating variables were cost overrun, time overrun and poor quality.

Among the discriminating variables used, the first and last were concluded to be the best way to separate risks into groups. According to Ogunsanmi et al. (2011), project members should carefully watch out for cost overrun and poor quality as both factors can classify encountered risks in projects.

Chang et al. (2010) addressed the design and construction coordination issues that users would likely encounter. They investigated coordination problems arising from design and construction overlap and presented solutions by studying specific cases and expert interview. The authors concluded that the coordination problems arise from improper planning and execution. Improper planning refers to too much details in the conceptual design and experience problems of having flexibility in the detailed design. Execution refers to having inconsistent design and construction works, long review process and little feedback between designer and contractor. The inconsistent design and construction works occurred when the design does not match the construction work. The long review process occurs when informal communication and trust do not exist within the design and build team. In the case of designers being subcontracted by the DB contractor, little feedback was experienced thus resulting to inconsistent detailed design consideration and constructability problems. All of the mentioned risks affected the DB projects in terms of increased time, cost, design change and rise of more conflicts. Chang et al. (2010) stressed the importance of communication and transmission of information to be vital to realize the advantage of design and build procurement.

2.2.6 Risk in Construction Projects

Many scholars have performed risk management and analyzed it in perceptions of either the owner or contractor. The nature of building projects having unique characteristics and different project delivery results in different of risk factors (Tsai and Yang, 2010). However, some similarities of risk factors can be encountered across different countries and can vary internally or externally aside from the differences in probability and impact (Tsai and Yang, 2010). For instance, in the Philippines, Reyes (2008) identified risks are similar with construction projects in USA (Kangari, 1995), Hong Kong (Ahmed et al., 1999), Kuwait (Kartam and Kartam, 2001), China (Fang et al., 2004) and Indonesia (Andi, 2006). Reyes (2008) also identified some risks that are specific to the Philippines such as political intervention and rebel task and analyzed them in the perception of contractors. His work included allocation of risks through examining the General Conditions of Contract (GCC) of the Government Procurement Policy Board (GPPB). The summary of the risks and Reyes' findings are seen in Table 2.7.

Table 2.7 Critical risks and allocations in the Philippine contractors' perspective (Reyes, 2008)

Sources	Risk Event	
Construction Related	1	Change in work
	2	Contractor competence
	3	Defective materials
	4	Labor and equipment productivity
	5	Labor, equipment and material availability
	6	Quality/Mistakes in work
	7	Safety/Accidents
	8	Suppliers/Subcontractors poor performance

Design	9	Defective design
	10	Deficiencies in specifications and drawings
Financial/ Economical	11	Inflation
	12	Delayed payment on contracts
	13	Financial failure of any party
Natural/ Environmental	14	Acts of God
	15	Environmental hazards of the project
	16	Unforeseen site conditions
Political/Legal	17	Changes in government regulations and tax-rate exchanges
	18	Cost of legal processes
	19	Permits and ordinances
	20	Political intervention
	21	Site access/Right-of-way
	22	War threats
Settlement Delays	23	Change order negotiations
	24	Delays in resolving contractual issues
	25	Delays in resolving litigation/arbitration disputes
Third Party	26	Labor disputes
	27	Third party delays/Public disorder
	28	Rebel tax

Design and build is gaining its popularity nowadays as many researchers have investigated on it in terms of its success, advantages, and risks. The benefit of fast-tracking the projects is notable with this type of procurement. Risks in projects are inevitable and was observed to be the similar in different countries and types of procurement. The aspects of time, cost, and quality are usually the objectives of the owner and the exposure to risks makes the whole process from planning to construction deviate from the desired outcome.

As mentioned earlier in the introduction, adoption of innovative methods in the construction industry is beneficial in solving technical issues (Ling and Poh, 2008). Therefore, among the screened contractors' risks from the work of Reyes (2008) as well as risks perceived by the owners in DB procurement, a total of 30 risks were identified as shown in Table 2.8.

The list shown in Table 2.8 is used as the initial risk list which was verified in DB projects in the Philippines.

Table 2.8 Summary of owners' and contractors' risks in DB projects

No.	Risk Event
1	Change in quantity/cope of work
2	Inconsistent design and construction work
3	Labor, equipment and material availability
4	Inadequate quality of work and need for correction
5	Safety/Accidents
6	Suppliers/Subcontractors failure due to poor performance
7	Design change
8	Delay in design
9	Inflation
10	Difficulty in inspection for progress payments
11	Financial failure of any party
12	Exceptionally inclement weather
13	Environmental hazards of the project
14	Unforeseen site conditions
15	Bureaucratic problems
16	Site access/Right-of-way issues

17	War threats
18	Change order negotiations
19	Delays in resolving contractual issues
20	Delays in resolving litigation/arbitration disputes
21	Labor disputes
22	Third party delays/Public disorder
23	Rebel tax
24	Constructability Problems
25	Lack of Value Management/Engineering
26	Difficulty in choosing proposals
27	Unable to get approvals
28	Deficiencies in specifications and drawings
29	Inconsistent warranty information and as-built drawing
30	Difficulty in property management and maintenance

2.3 Risk Management and BIM

(Lee et al., 2015a) found out that 20% of the warnings in the BIM model creation compose of 80% of the design errors, i.e. using a 20-80 Pareto principle. Warnings, which are also known as clashes and other notifications based on rules-based application of BIM software, are provided automatically when working with BIM. Warnings, specifically in terms of annotation (e.g. misplaced tag or call out), information (e.g. duplicate information of door numbers; non-geometric errors), and geometry (e.g. physical clashes of elements) were studied by the authors in three different case studies of BIM projects in California.

In relation to this thesis, their work verifies the importance of facility element as an important attribute relating both risks and BIM. On one hand, design errors are considered to have an effect to the overall project objectives, which is in essence a risk. On the other hand, BIM becomes an efficient tool in dealing with modifying design errors.

Chien et al. (2014) identified the critical risk factors when implementing BIM in construction projects. They comprehended on the critical risk factors that BIM users can encounter in their implementation. They used the decision-making trial and evaluation laboratory method (DEMATEL) in identifying critical risk factors in three different levels namely (1) industry level, (2) market level and (3) organization level of the Taiwanese construction industry.

For the market level, they found out that inadequate project experience and lack of available personnel were the critical risks when using BIM. For the market level, the design team (i.e., architects, consultants, owners, BIM service providers) experienced lack of available skilled personnel as critical risk factor. For the construction team (i.e., construction personnel, owners, BIM service providers) inadequate project experience and lack of available skilled personnel were the critical risk factors. In terms of organizational level, designers' critical risk factor were lack of BIM standards. For the construction personnel, inadequate project experience, insufficient data interoperability, management process change difficulties and lack of available personnel were the critical risks. For owners, inadequate project experience was found to be critical. For members of the academia, workflow transition difficulties were seen as the critical risk factor when implementing BIM. According to Chien et al. (2014) lack of available personnel and inadequate project experience were common critical risk factors due to the fact that BIM is still at the early adoption in the Taiwanese AEC industry. Also, government policy regarding BIM is at the early stages therefore educational institutes are not fully prepared to create BIM educational programs to train students for the industry.

To overcome the lack of practical implementation strategies of BIM in literature, Hartmann et al. (2012) described the use of BIM based tools in cost estimating of a construction company and risk management of an infrastructure project. For the risk management part, Hartmann et al. (2012) assigned a research student and conducted ethnographic research in the infrastructure project. Interviews with project managers, designers and engineers were conducted. The 4D model used in the project was used to visualize risk related properties namely: (1) location of the risk, (2) time-frame during which a risk may occur and (3) additional information such as in-depth description and ways to mitigate such risk. The use of the 4D model included viewpoints, text overlay and risk specific objects. The viewpoints were used to visualize risks in different angles in the digital construction site. The text overlay was used to indicate in a certain time period possible risks that might occur and therefore serves a reminder. The risk specific objects included smart tags that pops-out when the pointer is directed to the object thus helping visualization of the risk that might occur.

Hammad et al. (2012) studied how risks can be mitigated using BIM. They identified internal risks from literature which were defective design, deficiencies in drawings and specifications and changes made to the design. Based on understanding the concepts of BIM through existing publications, they suggested in general the ways how BIM can mitigate the risks. The view point of Hammad et al. (2012) showed how BIM can mitigate risks during the design phase.

There were different approaches of BIM and risk management based on literature. The first approach was by determining the risks that can be encountered when implementing BIM which are more on the barriers of implementation (Chien et al., 2014). Another approach was by using the BIM model for visualizing the risks that can happen in the construction site and by using it as a database for risk parameters in the project (Hartmann et al., 2012). Lastly, internal risks can be mitigated by the established benefits that BIM was perceived to contain based on literature (Hammad et al., 2012).

2.4 Research Gap

The approaches of risk management and BIM from literature were analyzing the barriers of BIM that implementers might encounter, using the BIM model for visualization, and conceptualizing the risks that can be mitigated by reviewing benefits of BIM.

Hammad et al. (2012) lacked the perspective of risk management. In addition, the use of BIM in the work of Hammad et al. (2012) included general ways on how BIM can mitigate the risk, focused on the design phase, and omitted elaboration on certain applications and uses.

The lack of academic study with regard to BIM and risk management can be supplemented by this research. No such methodology, framework, or analysis in aligning risk with selecting BIM uses or applications exists. The approach of identifying the owner's and contractor's critical risks and showing how those risks can be mitigated through BIM can help owners require BIM in their future projects. As owners are perceived to be the drivers of technological implementation, requiring BIM in their projects would lead firms to adopt BIM. This research would fill the gap of showing how uses of BIM can help in project risk management which can supplement BIM researches regarding risk and BIM, and catalyze BIM implementation in the Philippines.

CHAPTER 3
RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

After a thorough review of related literature, it was evident that a framework for the presentation of relationship between BIM uses and risks was necessary. In lieu with the objective and scope of this thesis, it is necessary to develop a framework methodology of selecting appropriate BIM uses for construction risk management by:

- Identifying the critical risks in the DB projects and current BIM uses
- Identifying the input, process, and output of each BIM use
- Developing the unified framework of risk and BIM uses
- Testing the framework against case studies, specifically DB projects that utilized BIM in all or some phases of the project lifecycle
- Developing a procedure that selects appropriate BIM uses for owners and contractors based on perceived critical risk levels risk assessment
- Providing conclusions

The framework development and case study provide information on designating optimal BIM uses for construction risk management. The framework also benefits any additional BIM uses and risks discovered in the future. The gap in literature, which is the sparse utilization of BIM for risk, is supplemented by this research through the methodology explained in this chapter.

This chapter starts by recapping the objective of this thesis. It then presents the theoretical and conceptual frameworks leading to the methodology development. The details of the methodology are then discussed. Finally, the respondents' profile and survey and interview structures are presented.

3.2 Research Objective

The main objective of this research is to identify appropriate BIM uses for construction risk management. The specific objectives are as follows:

- to develop a systematic framework in identifying appropriate BIM uses for project risks, and
- to develop guidelines in utilizing BIM uses for project risk management.

3.3 Theoretical Framework

Building information modeling (BIM) is a modern construction management method which is proven to be beneficial both in practice and academia (Bryde et al., 2013). The existence of relevant literature and case studies with regard to BIM has enabled the construction industry traverse in a new paradigm, just like from manual drafting to CAD. The generalization of BIM to be beneficial however remains a question due to barriers of implementation. Figure 3.1 shows the theoretical framework which represents the main hypothesis of this research.

As can be seen, the benefit of BIM extends to specific areas of project management as shown by the bigger circle. The smaller circle represents project management in which its small part is risk management.

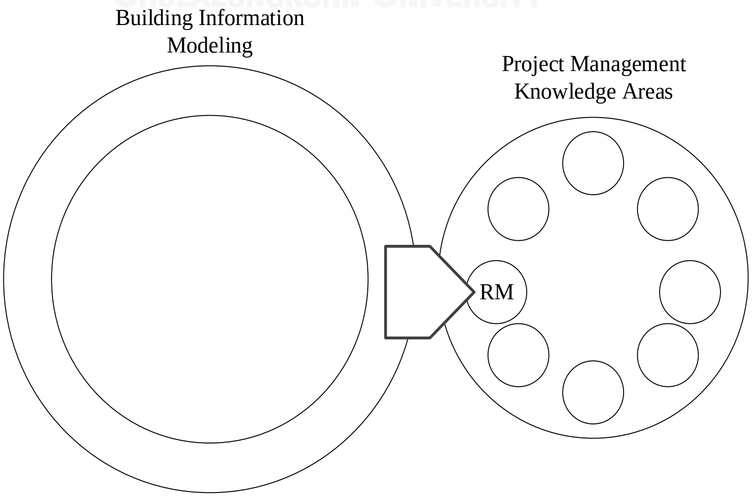

Figure 3.1 Theoretical framework

Past literature considered numerous benefits by BIM. The mentioned benefits basically revolve in the project through saved costs, reduced time, and high-quality delivered structures, thus represented by the outer circle. However, the inevitable exposure of projects to risk could hinder those objectives. Thus, risk management is employed by construction members as part of project management, represented by the small circle within the project management circle, in which the typical allocation of risks are to contractors and owners.

The research is based on two hypotheses: (1) owners request BIM because it can address their risks, and (2) contractors will use BIM since it can address their own risks and per owners' requests.

3.4 Conceptual Framework

The theory which relates BIM to risk management has led to the conceptual framework that is used in this thesis. Figure 3.2 shows the conceptual framework developed, which displays the established relationships between BIM and risk.

In developing the research methodology, the attributes of each risk and BIM use were systematically identified. The commonality in attributes gave a straightforward relationship between BIM and risk. The conceptual framework of what was adopted and modified from that of Tah and Carr (2001). Both risk and BIM has attributes that define their existence, which when related, could define their relationship. The common attributes are explained in Chapters 5 and 6, while their relationships are discussed in Chapter 7.

In this research, the elements of the building and the project lifecycle were based on OmniClass, which is an international standard recognized to define a common language for various elements related to the construction industry. To be specific, OmniClass Table 31 – Elements (OmniClass, 2012a) and OmniClass Table 21 – Phases (OmniClass, 2012b) were adopted. These industry standards are presented in Appendix A.

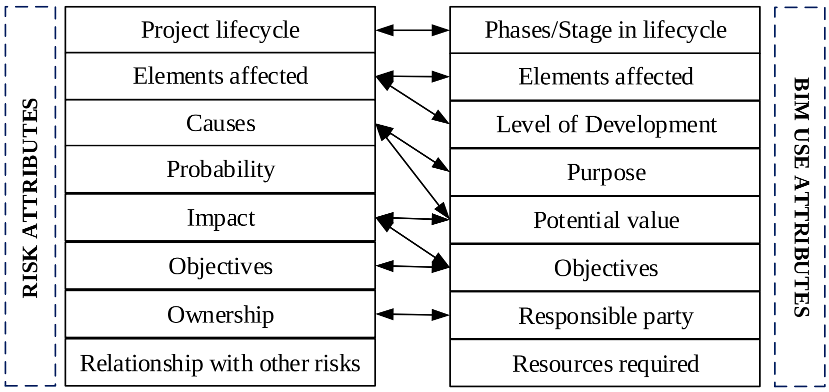

Figure 3.2 Conceptual framework

The OmniClass was chosen because it corresponds to the contents of this research. Both OmniClass standards were used with the new integrated project delivery (IPD) and were developed to fit the built environment (OmniClass, 2012b). Although the developed framework is intended to be generic and easily modifiable, the use of internationally recognized standards as an example presents its applicability through various regions, not only the Philippines or those with similar practice in the construction industry.

3.5 Research Methodology

Figure 3.3 shows the methodology adopted in this research. To comprehend the relationship between each step,

Figure 3.4 shows the input, process, and output and displays how each output becomes the input of the succeeding step.

Since this research is qualitative in nature, subjectivity is inevitable (Naoum, 2007). However, subjectivity was minimized by a defined process through case study applications. Based on the objective and the scope, exploratory qualitative research is best fit for this study due to the limited respondents knowledgeable about the topics (Naoum, 2007) and limited research with regard to BIM and risk.

3.5.1 Understand Relevant Concepts and Investigate the Current State of Research in the Philippines

This step is to review publications such as textbooks, journals, proceedings, reports, and websites. It focused on:

- Fundamental concepts of risk and risk management,
- Risk identification in design and build (DB) projects and major risks in the Philippines,
- Overview of BIM and BIM uses, and
- Overview of DB project delivery.

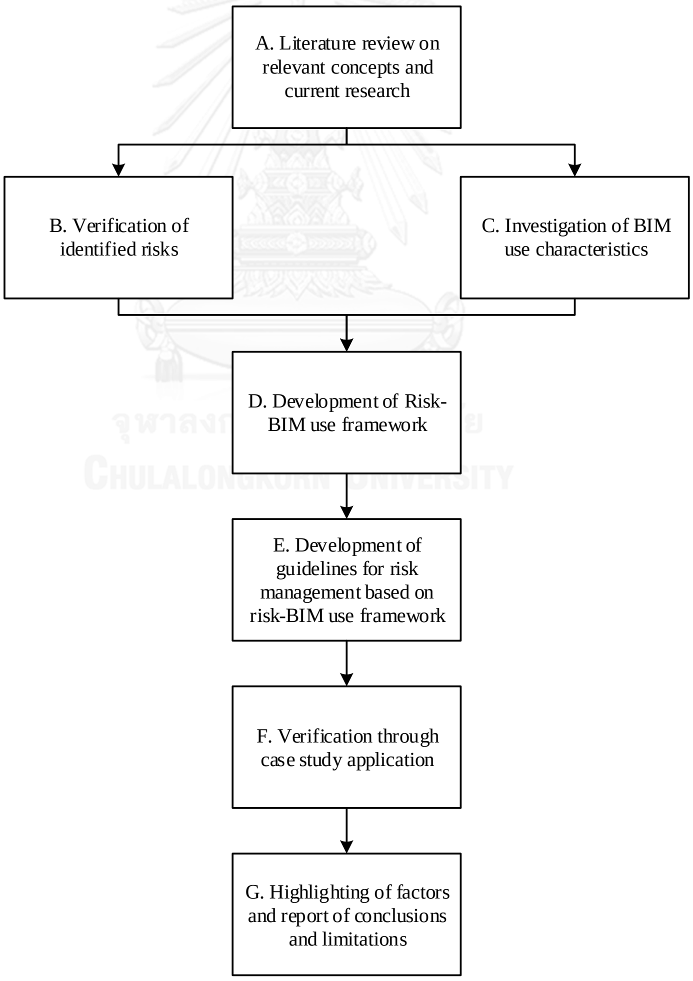

Figure 3.3 Research Methodology

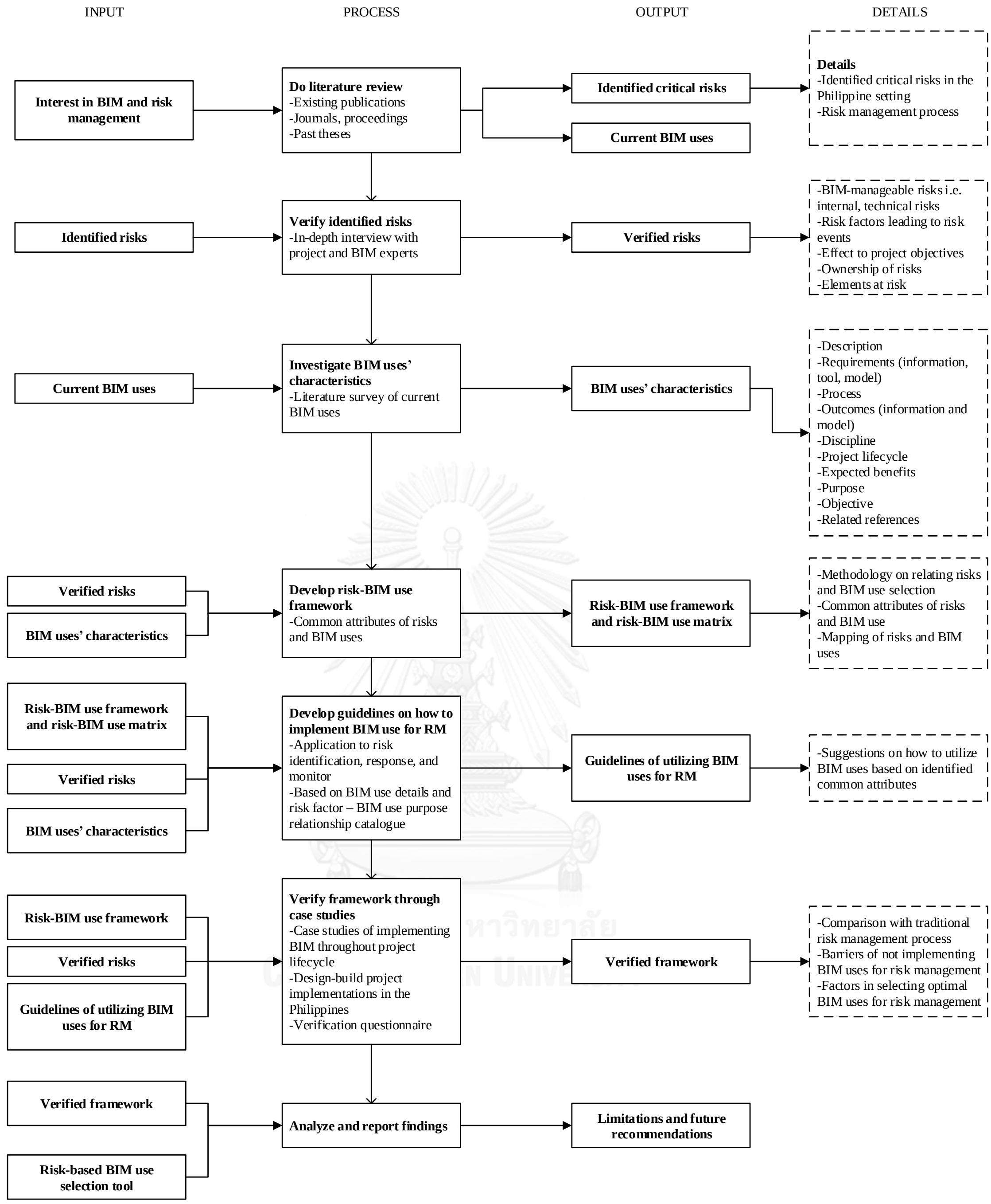

Figure 3.4 Research Methodology Input – Process – Output

3.5.2 Verify Identified Risks

This step is to conduct a survey through in-depth interviews with DB project and BIM experts. The survey was done to verify the BIM-manageable risks in DB projects in the Philippines. In addition, the risk factors leading to the risk events and their effects on the project objectives were identified. Finally, risk bearers were also identified to appreciate the party that is responsible for managing the risks and that will be affected once the risk event occurs. Appendix B shows the example questionnaire used for this step.

3.5.3 Investigate Attributes of Each BIM Use

This step is conducted simultaneously with the previous step. An intensive literature review was done to identify the current BIM uses. The output of this step are the BIM use characteristics, which include descriptions, requirements, processes, outcomes, disciplines, expected benefits, and their purposes. This step broadly elaborated the description of each BIM use leading to the analysis and application to the risk management step.

The processes of implementing a BIM use is integral to this step. The business process model and notation (BPMN) was adopted to show the general steps on utilizing each BIM use. The BPMN of each BIM use can be seen in Appendix D. Each BPMN showed the relationship between the requirements and outcomes as well as the required discipline its project lifecycle application.

3.5.4 Develop the Risk-BIM Use Framework

This step develops the framework that relates the risks and BIM uses. The framework was developed based on the literature review, risk verification, and BIM use characteristics steps. To be specific, the framework methodology was modified from Tah and Carr (2001) concerning project risk knowledge management. Using an analogous concept, the risks were related by identifying common attributes to bridge BIM and risk. This will be is discussed in Chapter 6. The output of this step provides a risk-BIM use matrix that highlights the available BIM uses to deal with such identified risks. Moreover, each relationship between risk and BIM use contained discussion on how to utilize the BIM use for risk management.

3.5.5 Explicate Implementation of BIM Uses for Risk Management

This step investigates how to implement BIM uses for risk management. The main output is the risk-BIM use relationship matrix which can overview of the relationship between risks and BIM uses. The details of how to implement the BIM uses for risk identification, risk response, and risk monitoring were provided in this step. Specifically, the common attributes that constitute the framework were highlighted and analyzed.

3.5.6 Verify the Framework through Case Studies of DB Projects in the Philippines

This step is to verify the framework developed in the previous step through case studies of implementing BIM throughout the project lifecycle. Three organizations that have DB projects currently or in the past were considered. The same with risk verification, a semi-structured interview was conducted to gather the usage of BIM for risk management. The example questionnaire for this step is seen in Appendix B.

The second batch of data collection can be divided into two parts: (1) verification of the framework, and (2) application of the framework through multiple case studies. The verification of the framework included refurbishing of some attributes such as elements at risks and responsible parties. The application of the framework included assessing identified risks in DB projects, and identifying current BIM uses and how they implement it in their risk management. The basic methodology adopted for the case studies consists of:

- Inquiring background information about the company
- Assessing critical risks
- Reviewing traditional risk management steps for mitigating risks
- Applying the developed framework to identify BIM uses for risk management of critical risks

- Analyzing the benefits and barriers of implementing such BIM uses for risk management
- Drawing conclusions from the case studies

The case study approach facilitates in-depth investigation of particular instances of phenomena (Fellows and Liu, 2008). This approach is applicable for this thesis mainly because of the availability of respondents knowledgeable about the topic. The common procedure adopted in the case studies provided a scientific approach, i.e., logical positivism, which can be judged by same criteria of internal, construct, and external validity and reliability, similar to other forms of scientific research (Fellows and Liu, 2008).

Three cases of BIM implementation were highlighted. Each general phase of the project lifecycle, i.e., pre-construction, construction, and post-construction, is covered by a case study. Upon applying the framework and inquiring about the BIM use of particular firms, the theoretical and actual BIM uses were identified, respectively. Included in the data collection is the traditional ways of implementing risk management which gave comparison of it to the risk management process using BIM as suggested in this thesis.

3.5.7 Draw Conclusions and State Limitations of the Research

This step reports the findings based on the developed and verified framework and case study examples. Its limitations and future recommendations were duly presented.

3.6 Profile of the Respondents

Since the concept is quite new in the Philippines, convenience sampling technique was adopted in this research. Convenience sampling is used where the nature of the research and population do not indicate any defined sample size. Thus the researcher collects data from samples readily available (Fellows and Liu, 2008). The expert surveys for the convenient sampling is recognized as an efficient method for obtaining the positions of large groups irrespective of group size (Steenbergen and Marks, 2007). The in-depth interviews and surveys were participated by the experts of

BIM and risk management. The criteria used to screen the experts for this research were proposed as shown in Table 3.1.

Prior to sending the cover letters, background checks of organizational structures and specific people were conducted to ensure qualifications. To be specific, the respondents desired for the letter were those senior positions related to IT/CAD of the company since BIM is related to it. Appendix B shows an example letter of request distributed to the respondents.

As shown in Table 3.2, the experts included a wide array of sectors representing the government, academia, and practitioners involved with the owners, contractors, and designers. Although the sample size is low, it represents a general perspective of the status of BIM in the Philippines since the topic is relatively new in the country.

Table 3.1 Respondent evaluation system

Area	Rating	Description of Respondent
BIM	★	Has basic knowledge about the topic
	★★	Has more than 3-year experience with BIM-related position in the company
	★★★	Has more than 3 year experience in a BIM-mature company and a BIM-related position in the company
Risk and Risk Management	★	Has basic knowledge about the topic
	★★	Has Implemented RM in more than 2 projects
	★★★	Practitioner, managerial position, risk manager in the company
DB Procurement	★	Has basic knowledge about the topic
	★★	Has experience with at least one project
	★★★	Has experience with more than two projects

Table 3.2 Respondents' evaluation

Resp.	Prof.	Position	Exp.	Rating		
				BIM	RM	DB
ACA1	CE	Lecturer, Senior Structural Engineer	5-10	★★★	★★	★★
ACA2	CE	Assistant Professor	5-10	★★★	★★	★★
ENC1	CE	Project Manager	>15	★	★★★	★★★
ECN2	CE	Managing Partner	>15	-	★★★	★
ENC3	CE	Structural & Geotechnical Section Head	>15	★★	★★★	★
ENC4	CE	Vice President/Director of Projects	>15	-	★★★	★
ENC5	CE	Senior Vice President	>15	-	★★★	★
DEV1	CE	Senior Manager for Operations	10-15	★★★	★★	★★
EPC1	CE	Project Manager	>15	-	★★★	★★★
ARC1	Archi	Associate	>15	★★★	★	★★
GOV1	CE	Director, Project Manager	>15	-	★★★	★★★
BIM1	CE	Applications Engineer	5-10	★★★	★	★
BIM2	CE	Applications Engineer	3-5	★★★	★	★
EPC2	CE	Structural Engineer	5-10	★★★	★	★★★
EPC3	EnviE	Project Manager	5-10	★★★	★★	★★★
ARC2	Archi	Principal Architect	5-10	★★★	★	★★
BIM3	Archi	Principal Architect	5-10	★★★	★	★★

Note: Resp. – Respondent
Prof. – Profession
Exp. - Experience

For the case studies the sampling was obtained from the referrals from academia connections and software vendors. To be specific, at least one firm was inquired for the three project lifecycle stages, namely, pre-construction, construction, and post construction. Due to the confidentiality agreement, company and individual names were not shown. Thus, the researcher used general descriptions of respondents, e.g. *Developer A* or *Architect 2,* to reference them.

3.7 Interview Structure

In this research, data collection was conducted twice. The first is to verify the identified risks and the second is to verify the framework developed. Both parts were done through questionnaire survey and in-depth interviews. Each interview was conducted from 45 to 90 minutes. For the risk verification, initial risks were identified through literature review on the studies of construction risk in Turkey (Oztas and Okmen, 2004), Singapore (Ling and Poh, 2008), Taiwan (Chang et al., 2010, Tsai and Yang, 2010), Nigeria

(Ogunsanmi et al., 2011), and the Philippines (Reyes, 2008). Upon the development of the risk-BIM use relationship framework, the elements were verified by utilizing the same method of data collection. Purely conducting survey questionnaire and distributing it to a group of respondents would be impractical due to the fact that there are only limited respondents knowledgeable with BIM. To this extent, statistical analyses were not appropriate for this research. This will be further elaborated in Chapter 9.

As mentioned previously, the qualitative nature of this thesis employs the interview technique as a method of data collection (Naoum, 2007). Thus, the analyses covered all responses from the experts, not entirely relying on established theoretical constructs, i.e., non-observable phenomena, or the author's perspective (Maxwell, 2013).

The second data collection includes risk assessment by the respondents of the case studies. The rating system was initially based on Chileshe and Yirenkyi-Fianko (2012), which measured the probability and impact of the risks in Nigerian construction projects. They utilized a four-point Likert scale which omits a midpoint. The midpoint was perceived to indicate a response to satisfy the interviewer and to avoid giving a socially unacceptable answer. Thus, it was replaced by a rating system by Wang et al. (2004), which they used in their international survey to develop a risk management framework in construction projects for international investors in developing countries, as shown in Table 3.3.

Table 3.3 Risk evaluation criteria (Wang et al. 2004)

Rating	Risk criticality
1	Not critical at all
2	Slightly critical
3	Somehow critical
4	Critical
5	Very critical
6	Very much critical
7	Exceptionally critical

The rating system is a 7-point scale, which defines the risk criticality of each risk events. Considering the amount of time the respondent would need to answer questionnaire, this new rating system provides a more efficient way of inquiring the respondents' position about the risk. The risk criticality considered in this thesis describes the effect on project objectives, i.e., impact, which the respondents perceived for the risks. Since risk management is not the core of this research, inquiring detailed information for the risk, i.e., probability and impact, was not necessary, though considered important. The precise estimation of both probability and impact could be insignificant despite the impediments in computing them (ICE, 2005).

At the last part of the risk verification, a question was imposed asking about the risks unique to the Philippine industry. Some risks, which will be discussed in the succeeding chapters, were emphasized by the respondents but no additional risks based on the initial list were encountered.

After the risk verification and framework development, the application and verification of the framework through case studies were carried out. The purpose is to test the framework developed and to identify the discrepancies of the actual and theoretical BIM uses for risk management purposes. This part also clarifies the reasons why BIM uses are not implemented for such risk management step, which are elaborated in the analysis.

3.8 Summary

This chapter presented the research methodology. It started with the development of the theoretical and conceptual frameworks, which led to the hypothesis and methodology used to fulfill the research objective. Then, the details of the research methodology were discussed. Finally, the profile of the respondents and the interview structure were presented.

The exploratory nature of this research employed a qualitative approach. The case studies provided insights regarding the use of BIM for risk management. The application of the framework developed was done to three case studies of early BIM adopters, which were presented and analyzed in the succeeding chapters of this thesis.

CHAPTER 4
DESIGN-BUILD PROJECTS IN THE PHILIPPINES

4.1 Introduction

In relation with the scope and objective of this research, design and build (DB) projects in the Philippines were examined. This section explores the utilization of local DB projects through past and current experiences of DB project participants. Prior to verifying risks in DB projects, it is important to know why clients prefer this kind of procurement and describe the status by:

- Identifying types of projects usually engage in DB procurement
- Reasons for selecting DB procurement
- Advantages of DB procurement.

This section is a by-product of the research methodology for which it gave an overview of how the Philippines utilizes DB projects and identify objectives why they select DB as a project delivery method.

4.2 Current Practice of DB Procurement in the Philippines

Table 4.1 shows 11 past and projects that adopted DB procurement in the Philippines. Stated also in the same table are reasons why clients select DB. According to a majority of the respondents, DB procurement is usually done for small projects, (e.g., small residential and commercial projects), residential projects, and plant projects. Some local developers, particularly the one considered in one of the case studies, have their own in-house designers and builders. Thus, DB procurement is used for their own projects. Lastly, plant projects such as one currently near Luzon Island, Philippines, also currently adopt DB procurement. The mentioned projects constitute the type of projects that usually adopt DB procurement in the Philippines.

Table 4.1 Example DB projects and reasons for implementing DB

Respondent	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5
Profession	CE	CE	CE	CE	CE
POV	Contractor	Contractor	Contractor	Owner	Contractor
Past/Current Projects that Implement DB	Commercial / Residential	Commercial / Residential	Infrastructure	Residential	Infrastructure
Reasons for implementing DB	More profit for the contractor Easier to manage	Changes are dealt easier Faster project delivery	Increased creativity and innovation in design Time savings	Efficient use of time Risk transfer to contractors (Single point of responsibility)	Efficiency Faster Project Improved coordination and communication Pro-owner since more risks are allocated to contractor Easier changes

Respondent 6	Respondent 7	Respondent 8	Respondent 9	Respondent 10	Respondent 11
Architect	CE	CE	EnviE	Architect	Architect
Owner	Owner	Contractor	Contractor	Contractor	Owner
Commercial and Residential	Infrastructure	Industrial/Plant	Industrial/Plant	Small commercial / residential projects	Residential
One-party responsibility Transfer risks Complex projects Fitout and interior design	Fast-track of project Simplified Easily modifiable Expertise in certain fields	Smoother construction execution Profitability (waive the fee of design)	More efficient construction execution Safer Ability to optimize design to have a more efficient proces Optimize materials for the process or for the plan Control of schedule	Profit-driven Faster, expedited process	Certain expertise of contractors in such projects

Note: POV – Point of View
CE – Civil Engineer
EnviE – Environmental Engineer

4.2.1 Respondent Profile

A majority of the respondents had been working in at least one DB project from the past. Thus, they are deemed to be knowledgeable with DB procurement. A total of 11 out of the 17 respondents have responded with regard to DB projects. As mentioned in Chapter 3, convenience sampling was adopted for this research. Therefore, the limited number of respondents represent those knowledgeable not only in DB projects but also in risk management and BIM. The number of samples does not statistically infer the current practice in the Philippines; however, provides a generalization for future reference as this research provides some factors that affect success in local DB projects.

The respondents present views for both the owner and contractor. Owner's views are represented by respondents from the developer, government official, and architects. The contractor's views are represented by the EPC contractor and architects. Considering both views is considered to be essential for this research since owners are usually the drivers for technological adoption (Lam et al., 2008) while in DB procurement, contractors are more exposed to risks (Jervis and Levin, 1988).

4.2.2 Reasons for Selecting DB Procurement

Table 4.1 highlights some factors why DB procurement is selected in the Philippines. The respondents were asked why DB procurement is adopted by both owners and contractors. The summary is as follows:

Owners

Technological expertise. A main driver for the DB for projects in the Philippines is the technological expertise of some contractors. The respondents representing the owner's side agreed to the extent that DB is selected for the expertise of some contractors in their field. Moreover, this is also applicable for DB contractors, which subcontracted work to trade contractors and employed DB delivery for works such as interior design works. The reliability of the contractors based on their past projects let owners decide to pass the design responsibility to the contractors.

Efficiency. Another advantage for DB project implementation is the added efficiency for the owner. The efficiency comes in terms of expedited project delivery through fast track of design and construction. Moreover, time savings were observed by the respondents, which validated the work of Songer and Molenaar (1997). Thus, basically owners in the Philippines use DB for faster delivery of projects.

A single point of responsibility. Since design and construction is carried out by a single entity, there is also single point of responsibility. The respondents have emphasized their desire of transferring most of the design risks to the contractor by employing a DB approach.

Flexibility. An important driver for DB procurement is flexibility. A respondent from an infrastructure project mentioned that DB is selected for easy modification of the design. Since contractual arrangements are simplified, and changes are not avoidable, there will be a smother process (Respondent 7, Interview, 15 September 2014).

The flexibility of DB results in time savings as well. The ability to easily manage change, e.g., change in scope of work and design, resolves to compressed project schedules and avoids tremendous change process usually employed during traditional procurement methods.

Cost-effectiveness. The respondent, who is a senior design review manager of a local developer, has the views of both owner and contractor and mentioned that "since Construction Company A is under the group of companies of Corporation Z (Developer), we practice DB. The corporation has its own design body and we are the construction body of it. We basically design and build for our own purposes. All projects by the developer is design by the design body and we construct it. We work hand-in-hand" (Respondent 15, Interview, 20 September 2014).

From the statement above, it can be inferred that DB also promotes cost-effectiveness for the side of the owner. The developer's ability to have its own design and construction bodies generates more profit instead of bidding the works to other stakeholders. Such practice enables them to expedite the project delivery and provokes cash inflow for the early utility of desired structures such as residential and commercial buildings. Thus, it is beneficial for the developer to provide services for its own and to have its own design and construction body.

Contractors

Profitability. A main advantage of DB for contractors is profitability. Respondent 10 emphasized that DB is suggested by the contractor to have better profit margin. DB is profit driven since the DB contractor gets profit not only in design but also construction (Interview, 20 September 2014).

Similar responses from the other respondents were observed. Most DB contractors considered profitability an important factor for DB delivery. In the case of the Philippines, professional organizations such as the United Architects of the Philippines (UAP) is trying to make the competition fair by setting guidelines for basic rates. However, many designers demand lower than the suggested rates just to get the project. Thus, the competition has led to the designers to adopt DB for better profit.

Manageability. Based on the responses of the contractors, manageability is a trait of DB project delivery. Basically, doing most of the parts of the construction lifecycle enables the DB contractor to easily control the project. Changes are dealt easier. Other advantages include faster project completion as well as increased coordination and communication between the designer and contractor. The results from the interviews coincide with the works of Songer and Molenaar (1997) and Chang et al. (2010). Their studies and DB projects in the Philippines share common attributes.

Creativity and Innovation. It was previously discussed that owners select DB for the technical expertise of contractors in special projects. It can therefore be relatable to the added creativity and innovation, which DB can offer. Since some contractors are employed to perform both design and build, they are able to incorporate their own design to accommodate their suggested construction method. It is however debatable if owners utilize DB for added innovation, as what contractors have perceived. This contradiction between technical expertise and added innovation has also been pointed out by del

Puerto et al. (2008) which reported that contractors perceive technicality as important while owners do not. It is also noteworthy that DB contractors in the Philippines utilize innovative methods since it can benefit them. For example, Respondents 8 and 9 who were involved in a DB plant project, adopted advanced software (will be discussed in Chapter 8). This presents the ability to incorporate innovation when performing DB projects. It was observed that the responses from the interviewees correspond with the works of Lam et al. (2008) and Ling et al. (2007).

Efficiency for Contractors. Using DB as a project delivery method results in efficient construction processes. The respondents representing the side of the contractor have emphasized the optimization of materials for the design and construction process. Due to the overlapping of activities, they were able to have various choices between specifications. It also adds up to better manageability, as discussed previously. As changes are inevitable in this kind of procurement, it can therefore optimize the design.

It is also noteworthy that the contractors were able to control the schedule. As this can be done with traditional procurement methods, the overall schedule can be optimized, especially with overlapping activities of design and construction to meet their deliverables, i.e., fast track.

In addition, better safety and more efficient communication were finally emphasized because DB delivery provided a more collaborative environment.

4.3 Technology for DB Projects

Four out of the eleven respondents have emphasized the importance of technology for DB projects. For the contractors' side, they were able to implement innovative methods for streamlining their design and construction processes. This implies that having up-to-date technology for some DB contractors can promote marketing for their services. For the owner, as the case of the developer, being innovative becomes beneficial for their operations as explained in Chapter 8. The dedication and commitment for innovative adoption, as mentioned by Respondent 4, has made DB project delivery more efficient. As noted by Ling et al. (2007), the commitment of the owner and owner's representative in innovation leads to benefits. Similarly, DB procurement is better fit for adopting innovation due to the increased collaboration and coordination within stakeholders (Jervis and Levin, 1988).

4.4 Conclusion

This chapter discussed how the Philippines utilizes DB projects. Although all the respondents came from the capital of the country, their extensive experience can clarify the current practice of DB in the Philippines. Based on the owners' and the contractors' responses, the common project objectives of implementing DB is to expedite project schedule, better profit, risk transfer, technological expertise and innovation, as well as manageability and efficiency.

The manageability and efficiency, as mentioned important by the respondents, promote increased collaboration and communication for the DB contracting parties. Since BIM is highly dependent on the collaboration of different stakeholders especially in the early phases of the project, implementing it for DB projects would be beneficial. Moreover, since most of the risks are transferred to the DB contracting party, the collaborative aspect of BIM would enable them to manage the risk more efficiently. The *"us versus them"* mindset (Turner, 2014) would be avoided.

As technology was highlighted by the groups of respondents, the utilization of innovation and technology for DB projects are therefore beneficial, concluding such past studies as Jervis and Levin (1988), Ling et al. (2007), del Puerto et al. (2008), and Songer and Molenaar (1997).

It is realized that the need for statistical methodology be necessary to presume some conclusions in this research. However, due to the limited number of respondents that are knowledgeable about all relevant topics, the proposed sample size is considered appropriate.

This section provided factors for future study which can focus on the DB projects in the Philippines. The output provides the objectives of owners and contractors when engaging in DB projects, which can help verify identified risks in the next chapter.

CHAPTER 5
RISKS IN DESIGN-BUILD PROJECTS

5.1 Introduction

This chapter presents the identification of risks in DB projects in the Philippines. It begins with identifying the critical risks from DB projects from literature and relevant studies from the Philippines. These risks were then verified by survey questionnaire and interviews with BIM and project experts. Each risk attribute which is common with that of BIM uses is discussed, namely, project lifecycle, elements, and ownership. The output, a simplified risk nomenclature, is a vital part of the framework development that relates risks and BIM.

5.2 Identifying Risks in DB projects

This part begins with compiling critical risks in DB projects from literature. Since relevant risk or risk management related studies with regard to the Philippine context were limitedly available, it was necessary to gather critical risks from other countries. Thus, these risks need to be verified to examine if they also correspond to the Philippine context.

The term "verified" as used in this research pertains to the first phase data collection. The verification was done in order to breakdown the identified risk events to the risk factors that are common in the Philippine construction projects. The risk verification from the in-depth interviews acquired knowledge from experts based on the perceived factors that occur leading to the identified risk.

The main objective of the verification process is to ensure all generic risks in DB projects were attained. The generic risks, which can be experienced in typical DB projects, were gathered and filtered from literature. Each project is unique and has many risks, which depend on several factors but the key sources are essentially the same (Smith, 2006). In addition, specific risks for the Philippine construction industry were inquired and will be explained in the subsequent sections.

The verification process begins with the evaluation of each risk by the respondents in the first phase of data collection. The respondents also decided whether or not the risk can be managed by BIM. A total of 30 identified risks was filtered down to 20 risks, which can be managed by BIM. The risks that were agreed to be unmanageable by BIM were excluded.

Table 5.1 shows the verified risks in DB projects in the Philippines. It can be observed that most of the risks are internal to the project. Some external risks, such as inclement weather and bureaucratic problems, were still included. These types of risks were perceived to be manageable by technological advancement such as BIM mainly because properly including them to the project planning through schedule contingency can help manage those risks.

Most of the risks that were excluded were external risks. They are war threats, rebel tax and third party delays, which were agreed to be unsolvable or manageable by BIM or technological implementation. In addition, financial risks such as financial failure of any party and inflation were also excluded. This is because the financial risks were not related to the implementation of technology. Lastly, contractual issues such as change order, negotiations, and delays in resolving litigation were also excluded.

In addition to verifying the BIM-manageable risks, additional inquiry were also included such as:

- Risk factors leading to risk events, as seen in Figure 5.1.
- Project lifecycle occurrence of each risk
- Impact to project objectives of time, cost, quality and scope
- Ownership of the risk.

Table 5.1 Risk verified in DB projects in the Philippines

No.	Risk Event	BIM-manageable	Not BIM-manageable
1	Change in quantity/cope of work	●	
2	Inconsistent design and construction work	●	
3	Labor, equipment and material availability	●	
4	Inadequate quality of work and need for correction	●	
5	Safety/Accidents	●	
6	Suppliers/Subcontractors failure due to poor performance	●	
7	Design change	●	
8	Delay in design	●	
9	Inflation		●
10	Difficulty in inspection for progress payments	●	
11	Financial failure of any party		●
12	Exceptionally inclement weather	●	
13	Environmental hazards of the project		●
14	Unforeseen site conditions	●	
15	Bureaucratic problems	●	
16	Site access/Right-of-way issues	●	
17	War threats		●
18	Change order negotiations		●
19	Delays in resolving contractual issues		●
20	Delays in resolving litigation/arbitration disputes		●
21	Labor disputes		●
22	Third party delays/Public disorder		●
23	Rebel tax		●
24	Constructability Problems	●	
25	Lack of Value Management/Engineering	●	
26	Difficulty in choosing proposals	●	
27	Unable to get approvals	●	
28	Deficiencies in specifications and drawings	●	
29	Inconsistent warranty information and as-built drawing	●	
30	Difficulty in property management and maintenance	●	

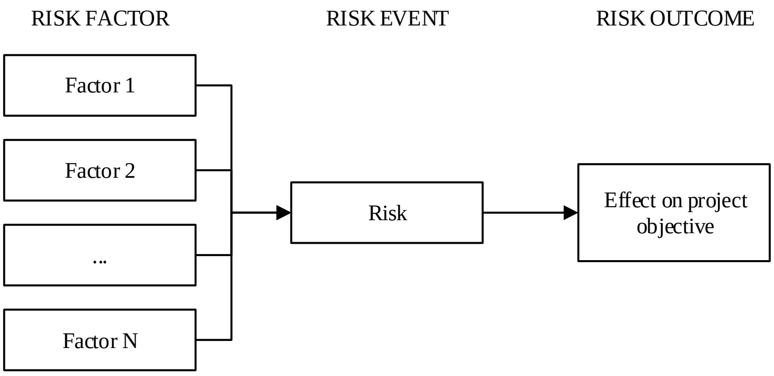

Figure 5.1 Relationship of risk factor, event, and outcome

5.2.1 Risk Breakdown Structure

The risk breakdown structure (RBS) is used to aid in the identification of risks (Hillson, 2002). For this research, the RBS adopted is shown in Figure 5.2.

The purpose of utilizing the RBS is to classify the identified risks from literature to their appropriate risk centers. A risk center, as utilized by Tah and Carr (2001), is similar to that of the risk category. The initial risk identified from literature was categorized for a systematized verification of the respondents. The risk centers used for this research are design related, construction related, financial related, environmental, post-construction related, and political/legal.

In order to identify the root causes of this risks, the relationship between Figure 5.1 is used as a foundation for risk verification. From the risk centers, the possible factors were identified by the respondents as shown in Table 5.2

5.2.1.1 Internal DB Project Risks

Design Related. The first risk center observed from the risk factors were design related risks. A total of five risk events were verified based on the expert interviews. Most of the design risks are common to the traditional project delivery method (DBB) and was explained in Reyes (2008).

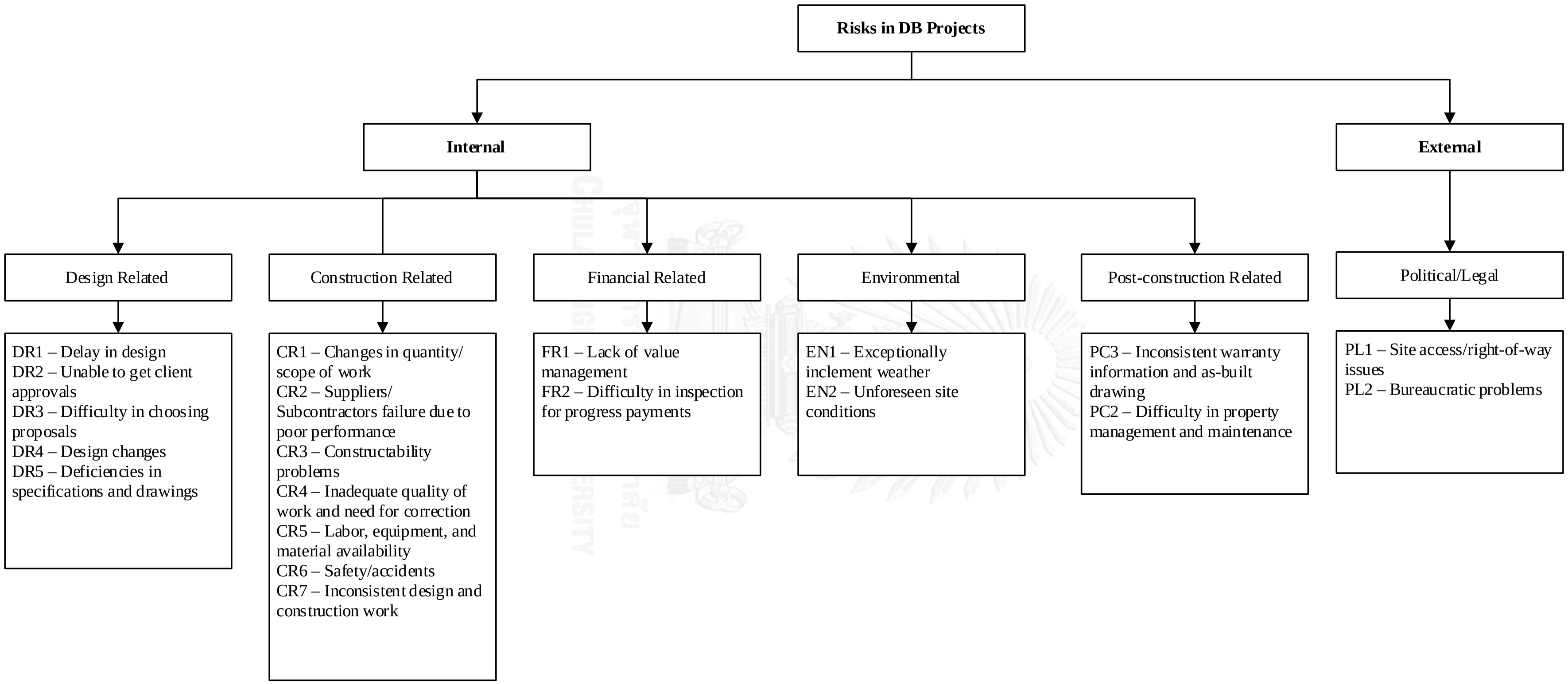

Figure 5.2 Risk breakdown structure

Table 5.2 Verified risk factors for identified risk events

Risk Events	Risk Factor
Design changes	-Vague requirements by clients -Erroneous drawings and specifications -Incompatible design and site condition -Improper planning and space utilization -Inflexibility of consultants
Delay in design	-Delay from other consultants -Tedious 2D design process -Vague requirements by clients
Deficiencies in specifications and drawings	-Human error -Lack of communication between stakeholders -Contractor's consultants incompetency
Difficulty in choosing proposals	-Vague requirements by clients -Owner's lack of knowledge to evaluate proposals -Too many proposals to evaluate -Clients are undecided
Unable to get client's approvals	-Insufficient time to prepare tender documents -Owner's lack of knowledge in construction and tender

It is important to note one of the design related risks which is *unable to get client's approval*. This risk is noteworthy in DB projects since most of the designs in the early stages of the project lack the details in inception stage. Factors such as long review process by the owners, approvals, and vague and excessive demands also exists in the context of the Philippines, similar to those in Malaysia (Adnan et al., 2008), Taiwan (Tsai and Yang, 2010) and Singapore (Ling and Poh, 2008). Since overlapping of activities occur in DB delivery, some client related issues mentioned exist because of clients' unsureness on what they want. These factors lead to the risk event which eventually causes delay and additional overhead costs for the DB contractor.

Construction Related. The next risk center is construction related risks. These risks usually happen in the construction stages. A total of 7 risks were verified in the DB projects in the Philippines.

Similar to the previous risk center, most of the construction related risks can also be found in traditional DBB project delivery method. A specific risks, which is constructability risk, is however noteworthy. *Constructability* risks, similar to Nigeria (Hammad et al., 2012) happen when the design cannot be constructed. It may be caused by overlooked conflicting items and lack of design reviews prior to construction. Usually, some of the elements might be overlooked due to human error and when delays persists. The desire to hasten the project completion perceives a risk of this kind of event to happen.

Financial. The third risk center is the financial related risks. A total of two risks were verified for this group.

It is noteworthy to examine the *lack of value management* risk. This risk was mentioned a lot of times by respondents. This event is usually caused by low working morale of contractors and use of inferior materials. The possibility of a restrictive attitude by contractor, especially when saving costs, could limit the use of carefully selected materials and specifications because they are in-charge also of the design. Moreover, since value is measured differently among stakeholders, lack of common objective usually exists. Lack of agreement to which entities are valuable also leads to the restriction to upfront costs instead of additional, long term benefits such as sustainability. The ability of technology to simulate material specification and usage would result to additional information to which are optimal to structures being built.

Environmental. The fourth risk center concerns about risks that are caused by environmental sources. These are the *exceptionally inclement weather* and *unforeseen site conditions.*

These risks were given emphasis by the respondents. Similar in DB projects in Turkey (Oztas and Okmen, 2004), the risk of an exceptionally inclement weather is likely to occur due to the geographic location of the Philippines wherein tropical storms are common. Recent studies also present the effect of weather as a primary cause of delay in local government projects (Calvelo et al., 2015). On one hand, the risk of the weather is usually accounted for during project scheduling, which is agreed can be optimized by utilizing BIM. On the other hand, as unforeseen site conditions are at most general to any construction projects, these can be managed also by BIM through simulations and advanced geological site investigations. Therefore these risks, although uncontrollable, can be managed by BIM and were included to the verified risks.

Post-Construction. The risk breakdown structure was similar to the work of Reyes (2008). One of the major differences is this category, which includes risk events in the post-construction stages.

The risks of *inconsistent warranty information* and *difficulties in property management* were verified to occur in Philippine DB projects. These were agreed to be caused by use of inferior materials, handling of information, and lack of communication with end users. Although these risks are mostly concerned by facility managers, since the contractors hand-in as-built drawings at the latter stages, information about the facility will be utilized by the end-users and facility managers. It was therefore agreed by the respondents that these issues can be mitigated by implementing BIM.

5.2.1.2 External DB Project Risks

Political/Legal. For this specific risk center, two risks events were verified to be manageable by BIM. These are *site-access/right-of-way issues* and *bureaucratic problems.*

These two risks were verified to be managed by BIM. The *site-access/right-of-way* and *bureaucratic problems* can be managed by site planning BIM use and 4D capability of BIM in adjusting with delays, respectively. Commonly, the *site-access/right-of-way* risks are caused by unidentified right of way issues, lack of knowledge on local regulations, and particular contractor’s right-of-way due to their construction method. The bureaucratic problems, which are usually caused by delays in legal processes, are out of control by the construction stakeholders. It is manageable through automatic adjustment of schedule and simulation using BIM, hence these were included in the verified risks list. It is however debatable since most respondents agreed to an extent that BIM can be used for this risk, but usually bribery and simply paying building officials can help manage these risks.

The purpose of the RBS is to have a systematic classification of risks. Adopting this would be useful for the framework proposed in this thesis since the framework is context dependent. Thus, each risk factor that can affect the risk event would have one risk code. The risk coding system adopted for this research is seen on Figure 5.3.

The risk coding was based on the RBS adopted for this research. Each code specifies the risk type, center, event, and factor as seen in Table 5.3. For instance, R.1.01.03.01 is an *internal risk* with a *design* risk center. The risk event is *deficiencies in specifications and drawings* and a specific risk factor of *drawing insufficiency due to human error.* The risk code gave a specific item for each risk factor which would be used to relate with BIM use purposes as specified by Kreider and Messner (2013).

5.2.2 Project Lifecycle Occurrence and Impact to Objectives

This section discusses the verified risks' project lifecycle occurrence and impact to the project objectives of time, cost, quality and scope. Table 5.4 shows the results based on the expert interviews. Each check signifies which phase of the project the risk will occur and in which objective would it most likely have an effect on.

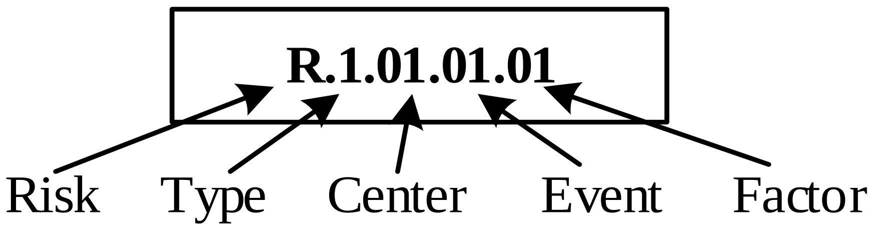

Figure 5.3 Risk coding system

Table 5.3 Risk catalogue detail

Risk Code	Type	Risk Center	Risk event	Factor	Risk Factor
R 1 .01 .01 .01	Internal	Design	Design changes	Client	Vague requirements by clients
R 1 .01 .01 .02	Internal	Design		Drawing insufficency	Erroneous drawings and specifications
R 1 .01 .01 .03	Internal	Design		Site	Incompatible design and site condition
R 1 .01 .01 .04	Internal	Design		Planning	Improper planning and space utilization
R 1 .01 .01 .05	Internal	Design		Consultant	Inflexibility of consultants
R 1 .01 .02 .01	Internal	Design	Delay in design	Consultant	Delay from other consultants
R 1 .01 .02 .02	Internal	Design		Drawing insufficency	Tideous 2D design process
R 1 .01 .02 .03	Internal	Design		Client	Vague requirements by clients
R 1 .01 .03 .01	Internal	Design	Deficiencies in specifications and drawings	Drawing insufficency	Human error
R 1 .01 .03 .02	Internal	Design		Communication	Lack of communication between stakeholders
R 1 .01 .03 .03	Internal	Design		Consultant	Consultant's incompentency
R 1 .01 .04 .01	Internal	Design	Difficulty in choosing proposals	Client	Vague requirements by clients
R 1 .01 .04 .02	Internal	Design		Client	Owner's lack of knowledge to evaluate proposals
R 1 .01 .04 .03	Internal	Design		Numerous proposals	Too many proposals to evaluate
R 1 .01 .04 .04	Internal	Design		Client	Clients are undecided

Table 5.4 shows the project lifecycle which has three major divisions of pre-construction (PC), construction (C), and post-construction (OM). The simplified subdivision of project lifecycle was adopted for the end-users of the framework. Utilizing detailed division of project lifecycle such as OmniClass Table 31 (OmniClass, 2012b) would be difficult for the respondents and users of the framework. For this research, OmniClass Table 31 was adopted and categorized to the three project lifecycle stages. Figure 5.4 shows the division of the project lifecycle stages.

Also on Table 5.4 are the project objectives affected by the risk. Each respondents were asked in which aspect the risk would have an effect on. Basically, each of the four objectives are interrelated and the respondents were asked which objective is or are most affected. The results show that some risks can have effect on one or more project objectives. The results would show the perceived risks that should be taken into consideration when analyzing project objectives.

It is noteworthy that this thesis does not focus on risk management of DB projects in particular. In other words, the verification did not include quantification of the probability and impact, although it was considered important in risk management studies. Since the objective of the verification process is only to determine when the risk would occur and which project objectives will be affected, the rating is not considered to be part of the thesis. However, evaluation of critical risks were done in the case studies which is part of the methodology of the developed framework.

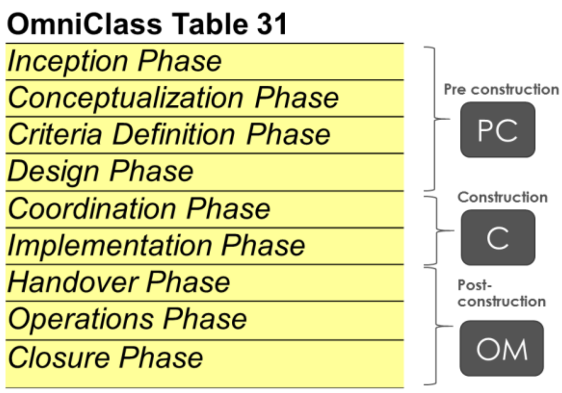

Figure 5.4 OmniClass Table 21 Division

Table 5.4 Project lifecycle occurrence and effect to project objectives

Risk Code	Risk Event	Project Lifecycle			Project Objectives			
		PC	C	OM	T	C	Q	S
DR1	Design changes	✓	✓		✓	✓		✓
DR2	Delay in design	✓			✓	✓		
DR3	Deficiencies in specifications and drawings	✓	✓		✓		✓	
DR4	Difficulty in choosing proposals	✓			✓	✓		✓
DR5	Unable to get approvals	✓			✓	✓		✓
CR1	Changes in quantity/scope of work	✓	✓		✓	✓	✓	✓
CR2	Inadequate quality of work and need for correction		✓				✓	
CR3	Difficulties/delays in labor, equipment, and material availability		✓		✓	✓		
CR4	Safety/accidents		✓		✓	✓		
CR5	Coordination with suppliers/subcontractors		✓		✓	✓	✓	
CR6	Constructability	✓	✓		✓	✓	✓	
CR7	Inconsistent design and construction work		✓				✓	
FR1	Difficulty in inspection for progress payments		✓			✓		
FR2	Lack of value management	✓	✓			✓	✓	
ER1	Exceptionally inclement weather		✓		✓	✓	✓	
ER2	Unforeseen site conditions		✓		✓	✓		✓
PL1	Site access/right of way issues		✓		✓	✓		
PL2	Bureaucratic problems	✓			✓			
PR1	Inconsistent warranty information and as-built drawing		✓	✓		✓	✓	
PR2	Difficulty in property management and maintenance			✓		✓	✓	✓

5.2.3 Elements Exposed to Risk Events

One of the common attributes both considered in risks and BIM uses is the elements of the project that can be affected. Smith (2006) said that one of the common issues considered in risks are the elements of the project that could be affected.

To have a common notation on the elements of the project that can be affected, OmniClass Table 21 (OmniClass, 2012a) was adopted. Table 5.5 shows the different elements subdivided for each project. The utilization of a standard such as OmniClass enabled a generic subdivision of elements for this thesis. Moreover, OmniClass tables were also used in some standards related to BIM implementation (CICRP, 2011, AIA, 2013).

The identification of which elements are affected by the risks was part of the verification process. Tables 5.5 and 5.6 show the description of OmniClass Table 21, and the elements at risk, respectively.

As seen on Table 5.6, most of the risks occur in the first four categories which are the substructure, shell, interiors, and services. This signifies that most of the risks that were verified were all part of the construction activities. Similar to the work of Tah and Carr (2001), some risk events occur in particular building elements. Having the knowledge of which building element will be at risk would enable project stakeholders to partake necessary actions to alleviate it.

Table 5.5 OmniClass Table 21 – Elements

Element	Description and examples
Substructure	Foundations, Subgrade enclosures, Slabs-on-grade, Water and Gas mitigation, Substructure related activities
Shell	Superstructure, Exterior Vertical Enclosures, Exterior Horizontal Enclosures
Interiors	Interior Construction, Interior Finishes
Services	Conveying, Plumbing, HVAC, Fire Protection, Electrical, Communications, Electronic Safety and Security, Integrated Automation
Equipment and Furnishings	Equipment, Furnishings
Special Construction and Demolition	Special Construction, Facility Remediation, Demolition
Site work	Site Preparation, Site Improvements, Liquid and Gas Site Utilities, Electrical Site Improvements, Site Communications, Miscellaneous Site Construction

Based on responses, risks of *difficulty in choosing proposals, unable to get approvals, and bureaucratic problems* have no direct effects on project elements. This is because these risks occur prior to the construction, which cannot be allocated by the element subdivision of OmniClass Table 21.

Table 5.6 Elements at risk

Risk Events	Substructure	Shell	Interiors	Services	Equipment and Furnishings	Special Construction and Demolition	Site work
Design changes	✓	✓	✓	✓	✓		
Delay in design	✓	✓	✓	✓	✓	✓	
Deficiencies in specifications and drawings	✓	✓	✓	✓			
Difficulty in choosing proposals							
Unable to get approvals							
Changes in quantity/scope of work		✓	✓	✓			
Inadequate quality of work and need for correction	✓	✓	✓	✓			
Difficulties/delays in labor, equipment, and material availability	✓	✓	✓	✓	✓	✓	✓
Safety/accidents	✓	✓	✓	✓	✓	✓	✓
Coordination with suppliers/subcontractors	✓	✓	✓	✓		✓	✓
Constructability	✓	✓	✓	✓		✓	
Inconsistent design and construction work	✓	✓	✓	✓			
Difficulty in inspection for progress payments	✓	✓	✓	✓	✓	✓	✓
Lack of value management	✓	✓	✓	✓	✓	✓	✓
Exceptionally inclement weather	✓	✓					✓
Unforeseen site conditions	✓						✓
Site access/right of way issues							✓
Bureaucratic problems							
Inconsistent warranty information and as-built drawing				✓	✓		
Difficulty in property management and maintenance		✓	✓	✓	✓		

5.2.4 Risk Allocation

Finally, the allocation or ownership of the risks was identified to be a common attribute between risks and BIM uses. For the risk part, the ownership is separated to two which is the bearer (i.e., affected by the consequence of the risk) and responsible (i.e., responsible for managing and implementing responses) (Ward, 1999). Each respondent was asked if the owner, contractor, or both (shared) would bear and be responsible for the risk. Table 5.7 shows the results from the interviews. These answers were based on both the responses of respondents and the work of Reyes (2008).

It is important to note that the work of Reyes included similar risks, but different project scope which is DBB projects. However, his work focused on the risk allocation and had similar results even in DB projects. The main difference is the allocation of design risks as it is usually internal to the DB contractor, which is sometimes an agreement between the contractor and partner design firm and usually excludes the owner. An additional item is the *bearer*. Table 5.7 shows that some risks have the different bearers and parties responsible. The importance of this table shows the relationship between the risks and ownership, which can be utilized in knowing the discipline responsible for managing the BIM uses. The bearer and responsible parties would also highlight the level of implementation of BIM use, as well as the sharing of information which would be suggested as the results of this thesis.

5.3 Conclusions

This chapter presented attributes of risks that are used in the development of the framework. The attributes identified were risk factors, occurrence in the project lifecycle, elements at risk, and ownership of risks. These factors were verified in the Philippine context; however, could be generalized to similar countries since risk identification was done through review from critical risks of other countries. The risk verification highlighted risk factors that affected the risk events. These risk factors are related to the BIM use purposes, which are explained on the succeeding chapters.

Table 5.7 Risk allocation

Risk Events	Who	
	Bearer	Responsible
Design changes	Contractor	Contractor
Delay in design	Contractor	Contractor
Deficiencies in specifications and drawings	Contractor	Contractor
Difficulty in choosing proposals	Owner	Owner
Unable to get client's approvals	Contractor	Owner
Changes in quantity/scope of work	Contractor	Contractor
Inadequate quality of work and need for correction	Contractor	Contractor
Difficulties/delays in labor, equipment, and material availability	Contractor	Contractor
Safety/accidents	Contractor	Contractor
Suppliers/subcontractors failure due to poor performance	Contractor	Contractor
Constructability issues	Contractor	Contractor
Inconsistent design and construction work	Owner	Contractor
Difficulty in inspection for progress payments	Owner	Owner
Lack of value management	Owner	Contractor
Exceptionally inclement weather	Shared	Owner
Unforeseen site conditions	Owner	Owner
Site access/right of way issues	Owner	Owner
Bureaucratic problems	Owner	Owner
Inconsistent warranty information and as-built drawing	Contractor	Contractor
Difficulty in property management and maintenance	Owner	Owner

The project lifecycle and elements at risk were adopted and modified from OmniClass Tables 31 and 21, respectively. The utilization of standards with regard to this attributes gave simplicity in terms of subdividing phases and tasks.

Finally, risk ownership included both the bearer and responsible for the risk. The bearer is the one who will face the consequences, while the responsible is the party who will implement measures to alleviate the risk. These important attributes were highlighted in this Chapter which will be used as important identifiers in allocating BIM uses for risks in the developed framework of this thesis.

This thesis did not focus on risk management entirely. Therefore, it was agreed by the researcher to exclude quantitative aspects, especially in probability and impact to project objectives, as it would be unnecessary to utilize such information. Although deemed important, quantifying these attributes were excluded.

CHAPTER 6
ATTRIBUTES OF BIM USES

6.1 Introduction

This chapter presents the attributes of the BIM uses. It begins with mapping the current BIM uses available in literature. A total of 30 BIM uses that are currently being adopted by BIM-mature countries were identified. Each attribute that is common with the risk attributes discussed in the previous chapter were elaborated in each subsequent section. The last section derives the conclusions that were based on the usability of these attributes to the developed framework of this thesis.

6.2 Definition of BIM Use

A BIM use is defined as "a method of applying building information modeling during a facility's lifecycle to achieve one or more specific objectives." (Kreider and Messner, 2013). This definition describes how to use BIM in a facility.

There are two ways that BIM uses can be classified. First is by classifying according to the facility phase, which was elaborated in the Chapter 2 of BIM Project Execution Planning Guide (CICRP, 2011). Second is based on the purpose of implementing BIM (Kreider and Messner, 2013). It is noteworthy that BIM does not alter the purpose but only the way by which the purpose is achieved (Kreider and Messner, 2013). Figure 6.1 and Figure 6.2 show the first and second classifications, respectively.

This research relied on both classifications since they are both used in the development of the framework. The first classification (CICRP, 2011) was used to identify the current BIM uses available, whereas the second classification (Kreider and Messner, 2013) was used as a core relationship between risks and BIM in the developed framework.

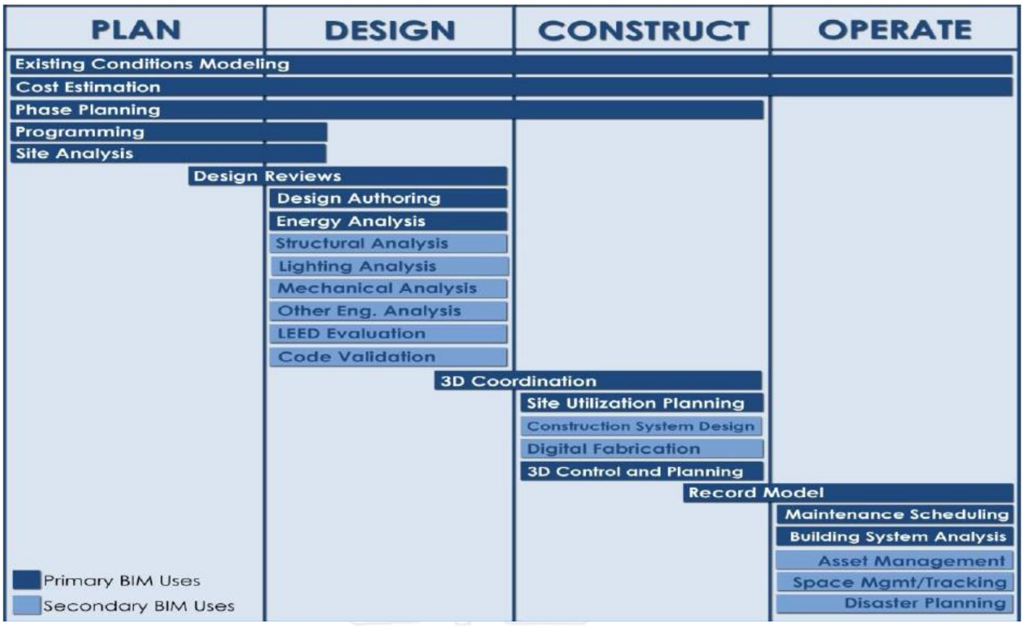

Figure 6.1 BIM uses arranged according to project lifecycle (CICRP, 2011)

6.3 Current BIM Uses

The current BIM uses utilized by other BIM-mature countries were reviewed based on more than 30 BIM-related standards, guidelines, and peer-reviewed articles. A total of 30 BIM uses were identified. Table 6.1 shows the mapping of BIM uses based on their appearance on some well-known standards and guidelines.

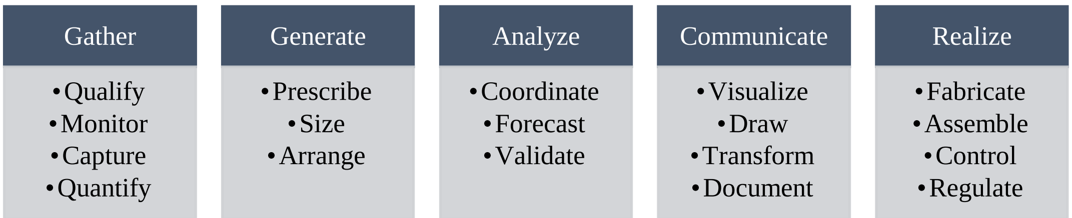

Figure 6.2 BIM use purpose classification (Kreider and Messner, 2013)

Table 6.1 Mapping of current BIM uses

BIM Uses	AEC (CAN) BIM Protocol (Canada BIM Council, 2012)	BIM Project Execution Planning Guide - Version 2.0 (CIC, 2010)	COBIM - Common BIM Requirement 2012 (buildingsmart, 2012)	Georgia Tech (GT) BIM Requirements & Guidelines for Architects, Engineers and Contractors (GIT, 2011)	NBIMS-US v2 (NIBS, 2013)	Singapore BIM Guide Version 2 (BCA, 2013)	Ku and Taiebat, 2011	Azhar et al., 2012	National Guidelines for Digital Modeling (CRC, 2013)
Existing Conditions Modeling	x	x	x	x		x		x	
Quantity Take-Off/Cost Estimation	x	x	x	x	x	x	x		x
Phase Planning/Scheduling	x	x	x	x		x	x		x
Site Analysis	x	x	x			x	x	x	x
Programming		x	x		x			x	x
Design Reviews		x	x	x	x	x	x		x
Code Validation		x	x			x			x
Sustainability (LEED) Evaluation		x	x	x			x		x
Structural Analysis		x	x	x		x			x
Facility Energy Analysis	x	x	x		x	x			x
Engineering Analysis		x	x		x	x			x
Design Authoring	x	x	x	x	x	x		x	x
3D Coordination	x	x	x			x	x	x	x
3D Control and Planning		x	x				x		x
Digital Fabrication/Shop Drawing		x	x	x		x			x
Construction System Design		x	x			x	x	x	x
Site Utilization Planning	x	x	x			x	x	x	
Record Modeling/Production Data Delivery	x	x	x	x		x			x
Safety/Disaster Planning		x					x		
Space Management and Tracking		x	x			x			x
Facility Management		x	x		x	x	x		x
Building Systems Analysis	x	x	x						x
Building Maintenance Scheduling		x	x						x
Options Analysis			x			x	x	x	
Project Progress Monitoring			x						x
Supply Chain Management							x	x	x
Lighting Analysis	x		x	x	x	x			
Quality Control Checks	x		x						
Visualization	x	x	x	x		x	x	x	x
Database Information Management						x	x		

6.4 BIM Use Details

This section presents the attributes that were analyzed for the development of the framework and analysis of how to implement the BIM uses for risk management. The underlying concept of identifying organizational needs, i.e., the input, process, and output, to implement BIM is considered. Although there is no single literature which provide the exact list of attributes needed to implement BIM, some essential attributes from well-known BIM execution planning guides (Epstein, 2012, CICRP, 2011) are considered. The following identified are the following:

- *Definition and expected benefit,* which summarizes the capability of the BIM use.
- *Requirements*, which include the model requirement, information requirement, and tool requirement.
- *Process*, which shows how the BIM use can be done based on literature and on the analysis through adopting business process model and notation (BPMN).
- *Outcomes*, which portray the output of applying such BIM use in the form of a specific model or information that can be generated.
- *Project lifecycle applicability* which shows *when* the BIM use can be implemented based on the three main division of pre-construction, construction, and post-construction.
- *Responsible party*, which shows the parties that are involved in the BIM use, which is displayed in the processes on the BPMN of each BIM use.
- *Elements applicable*, which show the different building elements which can be used with the BIM use.
- *BIM use purpose analysis*, which shows the relationship between the two previously discussed classifications of BIM uses. It relates the first and second classifications based on the author's analysis.

To illustrate this concept, BIM uses of *3D Coordination* and *Quantity Take-off/Cost Estimation (QTO/CE)* are analyzed. Appendix D shows the details of the remaining BIM uses.

6.4.1 BIM Use Definition and Expected Benefit

The first two attributes of BIM uses are definitions and expected benefits. The definition summarizes the capability of applying a BIM use. The expected benefits present the added values, which the users of the BIM use can experience. These definitions and expected benefits of the two BIM uses examples are summarized in Table 6.2.

6.4.2 Requirements

The principal requirements for implementing each BIM use are the information requirement, tool requirement, and model requirement. The information requirement refers to necessary inputs for implementing each BIM use and the source of such information, (i.e., which party to implement the BIM use). The tool requirement specifies the BIM tools that are required. The model requirement states the type of model that is applicable to such BIM use. Clearly, such model can be an outcome of another BIM use. For example, an outcome of design authoring is 3D model, which can be used for visualization, 3D coordination, and code/organizational standard checking.

6.4.2.1 Information Requirement

The information requirement presents the non-graphic information required in performing the BIM use. In utilizing BIM uses, BIM-related requirements such as BIM tools and modeled elements are required. However, non-graphic or information requirement are also required, as shown in Table 6.3.

As can be seen, to perform the *cost estimation* benefit of the *quantity take-off* BIM use, a cost database is required. A cost database is a non-graphic information used to provide the cost of each quantified element. For *3D coordination*, information such as contract requirements and organizational standards are required to properly allocate clashes when they are evaluated in the rules-based checking software.

Table 6.2 BIM Uses descriptions and expected benefits

BIM Use	Description	Expected Benefits
3D Coordination	The BIM use which can be used to detect clashes through compilation and coordination of 3D models of building systems. The process is used to avoid conflicts prior to construction.	**Coordination and efficiency** among building elements **Visualization** of conflicts prior to construction **Assignment of responsibility** for identified clashes with engineering systems **Reduction in** total construction **cost** and change costs
Quantity Take-Off/Cost Estimation	The BIM use which can be used to aid in the development of quantity take-offs particularly through model-based estimating. With the addition of cost database, cost estimation can be done subsequently. The process can be used throughout the project lifecycle.	Swiftly **generate quantities** in the decision making process Precisely **quantify** modeled materials **Visualization** of elements to be estimated Ability to **explore design options** according to its costs Reduction in total **estimating** time

6.4.2.2 Tool Requirement

An important aspect of BIM implementation is the BIM tool. For the BIM uses, tool requirements are divided into three major categories (Epstein, 2012): (1) BIM CAD Programs, (2) Rules-Based Analysis and Checking Applications, and (3) Middleware BIM Tools. The BIM CAD Programs are the core of the collaborative data environment ideally achieved by BIM. These programs produce the representations which primarily aid visualization. Examples of these programs are Revit and ArchiCAD. The Rules-Based analysis and checking applications basically provide distinctions between BIM uses. These tools, along with the CAD programs, provide solutions for the BIM use. Example of these rules-based analysis and checking are structural analysis by Tekla and clash analysis by Navisworks. Finally, middleware BIM tools regulate the BIM ideal for a single project database. They compile data from multiple programs which can be made accessible to other stakeholders as designers and contractors modify the common model. Example of these type is the Onuma System (Epsten, 2012).

The tool requirement used in this research, as shown on Table 6.3, suggests the required BIM tools to utilize a BIM use. For example, a BIM CAD program or *design authoring software* is required for both *quantity take-off* and *3D coordination* BIM uses. In addition, *model-based estimating software* and *model review application*, both considered as rules-based analysis and checking applications, are required for *quantity take-off* and *3D coordination*, respectively.

6.4.2.3 Model Requirement

The final aspect of the requirements is the model requirement. Some BIM uses, such as the two BIM use examples, need the 3D model of the facility prior to execution. These model requirements are usually outcomes of other BIM uses. The interrelation of BIM uses are seen through these requirements.

Table 6.3 Requirements and outcomes of selected BIM uses

BIM USE	REQUIREMENTS				OUTCOMES	DESCRIPTION	EXPECTED BENEFIT
	INFORMATION	IS	TOOL	MODEL			
Existing Conditions Modeling	Actual existing conditions gathered through (1) contact or (2) non-contact technique Photos of the site	O	BIM modeling software Laser scanning point cloud manipulation software 3D Laser scan Surveying equipment	N/A	Laser scan model Existing conditions model	This BIM use is done to develop a model based on the existing conditions of a site, facility, or specific area within a facility. Various ways of developing this model exists and are being developed. An example of this is laser scanning and conventional surveying techniques.	Efficient and accurate existing conditions documentation Enhanced visualization of existing conditions Future modeling benefits for retrofitting
Quantity Take-Off/Cost Estimation	Cost reports Analysis Method Cost Database	E,C	Model-based estimating software Design authoring software	3D model	BOQ Cost estimate of the project	The BIM use which can be used to aid in the development of quantity take-offs particularly through model-based estimating. With the addition of cost database, cost estimation can be done subsequently. The process can be used throughout the project lifecycle.	Swiftly generate quantities in the decision making process Precisely quantify modeled materials Visualization of elements to be estimated Ability to explore design options according to its costs Reduction in total estimating time
Visualization	Organizational template	A,E,C	Design authoring software Model checking software	3D model	Blowups Elevations 2D drawings	This BIM use helps with visualizzing and representing real elements in the model. This BIM use could automatically generate blow ups, elevations, and other details based on the information within the model	Visualization of the actual elements Efficient documentation process
Design Reviews		A,E,C,O	Design authoring software Model checking software	Design model	Design review information	This BIM use generates collaboration among the stakeholders when considering their designs. Design review is also called collaborative production environment (Sullivan, 2007). Evaluating of the project, previewing spaces, setting criteria, and etc. are some of the aspects included when considering this BIM use. This is usually done with the help of a computer software, virtual mock-ups, or immersive laboratories. This BIM use goes hand in hand with Design authoring (Sullivan, 2007).	Cost and time savings from constructing traditional mock-ups Real-time variations based on stakeholders' feedbacks Efficient criteria evaluation based on owners' needs Easier communication of design intent to other stakeholders Coordination and collaboration increase leading to better decisions
Design Authoring	Parametric Modeling Content Existing 2D plans and specs	A,E,C,O	Design authoring software	Program model	3D model	This BIM use is utilized to generate actual representations of facility elements of the proposed structure. This also goes hand in hand with design review as well as most of the BIM uses. This provides the first step of BIM wherein each discipline starts to generate models specific to their fields. The elements can be embedded with information which can be used for other BIM uses	Visualization of actual facility elements Faster revisions when changes occur
3D Coordination	Company implementation standards Contract requirements	A,E,C,O	Design authoring software Model review application	Design model	Information exchange requirements Coordination model Compiled coordination model	This BIM use promotes coordination with various stakeholders wherein clash detection is done to investigate the conflicting building elements.	Coordinate all models for clash detection Minimization of possible errors expected in construction Allocation of responsibilities for conflicting problems Visualization of conflicts

6.4.3 Process

BPMN was used to show how each BIM use can be implemented. Each BIM use's BPMN displays the common steps in achieving the purpose of the BIM use. Through the shown process, the project lifecycle and parties involved in the BIM use are identified. Process mapping enables teams to understand each BIM use's processes for efficient performance (CICRP, 2011). Figure 6.3 shows an example BPMN for *3D Coordination* BIM use. Some of the BIM use's BPMN are available in the BIM Project Execution Planning Guide (CICRP, 2011), as stated in Appendix D.

Figure 6.3 shows the process to implement the *3D Coordination/Clash Detection* BIM use. It states who are the responsible parties involved. In addition, requirements and outcomes are also provided. It can be observed that this BIM use can be applied during the pre-construction and construction stages. All stakeholders can contribute and be involved with this BIM use since model requirements from them are compiled. The output is the 3D coordination model, which provides information about the clashes of engineering systems. Thus, this BIM use can suggest appropriate actions, (i.e., risk response measures), to the responsible parties.

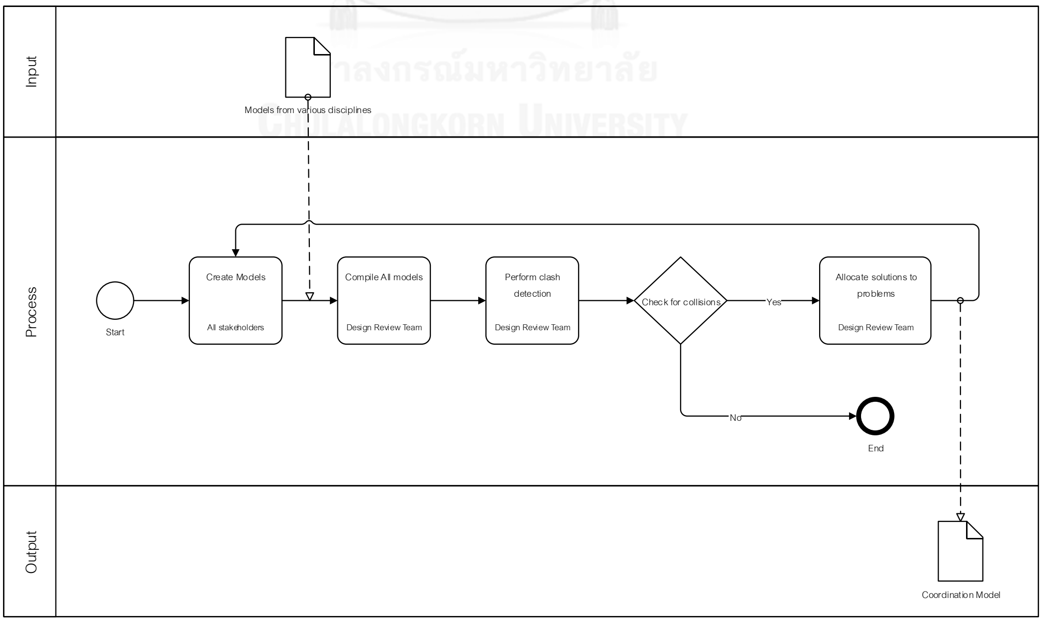

Figure 6.3 BPMN for 3D Coordination

6.4.4 Outcomes

The outcomes of the BIM uses can be either the information outcome required satisfying the purpose of the BIM use, or the model outcome which can be the model requirement for other BIM uses. For example, the *design authoring* BIM use has a *design model* outcome, which is required for both the *3D coordination* and *quantity take-off/cost estimation* BIM use. Moreover, upon accomplishing the *quantity take-off* BIM use, the information about the *bill of quantities* or *project cost* can be supplied. These outcomes are the results when BIM uses are implemented, based on the process and requirements supplied.

6.4.5 Project Lifecycle Applicability

One of the common attributes between risks and BIM uses is the project lifecycle (PLC) applicability. In terms of BIM uses' PLC, this is the phase in the project lifecycle when the BIM use can be utilized. For this research, the same standard (OmniClass) and the same division, (i.e., PC, C, and OM), were used. The uniformity and simplicity with using the same standard and division promotes user-friendliness of the framework.

Based on the example BIM uses, QTO/CE BIM use can be used throughout the project lifecycle, (i.e., PC, C, and OM), while 3D coordination can be used during PC and C only, as shown in Table 6.4.

The project lifecycle applicability of the BIM use can be related to the risks it can manage. The premise is that the BIM use should be used **on or before the risk might occur**, considering a proactive means of risk management.

6.4.6 Responsible Party

The responsible party, also known as discipline (Kreider and Messner, 2013), represents those who will implement the BIM use. For this research, since it focuses on DB projects, the allocation of responsibility is between the *owner* and *contractor.* The contractor involves the design disciplines, as per the definition of DB procurement. The responsible party would be the ones responsible in managing the risk, i.e. using BIM to proactively manage the risk or use it in the risk management process.

Table 6.4 BIM uses' project lifecycle applicability

BIM Use Code	BIM Use	PC	C	OM
BU1	Existing Conditions Modeling	x	x	x
BU2	Quantity Take-Off/Cost Estimation	x	x	x
BU3	Visualization	x	x	x
BU4	Database Information Management	x	x	x
BU5	Site Analysis	x		
BU6	Programming	x		
BU7	Design Reviews	x		
BU8	Code Validation	x		
BU9	Sustainability (LEED) Evaluation	x		
BU10	Structural Analysis	x		
BU11	Facility Energy Analysis	x		
BU12	Engineering Analysis	x		
BU13	Lighting Analysis	x		
BU14	Design Authoring	x		
BU15	Options Analysis	x		
BU16	3D Coordination	x	x	
BU17	Phase Planning/Scheduling	x	x	
BU18	Supply Chain Management	x	x	
BU19	3D Control and Planning		x	
BU20	Digital Fabrication/Shop Drawing		x	
BU21	Construction System Design		x	
BU22	Site Utilization Planning		x	
BU23	Project Progress Monitoring		x	
BU24	Quality Control Checks		x	
BU25	Record Modeling/Production Data Delivery		x	x
BU26	Safety/Disaster Planning			x
BU27	Space Management and Tracking			x
BU28	Facility Management			x
BU29	Building Systems Analysis			x
BU30	Building Maintenance Scheduling			x

(Note: PC = Pre-Construction, C = Construction, OM = Post-Construction)

6.4.7 Elements Applicable

The facility element is another common attribute between risks and BIM uses. These are elements in the facility or building on which BIM use will be implemented (Kreider and Messner, 2013). This research adopted the OmniClass Table 21 – Elements to break down the elements applicable for the BIM uses. Table 6.5 shows some of the BIM uses and the applicable elements according to the level 1 classification of OmniClass Table 21. Appendix D shows the elements applicable for the remaining BIM uses.

As shown in Table 6.5, there is a wide application in the shell, interiors, and services elements. The other levels of subdivision, (i.e., levels 2 and 3 of OmniClass Table 21), were excluded because it involves more items in the questionnaire, which would be tedious to answer. Moreover, the in-depth investigation of each element applicable is considered irrelevant, though important. This is because the objective of this research is aimed to provide a broader scope on how to implement BIM for risk management and the implementation of BIM in each organization is unique.

6.4.8 BIM Use Purpose Analysis

As mentioned in the literature review, BIM uses can be classified by either project lifecycle (CICRP, 2011) or by its purposes (Kreider and Messner, 2013). In this research, the 30 BIM uses identified were classified according to project lifecycle. However, the main relationship between the risks and BIM can be elaborated between the BIM use purpose classifications. Based on the previously mentioned attributes of BIM uses, the relationship between the two classifications was observed. For example, the description, expected benefits, and the outcome of the *QTO/CE* BIM use can result to the primary and secondary BIM use purpose of Gather – Quantify. The easy extraction of bill of quantities can also be related to the Communicate – Document. Figure 6.4 shows the relationship of the two BIM use classifications. Table 6.6 summarizes the results. Appendix E shows the risk-BIM use purpose catalogue.

Table 6.5 BIM uses' elements applicable

BIM Use	Elements Applicable for BIM Use						
	Substructure	Shell	Interiors	Services	Equipment and Furnishings	Special Construction and Demolition	Site work
Existing Conditions Modeling		✓	✓				
Quantity Take-Off/Cost Estimation	✓	✓	✓	✓	✓	✓	✓
Visualization	✓	✓	✓	✓	✓	✓	✓
Database Information Management	✓	✓	✓	✓	✓	✓	✓
Site Analysis		✓					✓
Programming	✓	✓	✓				
Design Reviews	✓	✓	✓				✓
Code Validation	✓	✓	✓	✓		✓	✓
Sustainability (LEED) Evaluation	✓			✓			
Structural Analysis	✓	✓					
Facility Energy Analysis		✓	✓	✓			
Engineering Analysis			✓	✓			
Lighting Analysis			✓	✓			✓
Design Authoring	✓	✓	✓	✓	✓	✓	✓
Options Analysis	✓	✓	✓	✓			
3D Coordination	✓	✓	✓	✓			
Phase Planning/Scheduling	✓	✓	✓	✓	✓	✓	✓

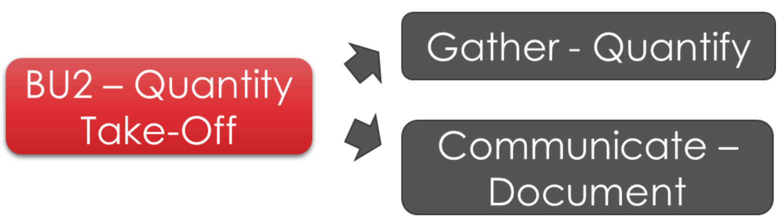

Figure 6.4 Formation of risk-BIM use purpose catalogue

Table 6.6 BIM uses related to its purposes

BIM Use Code	BIM Use	Primary Purpose	Secondary Purpose
BU1	Existing Conditions Modeling	Gather	Capture
		Communicate	Visualize
BU2	Quantity Take-Off/Cost Estimation	Gather	Quantify
		Communicate	Document
BU3	Visualization	Communicate	Visualize
		Communicate	Draw
BU4	Database Information Management	Communicate	Document
BU5	Site Analysis	Generate	Arrange

The relationship between the two BIM use classifications is vital to the developed for developing the proposed framework. Since this framework aims to identify the *appropriate* BIM uses from the set of 30 BIM uses, the primary and secondary purpose would then set the primary filter in relating the risks and BIM uses. A non-biased approach was employed in relating the two classifications and was purely based on content analysis, which relied on the extensive review of literature.

6.5 Conclusion

This chapter presents a total of 30 BIM uses classified according to project lifecycle. The 30 BIM uses were summarized from an extensive review of literature. The attributes of each BIM use were also presented.

The relationship between the two classifications of BIM uses, which is the risk-BIM use purpose catalogue, was identified. The lack of literature in relating the two classifications resulted in the author's structured and straightforward analysis based on the identified BIM use attributes.

The attributes identified in this chapter has three particular benefits: (1) for developing the framework, as will be discussed in the next chapter, (2) for identifying the relationship of the two BIM use classifications, and (3) for creating guidelines on using BIM uses for risk management. The first benefit would rely on the common attributes of project lifecycle applicability, responsible party, and elements applicable. The second and third benefit would rely on all identified attributes.

CHAPTER 7
RISK-BIM USE FRAMEWORK DEVELOPMENT

7.1 Introduction

From a comprehensive literature review, there is a research gap in relating risk management to BIM uses. There is an inadequate, systematic identification and explicit foundation in the relationship of BIM implementation and risk management.

The proposed framework of this research is called the *"risk -BIM use framework"*. It allows project planning teams to determine which BIM uses can be implemented to manage each project risk. The framework has the following interrelated objectives:

- To provide a structured approach of selecting BIM uses for users who want to use BIM in their projects,
- To identify which BIM uses can be used to manage risks along the project lifecycle,
- To create a procedure for relating new risks to current and future developed BIM uses, and
- To aid contractors and owners in integrating the use of BIM with their risk management process.

The information in accordance to construction project risks and the BIM uses were compiled from existing literature and a case studies using BIM during different project lifecycles.

7.2 Framework Details

The developed framework benefits the implementation of BIM. In line with the problem statement, the identification of critical risks related to the BIM uses, assists both contractors and owners in implementing BIM. This framework is designed to be user-friendly where users can add information to it since BIM is constantly improving and projects are unique in general where various risks might occur.

The risk-BIM use framework provides information to those who are starting to implement BIM. Since this framework benefits organizations that lack BIM experts, the suggestions in appropriate BIM uses and guideline for using it in their risk management process will help manage their projects. As this framework provides a risk-based approach in implementing BIM, using this framework is mostly beneficial during the early planning stages of the project.

There are five key elements in the framework which includes:

- **Detail setting**: the attributes of risks which are risk factors, project lifecycle occurrence, elements at risk, and ownership, as well as the attributes of BIM uses which are BIM use purposes, project lifecycle applicability, elements applicable for BIM uses, and the responsible party are identified.
- **BIM use purpose analysis**: the core relationship between risks and BIM, which is the analysis between risk factors and BIM use purposes (Kreider and Messner, 2013) are examined.
- **Risk investigation**: the attributes of an identified risk are examined. The elements of the risk would be filters for the 30 available BIM uses.
- **BIM use filtering**: based on the required attributes of the risks, the BIM uses are filtered according to the supplementary relationships of project lifecycle, elements, and ownership.
- **Update matrix**: a matrix was developed to summarize the findings of the framework which presents the available BIM uses to manage the risk, and identify the risks manageable by the BIM uses.

This chapter presents an example using the framework by analyzing some common critical risks in DB projects and relating them to their appropriate BIM uses.

7.2.1 Detail Setting

The first step is detail setting. It begins with analyzing the attributes of both the risks and the BIM uses, which were adopted and modified in the work of Tah and Carr

(2001). This framework utilizes three catalogues which are vital in identifying the relationship between risk and BIM. Figure 7.1 shows the relationship and the Figure 7.2 shows the contents of the catalogues.

Two of the three catalogues were mentioned in the previous chapters. The risk catalogue was explained in Chapter 5. The BIM Use catalogue was explained in Chapter 6. Finally the Risk-BIM Use Purpose Catalogue is explained in the subsequent section.

The detail setting focuses on the first two catalogues: (1) risk catalogue, and (2) BIM use catalogue. The contents of both catalogues include the common attributes that are needed which are the risk factors, BIM use purposes (Kreider and Messner, 2013), project lifecycle, elements, and responsible party. The output of this step is the two detailed catalogues of risk and BIM uses, as shown in Appendices C and D.

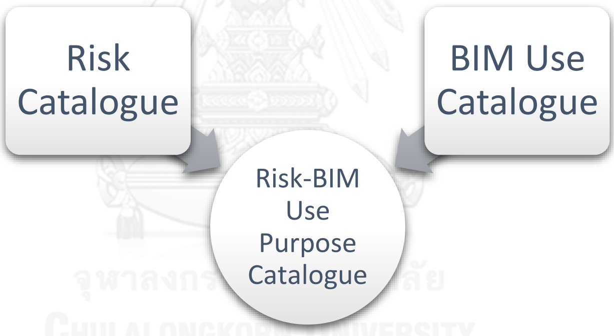

Figure 7.1 Relationship of the three catalogues of this thesis as adopted and modified from Tah and Carr (2001)

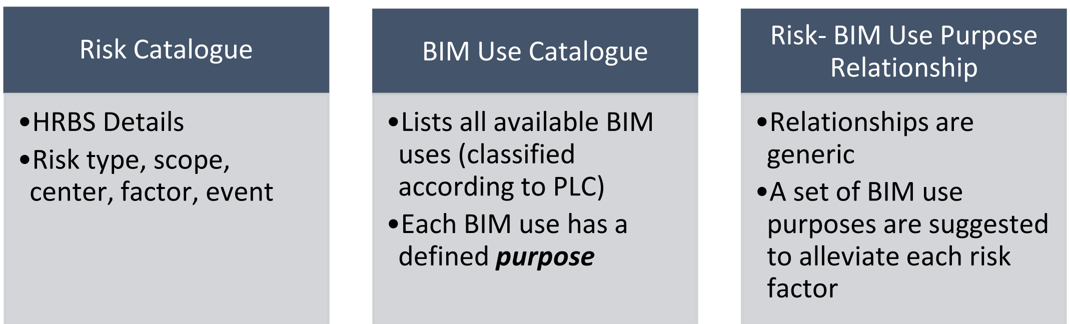

Figure 7.2 Catalogue details

7.2.2 BIM Use Purpose Analysis

This step has two sub-steps. The first one is relating the two BIM use classifications, and the second one is relating the risk factors to the BIM use purposes.

The first sub-step was explained in Subchapter 6.4.8. Since this research utilized both BIM use classifications, it is therefore necessary to analyze and relate them both.

This second sub-step highlights the third catalogue; the risk-BIM use purpose catalogue. This highlights the core relationship of risks and BIM use which is the risk factors and BIM use purposes. The risk factors identified from expert interviews were mapped with the BIM use purposes.

These common nomenclature of risk factors are then related to the BIM use purposes. Table 7.1 shows examples of risks and their appropriate BIM uses. Some risks would have similar risk factors which results to common BIM use purposes used to manage them.

As seen on Table 7.1, both deficiencies in specifications and drawings and design changes have a common nomenclature of *drawing insufficiency* as their risk factor. Thus, based on the principle that BIM implementation would be beneficial, the appropriate BIM use purpose to alleviate the risk is to *Communicate* – *Draw*. This presents a straightforward approach of relating the risk factors and BIM use purpose. It is argued that the utilization of a common language in describing risk factors while having uniform BIM use purposes mapped with them would provide easy and non-biased understanding of the relationship of risks and BIM use.

Allocating common BIM use purposes for similar risk factors would then be beneficial as it provides uniformity in the analysis and results and in turn limits subjectivity. Based on the same example, the common BIM use purpose would be to *communicate – visualize* for risk events that affected by risk factors of *inspection*. The BIM use purposes were predefined by Kreider and Messner (2013), which makes it convenient to present contextual analysis in alleviating risk factors through those specific purposes. The complete BIM use purposes for each risk factors are seen on Appendix E.

Table 7.1 Constructing common nomenclature for risk factors

Risk Event	Risk Factor	Common Nomenclature for Risk Factor	BIM Use Purpose
Constructability	Overlooked conflicting items	Drawing insufficiency	Analyze - Coordinate Communicate - Draw
	Incomplete design review	Inspection	Communicate - Visualize
Inadequate quality of work and need for correction	Lack of quality checks	Inspection	Communicate - Visualize
Deficiencies in specifications and drawings	Human error	Drawing insufficiency	Communicate - Draw
Design changes	Erroneous 2D drawings	Drawing insufficiency	Communicate - Draw
Site access/right-of-way issues	Lack of knowledge on local regulations	Inspection	Communicate - Visualize

7.2.3 Risk Investigation

The development of the risk-BIM use relationship matrix starts with investigating the risk, consequently identifying all the appropriate BIM uses which can be used for the risk basing on their similar attributes. The appropriate BIM uses are selected depending on the filters which will be discussed on the subsequent step.

This step starts upon reviewing both risk and BIM use catalogues. As soon as the project planning team agrees that all available risks and BIM uses are detailed, they can proceed with this step. It is assumed that for this research, all critical risks and widely used BIM uses were identified.

For this step, the risk event of *constructability issues* will be examined. The important attributes of the risk to be analyzed are risk factors, project lifecycle occurrence, elements at risk, and the responsible and affected parties. Table 7.2 shows the summary of the needed attributes of the *constructability* risk.

Initially, there are 30 available BIM uses to manage this risk, however, not all are directly related to the constructability risk. It is therefore upon the next step, to reduce the available BIM uses for managing the *constructability* risk.

7.2.4 BIM Use Filtering

This step filters the available BIM uses to those that can be ideally implemented for managing the risk. Based on the example of *constructability* on Table 7.2, it is necessary to examine the risk's attributes to identify the appropriate BIM uses to come along with it.

The filtering, based on the common attributes, are done in this order; (1) BIM use purpose filter, (2) project lifecycle filter, (3) elements filter, and (4) discipline filter.

Table 7.2 Constructability risk detail

Detail	Content
Risk factors	Incomplete design review Overlooked conflicting items Clashes with engineering systems Owners unsure if contractor's method statements or shop drawings are adequate
BIM use purposes required	Gather – Monitor Analyze – Coordinate Communicate – Document Communicate – Visualize
Project lifecycle occurrence	Pre – construction and Construction
Elements at risk	Substructure Shell Interior Services
Ownership	Bearer – Contractor Responsible – Contactor

7.2.4.1 BIM Use Purpose Filter

The first filter is the BIM use filter. From Table 7.3, it can be observed that from the risk factor-BIM use purpose catalogue, the required BIM uses based on the risk factors are highlighted. As a result, from a list of 30 BIM uses, it is reduced to 17 BIM uses.

The BIM use purposes provide the general essence of each BIM uses, which would then be beneficial with managing such risks.

7.2.4.2 Project Lifecycle Filter

The next filter is the project lifecycle filter. Upon filtering the BIM uses based on BIM use purposes, the project lifecycle filter is applied. It is used to identify which BIM use can be implemented on or before the occurrence of the risk. For instance, constructability risk occurs during both *PC and C* stages. Therefore, the applicable BIM uses are those that can be used before, or during the risk's occurrence. Table 7.4 shows the applicable BIM uses which were filtered from 17 down to 13 which can be used during pre-construction and construction stages.

Another example is when the risk occurs during *construction* stage. Since the BIM is often used proactively, i.e., before anything else happens, the BIM uses applicable during both PC and C are considered. The foundation of the thought is that the BIM use should be done first. It implies that the project lifecycle attribute of risks and BIM uses are not equal, though related. It is apparent that the project team should not wait for the risk to happen before doing something about it.

7.2.4.3 Elements Filter

After considering the BIM use purposes and project lifecycle application, the next filter would be the elements filter. The elements at risk were identified in the risk catalogue. It is therefore apparent that the applicable BIM uses can be implemented to those elements at risk. The elements filter would supplement any possible disparity when applying this framework. For instance, after applying the BIM use purpose and project lifecycle filter, *Site utilization planning* BIM use can be used for constructability risk. However, site utilization planning mostly focus on the site works, which is the last element according to OmniClass Table 31. It is therefore important to give relevance to these elements to properly identify the BIM uses which would certainly benefit the mentioned risk.

Table 7.3 BIM use purpose filter

BIM Use Code	BIM Use	Primary Purpose	Secondary Purpose
BU1	Existing Conditions Modeling	Gather	Capture
		Communicate	Visualize
BU2	Quantity Take-Off/Cost Estimation	Gather	Quantify
		Analyze	Forecasat
BU3	Visualization	Communicate	Visualize
		Communicate	Draw
BU4	Database Information Management	Communicate	Document
BU5	Site Analysis	Generate	Arrange
BU6	Programming	Generate	Prescribe
BU7	Design Reviews	Analyze	Validate
		Analyze	Coordinate
BU8	Code Validation	Analyze	Validate
BU9	Sustainability (LEED) Evaluation	Analyze	Validate
BU10	Structural Analysis	Analyze	Forecast
BU11	Facility Energy Analysis	Analyze	Forecast
BU12	Engineering Analysis	Analyze	Forecast
BU13	Lighting Analysis	Analyze	Forecast
BU14	Design Authoring	Communicate	Draw
		Generate	Arrange
		Generate	Size
BU15	Options Analysis	Communicate	Visualize
		Generate	Arrange
BU16	3D Coordination	Analyze	Coordinate
BU17	Phase Planning/Scheduling	Communicate	Visualize
		Communicate	Document
BU18	Supply Chain Management	Communicate	Visualize
		Communicate	Draw
		Communicate	Transform
BU19	3D Control and Planning	Realize	Control
BU20	Digital Fabrication/Shop Drawing	Realize	Fabricate
		Communicate	Document
		Realize	Assemble
BU21	Construction System Design (Virtual Mock Up)	Communicate	Visualize
		Realize	Assemble
BU22	Site Utilization Planning	Generate	Arrange
		Communicate	Visualize
BU23	Project Progress Monitoring	Gather	Monitor
BU24	Quality Control Checks	Communicate	Visualize
		Gather	Monitor
BU25	Record Modeling/Production Data Delivery	Communicate	Document
BU26	Safety/Disaster Planning	Communicate	Visualize
BU27	Space Management and Tracking	Gather	Qualify
		Generate	Arrange
		Communicate	Visualize
BU28	Facility Management	Gather	Monitor
		Generate	Arrange
		Realize	Control
BU29	Building Systems Analysis	Gather	Monitor
BU30	Building Maintenance Scheduling	Gather	Qualify

Table 7.4 Project lifecycle filter

BIM Use Code	BIM Use	Primary Purpose	Secondary Purpose
BU1	Existing Conditions Modeling	Gather	Capture
		Communicate	Visualize
BU2	Quantity Take-Off/Cost Estimation	Gather	Quantify
		Analyze	Forecasat
BU3	Visualization	Communicate	Visualize
		Communicate	Draw
BU4	Database Information Management	Communicate	Document
BU5	Site Analysis	Generate	Arrange
BU6	Programming	Generate	Prescribe
BU7	Design Reviews	Analyze	Validate
		Analyze	Coordinate
BU8	Code Validation	Analyze	Validate
BU9	Sustainability (LEED) Evaluation	Analyze	Validate
BU10	Structural Analysis	Analyze	Forecast
BU11	Facility Energy Analysis	Analyze	Forecast
BU12	Engineering Analysis	Analyze	Forecast
BU13	Lighting Analysis	Analyze	Forecast
BU14	Design Authoring	Communicate	Draw
		Generate	Arrange
		Generate	Size
BU15	Options Analysis	Communicate	Visualize
		Generate	Arrange
BU16	3D Coordination	Analyze	Coordinate
BU17	Phase Planning/Scheduling	Communicate	Visualize
		Communicate	Document
BU18	Supply Chain Management	Communicate	Visualize
		Communicate	Draw
		Communicate	Transform
BU19	3D Control and Planning	Realize	Control
BU20	Digital Fabrication/Shop Drawing	Realize	Fabricate
		Communicate	Document
		Realize	Assemble
BU21	Construction System Design (Virtual Mock Up)	Communicate	Visualize
		Realize	Assemble
BU22	Site Utilization Planning	Generate	Arrange
		Communicate	Visualize
BU23	Project Progress Monitoring	Gather	Monitor
BU24	Quality Control Checks	Communicate	Visualize
		Gather	Monitor
BU25	Record Modeling/Production Data Delivery	Communicate	Document

Based on the same risk, only one BIM use is filtered. Up to this point, the total applicable BIM uses are 12 BIM uses.

7.2.4.4 Discipline filter

After implementing the first three filters, the applicable ideal BIM uses can be implemented to manage the identified risks. This filter would then specify who will implement the BIM use.

It is important to note that every project is unique and allocation of the risk depends on the contract. This research discusses common allocation of risks based on the data collection conducted. Guidelines on how to use the BIM use will be discussed on the next chapter. It will also show the responsible party on how it can be used for their risk management process. And so, it is still the organization's decision on who will use the BIM use.

7.2.5 Matrix Update

The final step of the framework is the updating of the main output of this thesis, which is the risk-BIM use relationship matrix. After applying all filters, the appropriate BIM uses will be marked and mapped in the matrix. Table 7.5 shows the appropriate BIM uses (12 BIM uses) which can manage the *constructability* risk. Table 7.6 shows the main results of this thesis, which provided all of the risks and BIM use relationships.

Table 7.6 shows the risk-BIM use relationship matrix. Arranged column wise are the 30 BIM uses analyzed and detailed in this thesis. Arranged row wise are the 20 verified DB risks. It can be observed that a total of 137 relationships were mapped. This matrix show the ideal BIM implementation for the risks that were verified.

This matrix, however, does not show detailed steps on how to use each BIM use for the risk management process. Therefore, guidelines were proposed for each relationship which show the risk management steps of *risk identification, risk response, and risk monitoring.* Risk assessment was excluded from the analysis because it was conducted and specified by Kang et al. (2013) that the risk assessment was done on an external numerical analysis, i.e., fuzzy-AHP, and is not *yet* possible in the BIM system. Therefore, at the time this thesis was written, the availability of BIM uses which can assess the *probability* and *impact* of risk is still nonexistent.

Table 7.5 Mapping of possible BIM uses for managing constructability risk

Risk Code	BIM USES	BU1	BU2	BU3	BU4	BU5	BU6	BU7	BU8	BU9	BU10	BU11	BU12	BU13	BU14	BU15	BU16	BU17	BU18	BU19	BU20	BU21	BU22	BU23	BU24
	Risk Event	***ALL***				***PC***											***PC + C***			***C***					
C12	Constructability	●		●	●			●								●	●	●	●		●	●		●	●

Table 7.6 Risk-BIM Use Relationship Matrix

RISK \ BIM USE	BU1	BU2	BU3	BU4	BU5	BU6	BU7	BU8	BU9	BU10	BU11	BU12	BU13	BU14	BU15	BU16	BU17	BU18	BU19	BU20	BU21	BU22	BU23	BU24	BU25	BU26	BU27	BU28	BU29	BU30
	ALL				*PC*											*PC + C*			*C*						*C + OM*	*OM*				
Delay in design	●		●			●											●	●												
Unable to get approvals	●		●	●											●		●	●												
Difficulty in choosing proposals	●		●												●		●	●												
Changes in quantity/scope of work	●	●	●												●		●	●			●			●						
Design changes	●		●		●	●								●	●		●	●			●			●						
Exceptionally inclement weather		●								●	●	●	●																	
Deficiencies in specifications and drawings			●			●								●				●												
Coordination with suppliers and subcontractors	●		●	●		●											●	●		●	●	●		●						
Bureaucratic problems				●																										
Constructability	●		●	●			●								●	●	●	●		●	●		●	●						
Lack of value management/engineering	●	●	●												●		●	●			●	●	●	●						
Unforeseen site conditions			●				●								●	●	●	●				●		●						
Site access/right of way			●				●	●									●	●				●								
Inadequate quality of work and need for correction						●	●	●	●														●	●						
Difficulties/delays in availability of materials, equipment and labor						●											●			●										
Safety/Accidents	●		●		●		●							●	●		●	●			●	●	●	●						
Inconsistent design and construction work	●		●	●											●		●	●		●			●	●						
Difficulty in inspection for progress payments		●																●												
Inconsistent warranty information and as-built drawing				●													●			●			●	●	●		●	●	●	●
Difficulty in property management and maintenance	●		●	●											●		●	●	●		●	●		●	●	●	●	●		

7.3 Guidelines on Implementing BIM Uses for Risk Management

The guidelines supplement the objective of the research which is to show how BIM uses can be used for risk management. Cross-tabular analysis was done in analyzing the results. Table 8.7 shows all the BIM uses applicable in managing the *constructability* risk. It can be observed that a total of 12 BIM uses can be implemented for constructability, all having a benefit in doing risk identification, response, and monitor. Guidelines on how to implement the resulting BIM uses for the other risks are found in Appendix F.

The conceptualizations on how to use the BIM use for the risk management process are analyzed from the BIM use details elaborated in Chapter 6. Since each BIM use have unique details on implementation, the suggestions developed presents an overview on how the BIM use can be utilized for risk management. It does not present detailed steps and does not intend to be considered entirely accurate. Additionally, the guidelines do not present how an organization should use the BIM use. The establishment of requirements, responsible parties, and project lifecycle applicability still depends on the organizations implementing the BIM use.

The guideline for implementing BIM uses for risk management are used by both parties, i.e., the owner and contractor, but mostly on the contractor. This is because the scope of this research is DB project delivery, which allocates more risks to the contractor. The results of the guideline promotes collaboration of both parties in managing the risk.

It is also important to note that the level of detail (LoD) and level of development (LOD), both considered important when dealing with BIM, is not discussed in this thesis. It is however noteworthy that as the project progresses, higher LOD should be observed, which is apparent in any BIM implementation. The higher LOD would then give more information in which details about the risk can be included.

7.4 Framework Application Methodology

Utilizing this framework can proceed in two ways. The first one is when the desired BIM uses and/or project risks are in the risk catalogue. The second one is when a new risk and/or BIM use is added to the catalogue. The former is used when the project planning team, after initial examination of risks and BIM uses from the catalogues, considers the list sufficient. Then the framework methodology starts with 7.2.3, which is the *Risk Investigation.* The latter is used when a new BIM use or new risk is added to the catalogue, i.e., project planning team wants to manage a new risk or include a new BIM use. Then the framework methodology would start from 7.2.1, *Detail Setting.*

The previous subchapters presented a framework of relating risks and BIM uses which led to the relationship matrix output. A methodology, based on risk assessment, is proposed and adopted in the case studies in the next chapter. The methodology, called the *"risk-BIM use selection methodology"* is aimed to show how to use and benefit from the framework developed.

7.4.1 Framework User

The framework is designed to be convenient for the users. The users in the framework are divided into two. The first division consists of risk and BIM experts. The second division consists of users of the framework such as the owner and DB contractor.

The risk and BIM experts are required for their input in the first two steps which are *detail setting* and *BIM use purpose analysis*. Since the framework can be used to add more risks and BIM uses in the future, the knowledge and expertise of risk and BIM experts are required. Therefore, the framework heavily relies on the analysis of the risk and BIM use experts in detailing both risks and BIM uses.

The owner and DB contractor is the second division of users. The owner and contractor then applies the framework as described in Section 7.3. The application of the developed matrix would lead help the project planning team in identifying the recommended BIM uses based on the perceived critical project risks.

7.5 Conclusions

This chapter presented the framework developed for this research. It highlights the main output which is the risk-BIM use relationship matrix. The formation of the matrix utilized common attributes between risks and BIM which served as core and supplementary relationships. For the core relationship, the risk factors and BIM use purposes were mapped. For the supplementary relationship, the project lifecycle, elements of the facility, and responsible parties served as filters in allocating appropriate BIM uses.

An example application was presented by showing an example risk identified from the verification process. As a result, a number of BIM uses were ideally found per risk verified, which can be implemented for the risk management process.

In discussing how to utilize the BIM use for the risk management process, cross-tabular analysis was done. Guidelines were developed based on the overview on how to implement the BIM use based on the BIM use details such as requirements, BPMN, and expected benefits, as explained in Chapter 6.

As this framework provides an overview of all BIM uses available up to the time this thesis was written, it observes a number of limitations. First is the depth of describing how to implement the BIM use. It relates to the omission of analyzing the required LOD for each BIM use, although it is essential when discussing BIM implementation. Moreover, the framework provided straightforward comparisons which did not utilize quantitative aspects due to the limitation of respondents in the scope of study.

The framework presents the ideal BIM uses which can be implemented for managing the risks verified. The next chapter validates the framework as well as the guidelines developed. It shows the optimal factors to consider when implementing BIM uses through case studies in different project lifecycles of implementation.

CHAPTER 8
FRAMEWORK VERIFICATION

8.1 Introduction

This chapter discusses the verification method of the framework developed in this research. It starts with summarizing the case study methodology adopted for the three cases. Then each cases are analyzed based on the personal interviews conducted. Included in the analyses are the traditional risk management practice of the firms, current BIM uses implemented, barriers of not implementing BIM, factors to be considered in implementing BIM uses, and the necessity to implement BIM uses as provided in the guidelines developed in this research.

Unlike BIM-mature countries, BIM usage in the Philippines is still in its early stages. Consequently, most of the early adopters are the architects and designers. The cases selected are those organizations that were highly recommended by both academia and BIM software vendors, and are well-known for pioneering BIM adoption.

8.2 Case Study Methodology

For all three cases, a common methodology was conducted to show uniform analysis and presentation of results. The following presents the common procedure for conducting the case studies:

- Inquire background information of the company,
- Assess impact of risks,
- Review the company's traditional risk management steps for managing the critical risks,
- Apply the developed framework and present the guidelines of the thesis,
- Analyze the benefits of the company's current BIM uses and the barriers,
- Draw conclusions from the case studies.

The analysis includes several aspects. For each case study, the barriers from implementing BIM uses for risk management are discussed. Moreover, the factors to be considered when implementing, and the necessity of the BIM uses are highlighted. The optimality of selecting the appropriate BIM uses, based on the data and interview responses, are considered and suggested for each case study.

8.3 Results

This section presents all results of the case studies. The confidentiality agreement led to the exclusion of particular names of individuals and organizations. Moreover, the information gathered were, to an extent, the most that the researcher could collect due to the discretion of the companies' processes.

Table 8.1 shows the descriptions of the companies and individuals considered for the case studies. The data collection was done in a total of three weeks in the month of March 2015. As mentioned earlier in Chapter 3, case studies are the most appropriate way of data collection due to scarcity of respondents knowledgeable about the topic.

8.3.1 Case 1: Pre-Construction Phase (PC)

This section presents the first case which is from Company A, a local developer which employs DB for residential and commercial projects. The highlighted lifecycle phase pre-construction phase.

Table 8.1 Case study information

Case Study	Company Name	Role	Respondents
Case Study 1 (Pre-Construction Phase)	Company A	Developer	Respondent A1 Respondent A2
Case Study 2 (Construction Phase)	Company B	DB Contractor	Respondent B1 Respondent B2
Case Study 3 (Post-Construction Phase)	Company C	Developer	Respondent C1 Respondent C2

8.3.1.1 Description

Company A is one of the biggest developers in the Philippines. Under their organization, they have their own in-house design and construction bodies. To avoid conflicts in the transition of design to the construction stages, Company A recently opened another division called the Design Review Division. This division is in-charge of checking all drawings prior to construction. According to Respondent A1, the head of the design review division, "the company chose to implement BIM because we know that it would benefit the main purpose of the division. It would expedite the process since we have many projects to be reviewed on-hand" (Interview, 24 March 2015).

The roles of respondents A1 and A2 are civil engineer and BIM modeler, respectively. The design review division is headed by Respondent A1, who has ample experience in the field and is knowledgeable with project risks to expect during construction.

8.3.1.2 Assessment of Critical Risks

Table 8.2 shows the critical risks in the pre-construction stages. As mentioned in Chapter 3, the risk assessment criteria by Wang et al. (2004) is used for the evaluation of the impact of the identified risk. The rating of the occurrence is not included since it was already established in Chapter 5.

8.3.1.3 Traditional Risk Management Process

The objective of the division is to reduce construction costs that are related to the design and construction stages. Part of the semi-structured interview is asking if they perform risk management. They are knowledgeable, however, do not perform it formally. They mentioned that pre-construction conflicts generate higher costs during the construction process. The proactive measure to avoid conflicts is a form of risk response strategy, which are analyzed that they do unconsciously.

Table 8.3 shows the traditional risk management process according to risk identification, risk response, and risk monitoring of the critical risks. Cross-tabular analysis is performed. The risk identification of some risks lack description because the respondents mentioned that those risks are not addressed by the planning team.

Based on Table 8.3, it can be observed that most of the activities in the risk management process are practically common and are standard protocols in the organization. This case exemplifies an implicit application of risk management.

The common risk response measure is to mitigate the risk. The project experience along with constant communication, as seen from the details of risk management steps for the constructability risks, help the project stakeholders be intact with the project objectives.

8.3.1.4 Applicable BIM Uses vs Adopted BIM Uses

After identifying the critical risks and the traditional risk management process adopted by Company A, the developed framework was utilized. A total of 11 BIM uses were applicable to manage their critical risks. Table 8.4 shows the adopted and applicable BIM uses. To verify the proposed framework and matrix, Table 8.5 shows the critical risks perceived by Company A and the available BIM uses to manage it.

Table 8.2 Assessment of critical risks in pre-construction phase (Case 1)

Risk Event	A1	A2	Remark
Design changes	4	4	Critical
Delay in design	3	4	Not critical
Deficiencies in specifications and drawings	5	5	Critical
Unable to get approvals	2	3	Not critical
Changes in quantity/scope of work	3	3	Not critical
Constructability	6	5	Critical
Lack of value management	3	3	Not critical
Suppliers/subcontractors failure due to poor performance	4	4	Critical

Table 8.3 Traditional risk management process of Case 1

Critical Risk	Risk Identification	Risk Response	Risk Monitor
Design changes	Every milestone in the design process, each project team gathers to identify future complications about the design	***Mitigation*** Freeze the design process until all issues are met and resolved	Weekly progress reports and follow-ups
Deficiencies in specifications and drawings	N/A	***Mitigation*** Work closely with suppliers	Having constant communication, attending conventions, and being updated with products and technologies
Constructability risks	Usually unexpected and are identified in kick-off meetings by experienced project managers	***Mitigation*** Work closely with engineers and provide proactive resolution to problems through project experience	Constant communication and progress reports
Suppliers/subcontractors failure due to poor performance	N/A	***Mitigation*** Scheduled meetings	Frequent meeting and communications, and educate and

		stipulated in the contract and imposing penalties if not followed	help understand each stakeholder about the project goals

Company A, as mentioned earlier, is one of the BIM pioneers of the Philippines. The design review division is formed and is implementing BIM since the year 2010. Although the utilization and the company's adoption is limited to that particular division only, they are the ones who use BIM in the early project lifecycle to avoid conflicts and to identify risks in construction.

Currently, design review division of Company A utilizes BIM tools such as design authoring software and model checking software. They have a total of four stations with each station managed by a BIM modeler. The basic task of the modeler is to convert all 2D drawings, coming from different consultants, to 3D and perform clash detection (*3D coordination BIM use*).

Table 8.4 Current and suggested BIM uses

Current BIM Uses	Suggested BIM Uses
1. Visualization	1. Visualization
2. Design authoring	2. Design authoring
3. 3D coordination	3. 3D Coordination
4. Quantity take-off	4. Existing conditions modeling
	5. Site analysis
	6. Phase Planning/4D Scheduling
	7. Options analysis
	8. Programming
	9. Supply chain management
	10. Database information management
	11. Design Review

Table 8.5 Framework verification through Company A's critical risks

RISK / BIM USE	BU1	BU2	BU3	BU4	BU5	BU6	BU7	BU8	BU9	BU10	BU11	BU12	BU13	BU14	BU15	BU16	BU17	BU18	BU19	BU20	BU21	BU22	BU23	BU24	BU25	BU26	BU27	BU28	BU29	BU30
	ALL				*PC*											*PC + C*			*C*						*C + OM*	*OM*				
Delay in design	•		•			•											•	•												
Unable to get approvals	•		•	•											•		•	•												
Difficulty in choosing proposals	•		•												•		•	•												
Changes in quantity/scope of work	•	•	•												•		•	•			•			•						
Design changes	•		•		•	•								•	•		•	•			•			•						
Exceptionally inclement weather		•								•	•	•	•																	
Deficiencies in specifications and drawings			•			•								•				•												
Coordination with suppliers and subcontractors	•		•	•		•											•	•		•	•	•		•						
Bureaucratic problems				•																										
Constructability	•		•	•			•								•	•	•	•		•	•		•	•						
Lack of value management/engineering	•	•	•												•		•	•			•	•	•	•						
Unforeseen site conditions			•				•								•	•	•	•				•		•						
Site access/right of way			•				•	•									•	•				•								
Inadequate quality of work and need for correction						•	•	•	•														•	•						
Difficulties/delays in availability of materials, equipment and labor						•											•			•										
Safety/Accidents	•		•		•		•							•	•		•	•			•	•	•	•						
Inconsistent design and construction work	•		•	•											•		•	•		•			•	•						
Difficulty in inspection for progress payments		•																•												
Inconsistent warranty information and as-built drawing				•													•			•			•	•	•		•	•	•	•
Difficulty in property management and maintenance	•		•	•											•		•	•	•		•	•		•	•	•	•	•		

8.3.1.5 Guidelines on How to Incorporate BIM Uses for Risk Management

The guidelines developed by the researcher in implementing BIM for risk management are suggested after the assessment of critical risks. The results are presented in two ways: (1) is by showing how they can utilize the current BIM uses for their risk management process, and (2) is by showing the other possible BIM uses they can implement.

The first presentation of result provides the design review division of ways on how to implement the BIM use. Some of the risk management process suggested in this thesis are done instinctively because of their implementation of BIM. For instance, 3D coordination is capable of identifying risks in engineering systems, which is done by the division when they convert 2D drawings to 3D files and combining them. However, they do not utilize the potential of the 3D coordination to the risk response and risk monitor steps, which they can use the code generating program to automatically generate reports on who will be in-charge to manage the conflicts. Table 8.6 shows the current BIM uses and the suggested risk management process for the critical risks identified for Company A, while Table 8.7 shows the critical risk of *constructability issues* and the applicable BIM uses to manage it. The applicable BIM uses to manage the other risks in this thesis are presented in Appendix F.

Table 8.6 Summary of applicable BIM uses for RM process

Visualization			
Risk Event	*Identify*	*Response*	*Monitor*
Design change	✓	✓	✓
Deficiencies in specs and drawing	✓	✓	✓
Lack of coordination	✓	✓	✓
Constructability issues	✓	✓	✓

3D Coordination			
Risk Event	*Identify*	*Response*	*Monitor*
Design change			
Deficiencies in specs and drawing			
Lack of coordination			
Constructability issues	✓	✓	✓

Design authoring			
Risk Event	*Identify*	*Response*	*Monitor*
Design change		✓	
Deficiencies in specs and drawing	✓	✓	✓
Lack of coordination			
Constructability issues	✓	✓	✓

Table 8.7 Guidelines on implementing BIM uses for *constructability risk*

Constructability Issues (Pre-construction and construction phase)			
	Risk Identification	Risk Response	Risk Monitor
Existing Conditions Modeling			Along with visualization, this BIM use can automatically gather actual locations and geometry which would help monitor clashes that were identified before construction
Visualization	The parametric modeling capability of BIM can show actual representations which can determine clashes during modeling process	After clash detection, project members can visualize the actual clashes happening in the digital models which would subsequently occur in construction if not responded	
Database Information Management		Clash detection processes can document and inform project participants of their engineering systems that has problems	
Design Reviews	The design review would help stakeholders identify erroneous designs which would have problems in the future.		
Options Analysis		After design review and 3D coordination, various options on how to respond on the clashes can be chosen to provide optimal solution to the problem	
3D Coordination	This BIM use can identify overlooked conflicting systems prior to construction of the facility	Clashes with engineering systems can be assigned to respective stakeholders in charge of the modeling of the involved element	Repetitive conduction of clash detection would help the project team continuously monitor the facility elements upon addition of new elements.

Table 8.4 shows some BIM uses that are not suggested based on the critical risks, for instance, quantity take-off. The researcher then presented the risks that can be managed through their currently implemented BIM uses. This result provided another point of view in the developed risk-BIM use relationship matrix, which is the presentation of possible risks it can manage. Generally, the respondents are able to realize what BIM can do to manage the other risks based on the BIM use that they currently implement. The risks presented in Table 8.8 are the risks that can be managed with their currently implemented BIM uses during the pre-construction and construction stages.

The respondents acknowledged the guidelines that were presented to mitigate their critical risk. The division head became aware of all the possible BIM uses and argued that some are not necessary as of the moment due to some barriers of implementation.

8.3.1.6 Barriers from Implementing Other BIM Uses

Upon presenting the available BIM uses and the guidelines on how it can benefit the risk management process, *Company A* still experiences impediments from not fully implementing it. Some of the common barriers include learning curve, eagerness to adopt, and upfront investment cost.

Table 8.8 Risk-BIM use matrix for currently implemented BIM uses

BIM USES	BU2	BU3	BU14	BU16
Risk Event	QTO/CE	VIS	DES AUTH	3D COOR
Delay in design		●		
Unable to get approvals		●		
Difficulty in choosing proposals		●		
Changes in quantity/scope of work	●	●		
Design changes		●	●	
Exceptionally inclement weather	●			
Deficiencies in specifications and drawings		●	●	
Coordination with suppliers and subcontractors		●		
Constructability		●		●
Lack of value management/engineering	●	●		
Unforeseen site conditions		●		●
Site access/right of way		●		

Moreover, some important factors affect why Company A does not implement other BIM uses. These factors include the complicatedness of the suggested BIM use versus the traditional way of risk management, investment costs, learning curve, and internet capability of the Philippines. Each factors will be discussed in the subsequent subsections of this chapter, which discusses the barriers of BIM implementation in the organization and for their risk management process.

8.3.2 Case 2: Construction (C) and Post-Construction Phases (OM)

This section presents the second case which is from Company B, an international organization which currently employs DB in one of its plant projects. The highlighted lifecycle phases are the construction and post-construction phases.

8.3.2.1 Description

Company B is an international engineering, procurement, and construction company that specializes in offshore projects. An international organization, having all-Filipino employees, is considered in this research due to their advancement of technological implementation as compared to local firms. The Philippines, particularly in Manila, is considered as one of the primary hubs for business outsourcing due to the westernized culture, highly educated labor pool, work ethic, and relatively lower fees due to the low cost of living (BPOAustralasia, 2011). Two respondents working in an on-going offshore plant project in Luzon Island, Philippines were considered.

The company is one of the leading BIM adopters worldwide. The selection of an international organization was considered necessary to identify the processes on how they utilize technology in their risk management process, as well as to compare barriers in terms of BIM implementation.

The two respondents, being the project manager and structural engineer of the said on-going offshore plant, are interviewed. The same case study methodology was adopted and the framework developed was used and analyzed with their utilization of BIM.

For this section, OM phase is also discussed because the EPC contractor also does the operations of the said offshore plant project. However, the limitation of the applicability of BIM in FM (Becerik-Gerber et al., 2012), even in BIM mature countries, is still under investigation. Therefore this research would not elaborate much on the OM phases.

8.3.2.2 Assessment of Critical Risks

Although all risks were evaluated by Company B, only risks during the construction and post-construction phases are presented. Table 8.9 shows the assessment of the critical risks as perceived critical by the respondents. It is important to note that for this case, the point of view of the DB contractor is analyzed.

Based on Table 8.9, the last risk which is in the OM phase is not considered critical. Similar to DB projects reviewed in the literature, the most critical risks experienced by company B in the construction stages are common also in offshore projects. It is noteworthy that they emphasized inclement weather because of the high exposure to risk in the location of the project.

8.3.2.3 Traditional Risk Management Process

Company B mentioned that they are performing risk management, however, the respondents are not part of it. They emphasize change management, which is a different aspect of project management and is defined as any additions or deletions to project goals or scope (Ibbs et al., 2001). The objective of their risk and change management is to save costs and to have efficiency in execution particularly in the transition of design to construction. As EPC/DB contractors, according to the respondents, they have the advantage of improving the efficiency because they manage both design and construction work. Table 8.10 shows the traditional risk management process, which incorporates change management, in the critical risks that they assessed.

Table 8.9 Assessment of critical risks in construction phase (Case 2)

Risk Event	B1	B2	Remark
Inadequate quality of work and need for correction	4	5	Critical
Difficulties/delays in labor, equipment, and material availability	4	4	Critical
Safety/accidents	5	4	Critical
Suppliers/subcontractors failure due to poor performance	4	4	Critical
Constructability issues	6	6	Critical
Inconsistent design and construction work	4	5	Critical
Exceptionally inclement weather	5	5	Critical
Inconsistent warranty information and as built drawing	2	1	Not critical

It can be observed in Table 8.10 that Company B has a well-defined risk and change management procedure. They also rely heavily on the contract, which is expected when dealing with risks. In the case of the Philippines and specific to the current project that the respondents are having, the importance of the risk relating to weather is significant. The geographic location of the Philippines and the environment of the project situates the exposure of the site to the risk. Lastly, it is also noteworthy that as an international company having BIM as a practice, the adoption in their Manila office benefits the constructability risk wherein they perform design reviews prior to issuance of construction drawings.

Company B in Case 2 presents an example of how to implement BIM for risk management. Utilizing the BIM use of 3D coordination as a tool for risk identification has helped this particular DB contractor in identifying the risks prior to construction. Since the current project that Company B also employs DB project delivery, this particular BIM use benefits both designers and contractors. Aside from 3D coordination, they also use Visualization and Database Information Management as tools for their risk management process.

Table 8.10 Traditional risk management process of Case 2

Critical Risk	Risk Identification	Risk Response	Risk Monitor
Inadequate quality of work and need for correction	Through internal audits and employment of 3rd party auditors who are also part of the project and quality plan	*Mitigation* The organization has an internal auditor who checks the performance of the construction team	Weekly progress updates and manual punch listing
Difficulties/delays in labor, equipment, and material availability	Early planning stages of the construction and procurement team	*Mitigation* Prioritization of critical activities and proper scheduling of material delivery	Follow-ups and expediting of processes
Safety/accidents	Proper hazard identification in the site	*Mitigation* Company policy in terms of safety and safety plan	Periodic safety audits of site safety officers
Suppliers/subcontractors failure due to poor performance	N/A	*Mitigation* Giving of turnaround time, deadlines, and penalties as stipulated in the contract	Scheduled meetings

Constructability issues	Early collaboration of subcontractors during the design phase Constructability review and model review	*Mitigation* Utilization of PDMS to perform model review	Scheduled meetings and progress updates
Inconsistent design and construction work	N/A	*Mitigation* Change management and quality inspection during construction	Punch listing and follow-ups
Exceptionally inclement weather	Weather reports	*Transfer* Through force majeure clauses that protects them from liabilities *Mitigation* Expediting of process to keep up with project schedule	Progress monitoring

8.3.2.4 Applicable BIM Uses vs Adopted BIM Uses

The in-depth interviews of the respondents provide the applicable BIM uses based on how they describe their work processes when mitigating risks. Similar to the previous case, Company B's currently implemented BIM uses are shown below.

It is important to note that it is Company B's policy to rely on the client when implementing BIM or any technology for their processes. For instance, their current project has the same owner as their previous one, and they used plant design management system (PDMS). The client wants to continue using the same tool, even though more advanced tools are available.

Upon applying the framework developed in this thesis, it resulted that Company B could implement almost all BIM uses for their critical risks as shown in Table 8.11. To be specific, only *3D control and planning* BIM use was excluded because it focuses mainly on controlling construction equipment through integration of GIS, which is not a concern so far by Company B. A total of 23 BIM uses can be implemented based on their assessed critical risk; however, since they also include OM phase, all BIM uses for OM phase are also suggested. Based on the interview and their description of their processes, a total of twelve BIM uses are currently being implemented by the company as listed below. Appendix F shows the guidelines on how to implement these BIM use.

1. Quantity take-off
2. Visualization
3. Database information management
4. Design reviews
5. Structural analysis
6. Facility energy analysis
7. Engineering analysis
8. Design authoring

9. Options analysis
10. 3D coordination
11. Phase planning
12. Supply chain management

A general note is that Company B utilizes much of the visualization, design authoring and database management system, 3D coordination, design review, and engineering analyses. During the design phase, they develop and review the design in several phases, depending on the percentage completion of the design. For instance, the milestones are divided to 30%, 60% and 90% model reviews. In those reviews, there are several drawing issuances which are directly produced from the 3D drawings and pre-coordinated and clash detected through 3D coordination. The construction team is able to visualize the formation of the engineering elements and see the development of the plan that Company B designed.

Most of the BIM uses are already being implemented by Company B. Some BIM uses, which the author believes are not highlighted by the respondents during interview are suggested upon analyzing the critical risks. Since the profession limits them with their responsibilities in the project, other BIM uses were not discussed by the respondents. The reliance of the BIM use in the discipline becomes an important factor in implementation, which is also addressed in Chapter 6. For this case, since the respondents are project manager and structural engineer professionals, they did not focus on other BIM uses such as facility energy and engineering analysis, but was mention early on during the interview.

8.3.2.5 Guidelines on How to Incorporate BIM Uses for Risk Management

Since the implementation and adoption of BIM heavily relies on the client, it is suggested by the author to maximize the use of the BIM uses for their risk management process. Table 8.12 shows how they can incorporate the BIM uses in their risk management process of the inadequate quality of work and need for correction risk.

Table 8.11 Framework verification through Company B's critical risks

RISK \ BIM USE	BU1	BU2	BU3	BU4	BU5	BU6	BU7	BU8	BU9	BU10	BU11	BU12	BU13	BU14	BU15	BU16	BU17	BU18	BU19	BU20	BU21	BU22	BU23	BU24	BU25	BU26	BU27	BU28	BU29	BU30
	ALL				PC											PC + C			C						C + OM	OM				
Delay in design	●		●			●											●	●												
Unable to get approvals	●		●	●											●		●	●												
Difficulty in choosing proposals	●		●												●		●	●												
Changes in quantity/scope of work	●	●	●												●		●	●			●			●						
Design changes	●		●		●	●								●	●		●	●			●			●						
Exceptionally inclement weather		●								●	●	●	●																	
Deficiencies in specifications and drawings			●			●								●				●												
Coordination with suppliers and subcontractors	●		●	●		●											●	●		●	●	●		●						
Bureaucratic problems				●																										
Constructability	●		●	●			●								●	●	●	●		●	●		●	●						
Lack of value management/engineering	●	●	●												●		●	●			●	●	●	●						
Unforeseen site conditions			●				●								●	●	●	●				●		●						
Site access/right of way			●				●	●									●	●				●								
Inadequate quality of work and need for correction						●	●	●	●														●	●						
Difficulties/delays in availability of materials, equipment and labor						●											●			●										
Safety/Accidents	●		●		●		●							●	●		●	●			●	●	●	●						
Inconsistent design and construction work	●		●	●											●		●	●		●			●	●						
Difficulty in inspection for progress payments		●																●												
Inconsistent warranty information and as-built drawing				●													●			●			●	●	●		●	●	●	●
Difficulty in property management and maintenance	●		●	●											●		●	●	●		●	●		●	●	●	●	●		

Table 8.12 Guidelines in implementing BIM uses for *inadequate quality risk*

Inadequate quality of work and need for correction (Construction Stage)	Risk Identification	Risk Response	Risk Monitor
Programming		Conducting special planning through design authoring and programming BIM use would enable A/Es to allocate and optimize spaces, thus reducing the rework when changes occur.	
Design Review	The project stakeholders would be able to investigate the BIM upon checking all design options and resolving the issues prior to the construction or pre-fabrication of an element	Through visualization and design review, project stakeholders can visualize and respond to current problems through virtual mock-ups once they are identified.	
Code Validation	Through rules-based or model checking tools, local codes can be set as limits when modeling the elements, which can avoid future code related rework		Applying this BIM use to existing buildings would help owners and facility managers with monitoring building compliance through as-built building models.
Sustainability (LEED) Evaluation	Through combination with other BIM uses such as quantity take-off and design authoring, sustainability issues can be identified if desired to have a specific target LEED rating		
Project Progress Monitoring	Similar to traditional process, BIM-based project progress monitoring would identify punch lists which can be swiftly responded.	Recent developments utilize advanced point clouds and aerial drones to monitor project progress and help in responding to delayed facility elements during construction.	Those elements that are identified to be behind schedule or punch listed can be automatically monitored, rather than implementing time consuming traditional methods.
Quality Control Checks	Identified through model-checking software; the quality, in terms of compliance to the code and owner specifications would help identify future issues during design.		

8.3.2.6 Barriers from Implementing Other BIM Uses

Upon acknowledging the other BIM uses that the company could utilize, reasons why they won't implement the suggested BIM uses were inquired. Since their incorporation of technology is client-based, they rely on the clients' needs if they want to implement a new tool especially a BIM tool. Commonly, costs and openness to technology in terms of the more advanced tools available, are evaluated before investment. Another factor to be considered is the upcoming projects which would need to use the same tool. If it would contribute to the efficiency and can be utilized more in the future, the senior management is open to trainings and licenses.

Additionally, the respondents were asked between the comparison in adopting new technology or BIM in the organization of international and local firms. International firms, having well established protocols and up-to-date tools, are more open as compared to local firms. Education, as mentioned earlier in the previous case, also plays a vital role. It is important to make all levels in the organization understand the return of investment it can benefit by alleviating such risks in projects. Lastly, client requirement plays a big role. Since most projects of Company B are overseas, the requirement to utilize BIM is high. However, in terms of local projects, the respondents mentioned that the demand is scarce.

8.3.3 Case 3: Post-Construction Phase (OM)

This section presents the third case which is from Company C, also a local developer which employs DB in their own projects. This particular case presents the initiative of implementing BIM for the post-construction phase.

8.3.3.1 Description and BIM Motivation

The third case presents the intention of implementing BIM in the OM phase by a local developer, *Company C.* Company C houses its own design and construction teams. The construction team, Company D, is one of the BIM pioneers in the construction phase. Company D is under the supervision of Company C, in which all their condominium and commercial projects are being designed and constructed by Company D.

One respondent was inquired about Company C's motivation to implement BIM. Generally, since the BIM implementation is still on its pilot stages, the processes and standards of the companies are not yet polished. Therefore, Company D constructs manually, i.e., does not implement BIM fully or 'pseudo BIM' (Holzer, 2015) . The relevant BIM uses are design authoring, 3D coordination, and record modeling.

8.3.3.2 Current BIM Uses

The current BIM uses are design authoring and 3D coordination. Since there are very few stakeholders who use or are even knowledgeable about BIM, Company D receives 2D drawings and converts them to 3D for their purposes.

Company C's requirement in terms of facility management and post-construction purposes is to require Company D, the DB contractor for most of its projects, to provide *as-built BIM files.* These would then be the starting point of enabling and transitioning BIM from construction to post-construction. The idea of using the information generated from pre-construction to the operations phase is the essence of BIM, which Company C is trying to achieve.

8.3.3.3 Suggested BIM Uses for Risk Management

For facility management purposes, the suggested BIM uses to manage mostly operational risks are the following:

1. Record modeling
2. Safety disaster planning
3. Space management and tracking
4. Facility management
5. Building systems analysis
6. Building maintenance scheduling

Implementing all of those OM BIM uses would be the ideal implementation, however, given the experimental nature of status of BIM implementation in the Philippines as well as lack of standards and guidelines, achieving this in the short term would be close to very difficult, but not impossible.

Currently, researches are being performed to finally relate BIM and FM. Current facility management firms in the Philippines still use 2D and are reluctant to use a system because they already have something stable. It is observed that the risks covered in OM phases are very limited, since the whole operations phase covers a lot of areas. It is therefore suggested by the author to implement BIM and fully utilize it in both design and construction and utilize the information generated from those phases to the post-construction stages.

8.4 Discussion

From the details of the framework, the matrix output, and the cases provided, the relationship of risks and BIM uses were generated.

8.4.1 Traditional Risk Management Process

Most of the cases have considered that they do not formally conduct risk management, which make them unknowingly perform risk management processes. The risk identification is usually done by brainstorming through the planning stages, as observed from cases 1 and 2. Moreover, the common risk response procedure is to mitigate, which entails them to reduce the probability of the risks to happen by performing precautionary and proactive measures. Finally, risk monitoring procedure is quite similar in both cases for which they portrayed the usual progress reports and scheduled meetings.

The comparison of application of risk management between local and international firms differ in the utilization of technology. For case 2, which uses BIM for quite a while, utilizes risk identification and response through early clash detection and allocation of conflicts to the stakeholders. In the case of the Philippine firms as cases 1 and 3 portrayed, the utilization of BIM is still at its infancy and makes the whole process more difficult. These two example cases experience the learning curve which they require additional effort to convert everything to 3D prior to utilizing the 3D models for other BIM uses. This explains why the implementation of risk management to the critical risks in the local firms are still paper-based and the BIM implementation is mainly on the infancy phase.

8.4.2 Benefits from Implementing Current BIM Uses

The cases presented in this thesis are some of the companies in the Philippines that are considered to be the pioneers of BIM implementation. It shows that the maturity of the Philippines in terms of BIM implementation is infant, and the early adopters are mostly designers and developers.

It is quite commendable that some firms implement BIM due to the perceived increase in efficiency. Since the government does not require BIM yet, implementation now becomes a bottom-up, wait-and-see approach. Therefore the need to examine organizational processes, especially in DB contractors, would be beneficial and would affect the risks in projects.

Based on the cases provided, some of the BIM uses are not fully utilized for the risk management process. For instance, Case 1 could utilize the 3D coordination more by allocating responsibilities through automatic identification of errors and easy documentation, which would benefit risk monitoring. Case 2 could utilize 4D scheduling in mitigating delays due to exemplary weather. Finally, Case 3 could utilize the facility management BIM uses, although still under development in some BIM mature countries, to FM applications.

8.4.3 Barriers from Implementing Suggested BIM Uses

The barriers of the BIM uses observed in the Philippines' application in risk management is quite similar to the work of Eadie et al. (2013). It is relevant that the common barriers experienced by the cases presented in this thesis include the upfront investment costs, client demand, and education and learning curve.

From the barriers presented in the cases, the following factors should be considered to optimally select the BIM uses. Basically, BIM presents a new way of doing things, and presents a reason why many stakeholders are reluctant to implement. However, the complicatedness of some risks, such as the constructability risk, would be beneficial especially when BIM is adopted beforehand. Although the risk-BIM use framework presents ideal BIM uses for BIM implementation, an organization with limited resources cannot adopt them all (Won et al., 2013).

8.4.3.1 Education and Capability

Most of the respondents disagree with the barrier of lack of skilled personnel due to the abundance of BIM training centers in the Philippines. However, those training centers develop BIM modelers and does not know the main concept behind the improved processes that BIM has to offer. It is therefore the duty of the academia, especially in the building professionals (i.e., civil engineering, architecture, engineering courses, and facility management) to incorporate BIM and to transfer knowledge. Moreover, the capability of the experts and the future BIM team in utilizing the identified BIM uses should be assessed prior to implementation. Considering this would enable organizations have a more efficient and effective way of transitioning and transforming processes.

The lack of understanding corresponds to Holzier (2015). Most of the errors of early BIM implementers include over modeling and modeling without understanding. The lack of knowledge in constructability and serviceability would affect a perfectly modeled facility element. The intentions of using BIM would be useless if the modeler has no experience on how it will be built and how the facility will be maintained in the OM phase.

The knowledge regarding BIM does not only concentrate on the implementers, rather senior and executive level management should also be educated. Nontechnical organizational readiness was considered relatively more urgent than technological readiness, especially during the early adoption period. Since the Philippines is in the early stages of adoption, prioritizing nontechnical readiness should be done followed by detailed technical capability. This also involves upskilling of employees where trainings and investment on human resources would benefit implementation.

The importance of risk management especially in the different levels of project, company, and industry is also necessary. Since risks are inevitable, the approach of utilizing new and more efficient ways would become beneficial in managing these risks.

8.4.3.2 Project Size

Another factor to be considered in the optimality of selecting BIM uses is the project size. Since implementing more BIM uses equates to implementing more BIM tools, it is necessary to assess the need of using BIM. Some instances do not require the use of BIM especially with small projects. Similar to the barriers of case 2, the investment of a new BIM tool depends on how many projects it can benefit in the future, which is also important to assess.

8.4.3.3 Upfront Cost

As mentioned earlier, more BIM uses equates to more costs. Through utilizing the framework developed in this thesis, it is necessary to identify the BIM uses which would benefit most of the critical risks assessed by the implementing organization. Through that, it would be beneficial and worth investing since it can affect many risks in the progression of the projects.

However, it is important to note that construction is project-based in nature. Some risks can only be specific with some projects. The benefit of implementing BIM for risk management can be good for some projects, but would be financially infeasible with others. Therefore, adopting most of these solutions might be technically possible and ideally beneficial, but appears to be unwise from an organization's business perspective.

8.4.3.4 Pilot Projects

It can be observed that implementing BIM starts with using the BIM uses of visualization and coordination, corresponding to the work of Taylor and Bernstein (2009). Prior to transitioning to more advanced BIM uses, which are the analyses and supply chain integration of BIM uses, companies should conduct pilot projects and identify their respective needs. It also reflects to the notion of 'learning-by-doing' which is related to the next section of experiencing a learning curve.

A drawback of the framework is its idealistic nature. It identifies all the possible BIM uses but does not necessarily provide the immediate needs. This therefore provides more stipulation in this research area of relating risks and BIM uses.

8.4.3.5 Learning Curve and Eagerness to Adopt

Relative to having pilot projects is the learning curve that an organization must experience before paving its way to smoother processes. The learning curve currently being experienced by cases 1 and 3 have shown more effort in trying to implement BIM as compared to manually doing their processes. It comes with a firm belief in the perceived benefits, which both companies A and C recognized as they decided to implement BIM.

An important factor also is the eagerness to adopt. Combined with education and pilot projects, the senior management must also be inclined to the construction industry's paradigm shift.

The presence of numerous professionals, as seen in case 2, limits the implementation of BIM uses. Since BIM is designated to be more efficient, some employers would rather employ more manpower than investing in technology. It resonates to the abundance of labor forces in the Philippines which backups the abundance of BIM modelers. It all boils down to the responsibility of the educational sector to incorporate to the curriculum (Ku and Taiebat, 2011) the basic knowledge regarding BIM and how it can benefit the project, such as in risk management.

8.4.3.6 Internet

More recent developments of BIM utilizes the cloud and the internet. However, it is considered a barrier in the Philippines since bandwidth has been the problem of the nation. Currently, the Philippines ranks the slowest among the ASEAN countries (GMA,

2014) which portrays the difficulty of achieving the full potential of BIM which is collaboration and real-time update of models.

8.4.3.7 Client Demand

As mentioned earlier, client demand plays an important role in BIM implementation. As clients have more control on what tools to use in the project, unless the clients do not need it, the contractors would not use it. It is the responsibility of the contractors and construction managers, as they are more knowledgeable with the current tools, to educate the clients to lead them to implement BIM.

Clients with well-defined objectives play a big role in BIM implementation. Risk management starts with defining objectives in which the same objectives can affect BIM implementation. The risks identified can be used with the framework developed in this research and thus can be related to BIM implementation. However, clients also need the knowledge on what they want to benefit from BIM implementation. Project teams can develop data-rich models but can be useless will be limited if clients are aware of the information requirements. BIM efforts can be useless if the clients do not know what they want to get from it (Holzer, 2015).

The utilization of the developed framework would benefit the clients. The flexibility and the simplicity of the framework in relating risks and BIM uses would be useful. As risks are inevitable, and would likely hinder project objectives, adopting ways to mitigate these risks would be a straightforward marketing method in encouraging clients to adopt BIM for their projects.

8.4.3.8 Government Support and Governing Body

The final factor in the implementation of BIM for risk management, and for BIM implementation in general is the government support. Many BIM mature countries impose a top-down approach in implementation. The government also holds the better key in transforming the construction industry. Once they require BIM, the industry and academe would have no choice but to cooperate.

A governing body, as suggested by the respondents, would also be beneficial. Since BIM implementation is usually encouraged by software vendors, they usually have commercial purposes as to why they encourage BIM implementation. A governing body composed of academia and industry, aimed for the improvement of the construction industry in the country, is necessary.

8.4.4 Merit of Implementing BIM Uses

Utilizing BIM for risk management purposes benefits the risk management's objectives. For most of the cases, cost reduction and efficiency are the objectives. Perceiving BIM to be an agent for cost savings, especially when managing risks in the project lifecycle, led to the implementation of BIM. It was realized, upon analyzing the case studies, that there is more to be benefitted from the cases' implementation of BIM.

The current BIM uses implemented were not fully utilized to its potential. In terms of risk management, they could still utilize the BIM uses not just for risk response. For instance, case 1 provided more risks that can be managed from the current BIM uses that the company has implemented. Therefore the company could still benefit from their current BIM uses, which they could utilize and incorporate in to their company's standards. This reflects to what Holzer (2015) refers to as 'pseudo BIM'. Pseudo BIM is described as pretending to implement BIM whereas in reality, a traditional 2D CAD workflow is used to deliver projects.

Another instance where BIM uses are not fully implemented is the lack of information sharing, as depicted by the first case study. The multi-disciplinary coordination and data integration opportunities that BIM has to offer are not practiced due to the natural fragmentation of the construction industry. Beyond this capability, the use of BIM is simply for visual referencing and is essentially not optimized.

However, some BIM uses are not required. Based on the barriers and factors to be considered, as discussed previously, the BIM uses should be utilized progressively according to the paradigm shifts provided by Taylor and Bernstein (2009). At the current status of BIM in the Philippines, as perceived by the author, the optimal BIM uses should be based on visualization and coordination.

8.4.5 Necessity of Implementing BIM Uses

The complicatedness of some risks require the use of BIM uses in risk management process. For instance, the constructability risk, if done manually, would be tedious to the inexperienced eye (i.e., new engineers). Moreover, it would become an effective communication tool and would promote collaboration among the project stakeholders.

Detecting errors has been a job for project members through cognitive processes (Lee et al., 2015a). As BIM can help detect design errors automatically, it benefits the aforementioned constructability risk. As a result, BIM can enhance the thinking process in detecting errors. Thus, it would increase the efficiency of identifying design-related risks and help reduce rework.

Another example is in the modification of changes in construction. Design changes or changes in scope risks would also benefit automated design authoring as well as progress monitoring capabilities of BIM. Phase planning would benefit the said changes and would help ease the process.

For facility management risks, although it was not covered that much in this thesis, is also necessary. The information generated from the early stages would benefit the end-users (e.g., facility managers, clients, and building occupants) when the structure is in operations phase. Companies in the Philippines can start producing as-build 3D models, as illustrated by Case 3, to start transitioning BIM to FM.

With all the opportunities such as the improvement of IT infrastructure and the ASEAN integration, the implementation of BIM would also provide new markets. Risks would be inevitable in any country and project and the benefit of adopting this framework as well as implementation of BIM in general would pave the way in achieving project objectives efficiently.

Generally, direct implementation of BIM would result to sparse and disoriented processes. All the ingredients, from nontechnical capabilities, tools, and policy are required before moving and transitioning to BIM. The importance of modernization especially in the digital world nowadays would benefit the industry in moving forward and compete in the market with vast opportunities.

8.5 Conclusion

This chapter presented three case studies of early BIM adopters in the Philippines. Each case study portrayed example implementation of BIM for risk management in the pre-construction, construction, and post-construction stages.

Each case study followed a similar methodology which is developed by the author for using the framework presented in this thesis. The methodology enables the analysis of current (i.e., traditional, non-BIM) risk management process as well as highlighting of critical risks perceived by the responses. It also utilized the developed guidelines on using BIM for risk management from the analysis of the attributes of BIM uses.

The barriers of adopting the suggested BIM uses for risk management led to the identification of factors to be considered when deciding to implement BIM for the said purpose. The factors were *education and capability, project size, upfront cost, pilot projects, learning curve and eagerness to learn, internet connection, client demand, and government support and governing body.* These factors should be taken in to consideration when deciding to utilize BIM for risk management and for BIM implementation in general with regard to the Philippine setting.

Based on the characteristics of some risks in the case studies, it was found out that some BIM uses are necessary for implementation for a more efficient risk management. The benefit of BIM would ease the stakeholders in terms of risk identification, response, and monitor. This is related to the complexity of risk and the opportunities to which the Philippine construction industry is currently experiencing.

CHAPTER 9
CONCLUSION

9.1 Conclusions

The usual barrier from implementing BIM is the lack of qualified experts and the upfront investment costs especially with BIM tools. It has been a problem in identifying which area to adopt BIM and which applications should be used. Moreover, the exploration with regard to the relationship between risk and BIM is still lacking. This research explored risks which are inevitable in the project level. The main objective of this research is to identify the appropriate BIM uses for construction risk management and utilize a risk-based approach in BIM implementation.

In lieu of this, DB projects in the Philippines are the primary scope of this research. DB is selected since it has been proven to be an effective procurement method in BIM. Furthermore, this type of procurement promotes technological adoption, which is the essence of BIM. The allocation of both design and construction responsibility to one entity provides the essential use of BIM to be effective due to the collaborative environment of DB procurement. The increased communication and collaboration provided by the nature of DB procurement has led to the opportunities in BIM implementation, as presented in the case studies.

To satisfy the primary objective of this research, risks and BIM uses are discussed in detail. Common attributes are identified. Core and supplementary relationships are suggested based on the attributes of both risks and BIM uses. The core relationship is from the risk factors that were verified by DB and BIM experts in the Philippines with the BIM use purposes by Kreider and Messner (2013). Supplementary relationships from project lifecycle, facility elements, and the responsible party are highlighted. These four relationships constitute the framework developed in this research, which is the core of this research.

A five step risk-BIM use framework is proposed. This framework is aimed to relate the risks and BIM uses through the mentioned relationships. The core relationship serves as the main link between the risk and BIM uses, while the supplementary relationships serve as filters in selecting the appropriate BIM uses for managing the risk. The output of the risk-BIM use framework is the risk-BIM use matrix, which summarizes the BIM uses capable of managing DB risks based on the similar attributes identified.

For each risk and BIM use relationship generated, guidelines on how to utilize the BIM uses for risk management are also presented. These guidelines are developed based on the requirements, processes, definitions, and expected benefits of each BIM uses. The guidelines highlighted how to implement the BIM uses for risk management steps of risk identification, risk response, and risk monitoring.

The framework is verified through three different case studies in the Philippines which followed a proposed methodology of utilizing the framework developed. The methodology adopted for the case studies provided the validation of the proposed framework. Each case study explored a project lifecycle corresponding to the pre-construction, construction, and post-construction stages. The case studies also provided examples of early BIM implementers in the Philippines with projects such as high-rise buildings and plant projects. The BIM uses to be ideally used for each case study are presented and discussed.

Finally, factors were identified to optimally select the BIM uses to be implemented for construction risk management of DB projects. The factors include education and capability, project size, upfront cost, pilot projects, learning curve and eagerness to adopt, internet, client demand, and government support and governing body.

9.2 Benefits of the Study

This study has presented results which can help construction professionals in BIM implementation. The first output, the risk-BIM use framework, contributes to the body of knowledge in terms of relating risk and BIM, and in terms of new risks and BIM uses developed in the future. The second output, the risk-BIM use relationship matrix, provides information regarding which BIM uses can be implemented to manage critical risks in construction projects. Moreover, an organization who started implementing BIM can identify which risks can be managed based on its currently implemented BIM uses. The third output presents guidelines on how to incorporate BIM uses in the risk management process. Construction professionals could utilize the guidelines and see how these BIM uses identify, respond, and monitor project risks. Finally, factors are suggested in terms of BIM implementation for risk management, and in general, in the Philippine setting. The factors can be used in assessing the BIM uses to be implemented with similar construction environment as that of the Philippines.

These outputs could lead to further developments of this study in which the author explored the relationship between risks and BIM. It also becomes a scene-setting research work on BIM-related study that is concerned with the Philippine construction industry. Moreover, the methodology adopted in this research, particularly in the development of the framework, can be used for qualitative exploratory researches in the future.

The benefits of BIM can be experienced once stakeholders are committed with the transition (Holzer, 2015). The case studies in this research showed opportunities on how to use BIM for risk management. These example cases benefit to those organizations planning to implement BIM in the future and also informs about the possible barriers and factors to be experienced and considered.

9.3 Limitations

The exploratory nature of this thesis, combined with the limited number of respondents, made this work qualitative in nature. Moreover, the country-specific scope of this work limits the application of the framework only to Philippine projects. Lastly, the numerous relationships identified between risks and BIM uses gave an overview of how to implement the BIM use for risk management. The author believes that this would become a scene-setting work to the further developments of the relationship of risks and BIM, and BIM related research in the Philippine construction industry.

9.4 Recommendations for Future Research

The first recommendation is the verification of this study in BIM-mature environment with many respondents. Since BIM implementation in the Philippines is still in its early stages, the verification of more advanced BIM uses cannot be done in this research. Based on the analysis of the case studies in comparison with the paradigm by Taylor and Bernstein (2009), the BIM implementation is usually in the visualization and coordination paradigm. Thus, verifying the analysis and supply chain integration paradigm, including facility management applications, is required.

The results of this thesis has provided a conceptual level on implementing BIM for risk management. It is therefore suggested for future research regarding BIM and risk management to go to the application level. A good start would be to elaborate one relationship established in the risk-BIM use matrix and apply it through case studies. The author would also suggest to provide detailed implementation in managing the verified risks and by specifying LOD and information exchange in the BIM use.

It is also suggested by the researcher to explore the applicability of the framework to other project delivery method such as CM at risk, DBB, and IPD (integrated project delivery). The modification of the framework would start with establishing the roles and highlighting the appropriate BIM uses based on the concerned parties. The risks might not vary so much with the current framework; however, the allocation of the BIM use would be more affected.

To clearly establish the merit of using BIM for risk management, comparative analysis of BIM and non-BIM risk response measures is suggested. Quantifying the benefit in terms of the risk management objectives such as time, cost, and quality, and comparing it with BIM and non-BIM risk response measures would provide a clearer perspective in BIM implementation.

Finally, it is suggested that the current status of BIM implementation in the Philippines to be explored. The identification of the common BIM uses implemented coupled with identifying the barriers of BIM implementation in different construction stakeholders would provide a big picture on the current status in the Philippines. Establishing the current maturity of BIM implementation would also provide a benchmark in moving towards the BIM paradigm.

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APPENDICES

APPENDIX A

OMNICLASS STANDARDS

OmniClass Table 21 – Elements

OmniClass Number	Level 1 Title	Level 2 Title
21-01 00 00	Substructure	
21-01 10		Foundations
21-01 20		Subgrade Enclosures
21-01 40		Slabs-On-Grade
21-01 60		Water and Gas Mitigation
21-01 90		Substructure Related Activities
21-02 00 00	Shell	
21-02 10		Superstructure
21-02 20		Exterior Vertical Enclosures
21-02 30		Exterior Horizontal Enclosures
21-03 00 00	Interiors	
21-03 10		Interior Construction
21-03 20		Interior Finishes
21-04 00 00	Services	
21-04 10		Conveying
21-04 20		Plumbing
21-04 30		Heating, Ventilation, and Air Conditioning (HVAC)
21-04 40		Fire Protection
21-04 50		Electrical
21-04 60		Communications
21-04 70		Electronic Safety and Security
21-04 80		Integrated Automation

21-05 00 00	Equipment and Furnishings	
21-05 10		Equipment
21-05 20		Furnishings
21-06 00 00	Special Construction and Demolition	
21-06 10		Special Construction
21-06 20		Facility Remediation
21-06 30		Demolition
21-07 00 00	Sitework	
21-07 10		Site Preparation
21-07 20		Site Improvements
21-07 30		Liquid and Gas Site Utilities
21-07 40		Electrical Site Improvements
21-07 50		Site Communications
21-07 90		Miscellaneous Site Construction

OmniClass Table 31 – Phases

Number	Level 1 Title	Definition
31-10 00 00	Inception Phase	Phase for establishing the project vision and means to satisfy the client's business or public service requirement, including site selection, planning considerations, establishment of timeline, method of delivery, budget and which identifies necessary resources (design, legal, financing, insurance, etc.).
31-20 00 00	Conceptualization Phase	Phase to identify the major design ideas in the context of programmatic objectives, facility performance, and activity parameters, to define spaces, and to initiate basic project element considerations.
31-30 00 00	Criteria Definition Phase	Phase to create and refine schematic diagrams of the basic project elements - substructure, shell, interiors, equipment, services, equipment and furnishings, special construction and demolition, and building sitework - that fully establish project spatial and element criteria as the Basis of Design.

31-40 00 00	Design Phase	Phase in which project team establishes means of satisfying project Basis of Design requirements with technical solutions, evaluates alternatives through value analysis or similar processes, and completes initial documentation - Drawings and specified Work Results - for the designed project.
31-50 00 00	Coordination Phase	Phase that bridges the design effort with implementation by integrating constructability and feasibility evaluations of the design in order to further develop spaces, elements, products, and materials necessary for the procurement and execution of the Work irrespective of the method of delivery.
31-60 00 00	Implementation Phase	Phase to implement the coordinated design through construction planning, prefabrication, and field execution characterized by constructor 'means and methods,' and Basis of Construction strategies, controlled by quality assurance and control protocols.
31-70 00 00	Handover Phase	Phase to evaluate the completed Work through testing, inspection, and commissioning activities, including for any Owner-furnished equipment, to ensure that design/performance criteria are met while conforming to applicable codes and standards, and transfer project knowledge from the design/construction team to the Owner/facility management team via demonstrations, training, and documentation.
31-80 00 00	Operations Phase	Phase in which owner or a designated agent occupies, uses, and manages and maintains a facility, which may also include partial or whole facility renovation, repair, reconditioning or remodeling activities as part of the project use lifecycle.
31-90 00 00	Closure Phase	Phase which includes facility closure, preparation for unknown future use, demolition in whole or part, foreclosure, sale, or similar dispensation initiated by the decision that the facility no longer meets the needs of the Owner and cannot be feasibly reconfigured for continued use by that Owner.

APPENDIX B
COVER LETTER AND QUESTIONNAIRES

EXAMPLE COVER LETTER

To whom it may concern,

I am a Filipino graduate student at Chulalongkorn University, Bangkok, Thailand, doing my Master's thesis in Civil Engineering. Project risk management and building information modeling (BIM) has been of interest to me and I would like to contribute to the country by conducting research about it with Philippine organizations as my research scope. Risk management and BIM has been proven to be very useful and many participating organizations in Thailand gained benefits from it. Risk management has been recognized as a useful project management tool while BIM is a new innovation which intends to change the design and construction in general. In addition, Chulalongkorn University is very active in terms of research about risk management and BIM.

My research topic is about designating optimal BIM implementation for risk management in DB projects. Basically I would examine owners' and contractors' risks that can be mitigated by implementing BIM. The designers and consultants, as they work for the owners' side, would be a great source for gathering this kind of information and your firm's expertise is of great help. Also, your firm is known as one of the pioneers of BIM technology and your input in my research would be essential.

I will contact your office to set up a mutually convenient time for this informational meeting. I know that time is very important therefore this interview will be short and concise and would not exceed 30 minutes. Please see the next page for some of the example questions to be asked.

Sincerely,

Mervyn Jan S. Malvar

Example Questions:

1. Do you know DB procurement?

2. What are the issues/problems that owners experience in DB projects or any project in general?

3. What are their possible sources?

4. Do you know building information modeling (BIM)?

5. Why do you use BIM? or Why aren't you using BIM?

6. What are the benefits you've experienced when using BIM?

7. What do you use BIM for?

8. In your opinion, what can BIM do/solve which can address owners' and contractors' issues?

EXAMPLE QUESTIONNAIRES

FIRST PHASE DATA COLLECTION

Introduction and Purpose

My name is Mervyn Jan Malvar. I am a Master's student at Chulalongkorn University, Bangkok, Thailand, working with my faculty advisor, Assoc. Prof. Dr. Veerasak Likhitruangsilp, in the Department of Civil Engineering. I would like to invite you to take part in my research about the "DESIGNATING BIM USES FOR CONSTRUCTION RISK MANAGEMENT IN DB PROJECTS."

Your input will be of great help for the research. Please take your time in answering the questions. Thank you for your time and contribution.

The session includes three parts. The first part will be about your personal information. The second part is about verification of risks that owners/contractors experience in DB projects. Finally the last part is about the assessment of each risks probability and impact.

SECTION 1: PERSONAL INFORMATION

1. How long have you worked in the construction industry?

- ☐ < 3 years
- ☐ 3 – 5 years
- ☐ 5 – 10 years
- ☐ > 10 years

2. What is your role in the project?

- ☐ Owner
- ☐ Consultant (A/E)
- ☐ Contractor
- ☐ Construction manager
- ☐ Supplier
- ☐ Fabricator
- ☐ Others (Please specify):_____________

3. Your position in your company is:

- ☐ Project engineer
- ☐ Supervisor
- ☐ Manager
- ☐ Executive
- ☐ Others (Please specify):____________

4. Do you know DB procurement/delivery system?

- ☐ YES
- ☐ NO

5. How many DB projects have you participated in?

- ☐ Nothing
- ☐ 1 Project
- ☐ 2 Projects

☐ >3 Projects

6. What types of DB projects were you involved in? You can check more than one.

☐ Commercial and office
☐ Residential
☐ Industrial
☐ Ports
☐ Roads and highways
☐ Irrigation and dams

7. How many employees do you have in your company?

☐ 1-4
☐ 5-9
☐ 10-19
☐ 20-49
☐ 50-99
☐ 100-199
☐ 200-499
☐ 500-999
☐ 1000-1999
☐ 2000 and over

8. Your company's asset size is at a range of:

☐ MICRO: <Php 3million
☐ SMALL: Php 3,000,001 – Php 15,000,000
☐ MEDIUM: Php 15,000,001 – Php 100,000,000
☐ LARGE: > Php 100,000,000

9. Do you have a current DB project in-hand?

10. Did you use BIM for that project?

11. Which project phase did you use BIM for?

SECTION 2: RISK VERIFICATION

Please check if this risk event is applicable in the Philippine setting.

No.	Risk Event	Verified	Not Verified	Risk factors
1	Change in quantity/cope of work			
2	Inconsistent design and construction work			
3	Labor, equipment and material availability			
4	Inadequate quality of work and need for correction			
5	Safety/Accidents			
6	Suppliers/Subcontractors failure due to poor performance			
7	Design change			
8	Delay in design			
9	Inflation			
10	Difficulty in inspection for progress payments			
11	Financial failure of any party			
12	Exceptionally inclement weather			
13	Environmental hazards of the project			
14	Unforeseen site conditions			
15	Bureaucratic problems			
16	Site access/Right-of-way issues			
17	War threats			
18	Change order negotiations			

19	Delays in resolving contractual issues			
20	Delays in resolving litigation/arbitration disputes			
21	Labor disputes			
22	Third party delays/Public disorder			
23	Rebel tax			
24	Constructability Problems			
25	Lack of Value Management/Engineering			
26	Difficulty in choosing proposals			
27	Unable to get approvals			
28	Deficiencies in specifications and drawings			
29	Inconsistent warranty information and as-built drawing			
30	Difficulty in property management and maintenance			

SECTION 3: RISK ASSESSMENT

Please provide the risk factors (i.e. causes of the risk events) and tick when the risk likely will occur, its severity, and impact to project objectives.

Risk Code	Risk Event	PROBABILITY			EFFECT ON			
		PC	C	OM	T	C	Q	S
1	Change in quantity/cope of work							
2	Inconsistent design and construction work							
3	Labor, equipment and material availability							
4	Inadequate quality of work and need for correction							

5	Safety/Accidents							
6	Suppliers/Subcontractors failure due to poor performance							
7	Design change							
8	Delay in design							
9	Inflation							
10	Difficulty in inspection for progress payments							
11	Financial failure of any party							
12	Exceptionally inclement weather							
13	Environmental hazards of the project							
14	Unforeseen site conditions							
15	Bureaucratic problems							
16	Site access/Right-of-way issues							
17	War threats							
18	Change order negotiations							
19	Delays in resolving contractual issues							
20	Delays in resolving litigation/arbitration disputes							
21	Labor disputes							
22	Third party delays/Public disorder							
23	Rebel tax							
24	Constructability Problems							
25	Lack of Value Management/Engineering							
26	Difficulty in choosing proposals							
27	Unable to get approvals							
28	Deficiencies in specifications and drawings							
29	Inconsistent warranty information and as-built drawing							
30	Difficulty in property management and maintenance							

<u>SECOND PHASE DATA COLLECTION</u>

SECTION 1: Personal Information

Company:

Name of Interviewee:

Date of Interview:

How long have you worked in the construction industry?	
What is your role in the project?	
Do you know DB?	
Have you engaged in any DB project? How many? What types of projects?	
What are the reasons why DB is selected?	
How many years of BIM experience do you have?	
Which project phase you usually use BIM for?	

SECTION 2: Risk Assessment

Based on the following scale, evaluate the following risk events' criticality, and when would it occur.

Risk Code	Risk Event	Risk Criticality	PROB		
			PC	C	OM

DR1	Design changes				
DR2	Delay in design				
DR3	Deficiencies in specifications and drawings				
DR4	Difficulty in choosing proposals				
DR5	Unable to get approvals				
CR1	Changes in quantity/scope of work				
CR2	Inadequate quality of work and need for correction				
CR3	Difficulties/delays in labor, equipment, and material availability				
CR4	Safety/accidents				
CR5	Coordination with suppliers/subcontractors				
CR6	Constructability				
CR7	Inconsistent design and construction work				
FR1	Difficulty in inspection for progress payments				
FR2	Lack of value management				
ER1	Exceptionally inclement weather				
ER2	Unforeseen site conditions				
PL1	Site access/right of way issues				

PL2	Bureaucratic problems				
PR1	Inconsistent warranty information and as-built drawing				
PR2	Difficulty in property management and maintenance				

SECTION 3: Traditional risk management method

What is the current practice of the company/organization in dealing with the corresponding risks?

RISK EVENT		Traditional risk management methods		
		Risk Identification	Risk Response	Risk Monitor
DR1	Design changes			
DR2	Delay in design			
DR3	Deficiencies in specifications and drawings			
DR4	Difficulty in choosing proposals			
DR5	Unable to get approvals			

CR1	Changes in quantity/scope of work			
CR2	Inadequate quality of work and need for correction			
CR3	Difficulties/delays in labor, equipment, and material availability			
CR4	Safety/accidents			
CR5	Coordination with suppliers/subcontractors			
CR6	Constructability			
CR7	Inconsistent design and construction work			
FR1	Difficulty in inspection for progress payments			
FR2	Lack of value management			
ER1	Exceptionally inclement weather			
ER2	Unforeseen site conditions			

PL1	Site access/right of way issues			
PL2	Bureaucratic problems			
PR1	Inconsistent warranty information and as-built drawing			
PR2	Difficulty in property management and maintenance			

SECTION 4: Elements at Risk

Instruction:

Kindly tick the facility elements that usually encounter problems in your past DB projects.

Risk No.	Risk Events	Substructure	Shell	Interiors	Services	Equipment and Furnishings	Special Construction and Demolition	Site work
DR1	Design changes							
DR2	Delay in design							
DR3	Deficiencies in specifications and drawings							
DR4	Difficulty in choosing proposals							
DR5	Unable to get approvals							
CR1	Changes in quantity/scope of work							
CR2	Inadequate quality of work and need for correction							

CR3	Difficulties/delays in labor, equipment, and material availability							
CR4	Safety/accidents							
CR5	Coordination with suppliers/subcontractors							
CR6	Constructability							
CR7	Inconsistent design and construction work							
FR1	Difficulty in inspection for progress payments							
FR2	Lack of value management							
ER1	Exceptionally inclement weather							
ER2	Unforeseen site conditions							
PL1	Site access/right of way issues							
PL2	Bureaucratic problems							
PR1	Inconsistent warranty information and as-built drawing							
PR2	Difficulty in property management and maintenance							

SECTION 5: CURRENT BIM USES

Instruction:

Kindly tick the facility elements that usually encounter problems in your past DB projects.

BIM Use Code	BIM Use	Using right now?	PC	C	OM
BU1	Existing Conditions Modeling				
BU2	Quantity Take-Off/Cost Estimation				
BU3	Visualization				
BU4	Database Information Management				
BU5	Site Analysis				
BU6	Programming				
BU7	Design Reviews				
BU8	Code Validation				
BU9	Sustainability (LEED) Evaluation				

BU10	Structural Analysis				
BU11	Facility Energy Analysis				
BU12	Engineering Analysis				
BU13	Lighting Analysis				
BU14	Design Authoring				
BU15	Options Analysis				
BU16	3D Coordination				
BU17	Phase Planning/Scheduling				
BU18	Supply Chain Management				
BU19	3D Control and Planning				
BU20	Digital Fabrication/Shop Drawing				
BU21	Construction System Design				
BU22	Site Utilization Planning				
BU23	Project Progress Monitoring				
BU24	Quality Control Checks				
BU25	Record Modeling/Production Data Delivery				
BU26	Safety/Disaster Planning				
BU27	Space Management and Tracking				
BU28	Facility Management				
BU29	Building Systems Analysis				
BU30	Building Maintenance Scheduling				

<u>APPLICATION OF FRAMEWORK BASED ON CRITICAL RISKS</u>

SECTION 6: Presentation of available BIM uses based on risks' criticality assessment [Presentation of available BIM uses]

SECTION 7: Barriers of not implementing BIM Uses for risk management

Barriers Perceived
Lack of skilled personnel
Lack of client demand
Cultural resistance
High investment cost
Lack of additional project finance to support BIM
Resistance at operational level
Reluctance of other discipline to share information
Lack of immediate benefits
Legal issues around ownership of the model
Training and finding people who understand BIM
Understanding of the required hard- and software products for efficient BIM adoption
Required collaboration and integration
Clear understanding of new roles and responsibilities

What are the additional barriers that were not mentioned from the list?

APPENDIX C

RISK CATALOGUE

Risk Events	Type	Scope	Risk Center	When			Who		Elements at Risk							Risk Outcome			
				PC	C	OM	Bearer	Responsible	Substruc-ture	Shell	Interiors	Services	Equipment and Furnishings	Special Construc-tion and Demolition	Sitework	T	C	Q	S
Design changes	Internal	Global	Design	✓	✓		Contractor	Contractor	✓	✓	✓	✓	✓			✓	✓		✓
Delay in design	Internal	Global	Design	✓			Contractor	Contractor	✓	✓	✓	✓	✓	✓		✓	✓		
Deficiencies in specifications and drawings	Internal	Global	Design	✓	✓		Contractor	Contractor	✓	✓	✓	✓				✓		✓	
Difficulty in choosing proposals	Internal	Global	Design	✓			Owner	Owner	✓	✓	✓	✓	✓			✓	✓		✓
Unable to get client's approvals	Internal	Global	Design	✓			Contractor	Owner	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Changes in quantity/scope of work	Internal	Global	Construction	✓	✓		Contractor	Contractor		✓	✓	✓				✓	✓	✓	✓
Inadequate quality of work and need for correction	Internal	Local	Construction		✓		Contractor	Contractor	✓	✓	✓	✓						✓	
Difficulties/delays in labor, equipment, and material availability	Internal	Local	Construction		✓		Contractor	Contractor	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Safety/accidents	Internal	Global	Construction		✓		Contractor	Contractor	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Suppliers/subcontractors failure due to poor performance	Internal	Local	Construction		✓		Contractor	Contractor	✓	✓	✓	✓		✓	✓	✓	✓	✓	
Constructability issues	Internal	Local	Construction	✓	✓		Contractor	Contractor	✓	✓	✓	✓		✓		✓	✓	✓	
Inconsistent design and construction work	Internal	Local	Construction		✓		Owner	Contractor	✓	✓	✓	✓						✓	
Difficulty in inspection for progress payments	Internal	Local	Financial		✓		Owner	Owner	✓	✓	✓	✓	✓	✓	✓		✓		
Lack of value management	Internal	Global	Financial	✓	✓		Owner	Contractor	✓	✓	✓	✓	✓	✓	✓		✓	✓	
Exceptionally inclement weather	External	External	Environmental		✓		Shared	Owner	✓	✓					✓	✓	✓	✓	
Unforseen site conditions	External	External	Environmental		✓		Owner	Owner	✓						✓	✓	✓		✓
Site access/right of way issues	External	External	Political		✓		Owner	Owner							✓	✓	✓		
Bureaucratic problems	External	External	Political	✓			Owner	Owner	✓	✓	✓	✓	✓	✓	✓	✓			
Inconsistent warranty information and as-built drawing	Internal	Global	Post-Construction		✓	✓	Contractor	Contractor				✓	✓				✓	✓	
Difficulty in property management and maintenance	Internal	Global	Post-Construction			✓	Owner	Owner		✓	✓	✓	✓				✓	✓	✓

Risk Code					Type	Risk Center	Risk event	Risk Factor	Risk Factor Simplified
R	1	.01	.01	.01	Internal	Design	Design changes	Vague requirements by clients	Client
R	1	.01	.01	.02	Internal	Design		Erroneous drawings and specifications	Drawing insufficency
R	1	.01	.01	.03	Internal	Design		Incompatible design and site condition	Site
R	1	.01	.01	.04	Internal	Design		Improper planning and space utilization	Planning
R	1	.01	.01	.05	Internal	Design		Inflexibility of consultants	Consultant
R	1	.01	.02	.01	Internal	Design	Delay in design	Delay from other consultants	Consultant
R	1	.01	.02	.02	Internal	Design		Tideous 2D design process	Drawing insufficency
R	1	.01	.02	.03	Internal	Design		Vague requirements by clients	Client
R	1	.01	.03	.01	Internal	Design	Deficiencies in specifications and drawings	Human error	Drawing insufficency
R	1	.01	.03	.02	Internal	Design		Lack of communication between stakeholders	Communication
R	1	.01	.03	.03	Internal	Design		Consultant's incompentency	Consultant
R	1	.01	.04	.01	Internal	Design	Difficulty in choosing proposals	Vague requirements by clients	Client
R	1	.01	.04	.02	Internal	Design		Owner's lack of knowledge to evaluate proposals	Client
R	1	.01	.04	.03	Internal	Design		Too many proposals to evaluate	Numerous proposals
R	1	.01	.04	.04	Internal	Design		Clients are undecided	Client
R	1	.01	.05	.01	Internal	Design	Unable to get approvals	Insufficient time to prepare tender documents	Documentation
R	1	.01	.05	.02	Internal	Design		Owner's lack of knowledge in construction and tender	Client
R	1	.02	.01	.01	Internal	Construction	Changes in quantity/scope of work	Clients are undecided	Client
R	1	.02	.01	.02	Internal	Construction		Uncertain scope of work	Scope
R	1	.02	.01	.03	Internal	Construction		Erroneous quantity	Quantity
R	1	.02	.02	.01	Internal	Construction	Inadequate quality of work and need for correction	Low quality of materials	Material
R	1	.02	.02	.02	Internal	Construction		Lack of quality checks	Inspection
R	1	.02	.02	.03	Internal	Construction		Disregard of local building code	Bureaucratic
R	1	.02	.03	.01	Internal	Construction	Difficulties/delays in labor, equipment, and material availability	Low quality of materials	Material
R	1	.02	.03	.02	Internal	Construction		Import of materials	Material Import/Transportation
R	1	.02	.03	.03	Internal	Construction		Transportation problems	Material Import/Transportation
R	1	.02	.04	.01	Internal	Construction	Safety/Accidents	Lack of safety inspection	Inspection
R	1	.02	.04	.02	Internal	Construction		Unforseen accidents/hazards on site	Site
R	1	.02	.04	.03	Internal	Construction		Lack of safety measures	Planning
R	1	.02	.05	.01	Internal	Construction	Coordination with suppliers/subcontractors	Lack of communication with subcontractors	Communication
R	1	.02	.05	.02	Internal	Construction			Communication
R	1	.02	.05	.03	Internal	Construction		Incompetent subcontractors	Subcontractor
R	1	.02	.06	.01	Internal	Construction	Constructability	Incomplete design review	Inspection
R	1	.02	.06	.02	Internal	Construction		Overlooked conflicting items	Drawing insufficiency
R	1	.02	.06	.03	Internal	Construction		Clashes with engineering system	Drawing insufficiency
R	1	.02	.06	.04	Internal	Construction		Owners are unsure if contractor's method statements or shop	Client
R	1	.02	.07	.01	Internal	Construction	Inconsistent design and construction work	Overlooked items in quality inspection	Inspection
R	1	.02	.07	.02	Internal	Construction		Interruption of client's consultants regarding design	Client
R	1	.03	.01	.01	Internal	Financial	Difficulty in inspection for progress payments	Misjudged cost estimate	Drawing insufficiency
R	1	.03	.01	.02	Internal	Financial		Difficulty in quantifying actual works done	Drawing insufficiency
R	1	.03	.02	.01	Internal	Financial	Lack of value management	Low working morale	Contractor
R	1	.03	.02	.02	Internal	Financial		Contractor taking advantage of owner	Contractor
R	1	.03	.02	.03	Internal	Financial		Uncertain specifications of materials	Material
R	1	.04	.01	.01	Internal	Environmental	Exceptionally inclement weather	Adverse weather conditions	Weather
R	1	.04	.02	.01	Internal	Environmental	Unforeseen site conditions	Uncertain subsurface conditions	Site

R	2	.05	.01	.01	External	Political/Legal	Site access/right of way issues	Unidentified right of way issues	Right-of-way
R	2	.05	.01	.02	External	Political/Legal		Lack of knowledge on local regulations	Inspection
R	2	.05	.01	.03	External	Political/Legal		Contractor's rights-of-way due to particular method of constru	Method of construction
R	2	.05	.02	.01	External	Political/Legal	Bureaucratic problems	Delay in requesting permits	Bureaucratic
R	1	.06	.01	.01	Internal	Post-Construction	Inconsistent warranty information and as-built drawing	Use of low grade materials	Material
R	1	.06	.01	.02	Internal	Post-Construction		Lack of informationon building elements	Information
R	1	.06	.01	.03	Internal	Post-Construction		Warranty on facility performance is mishandled	Information
R	1	.06	.02	.01	Internal	Post-Construction	Difficulty in property management and maintenance	Lack of communication with end users	Communication
R	1	.06	.02	.02	Internal	Post-Construction		Lack of automation	Communication
R	1	.06	.02	.03	Internal	Post-Construction		Maintenance of building systems	Maintenance

APPENDIX D

BIM USE CATALOGUE

BIM Uses Description, Expected Benefit, and Relevant References

CODE	BIM USE	DESCRIPTION	EXPECTED BENEFIT	RELEVANT REFERENCES
BU1	Existing Conditions Modeling	This BIM use is done to develop a model based on the existing conditions of a site, facility, or specific area within a facility. Various ways of developing this model exists and are being developed. An example of this is laser scanning and conventional surveying techniques.	Efficient and accurate existing conditions documentation Enhanced visualization of existing conditions Future modeling benefits for retrofitting	(CICRP, 2011) (Jung et al., 2014) (Volk et al., 2014) (Lee et al., 2015b)
BU2	Quantity Take-Off/Cost Estimation	The BIM use which can be used to aid in the development of quantity take-offs particularly through model-based estimating. With the addition of cost database, cost estimation can be done subsequently. The process can be used throughout the project lifecycle.	Swiftly generate quantities in the decision making process Precisely quantify modeled materials Visualization of elements to be estimated Ability to explore design options according to its costs Reduction in total estimating time	(Choi et al., 2015, Lee et al., 2014, Monteiro and Martins, 2013, CICRP, 2011)
BU3	Visualization	This BIM use helps with visualizing and representing real elements in the model. This BIM use could automatically generate blow ups, elevations, and other details based on the information within the model	Visualization of the actual elements Efficient documentation process	(CICRP, 2011)

BU4	Database Information Management	This BIM use describes the process of using the BIM model as a database for information. The information regarding the facility is generated from pre-construction which is utilized and developed to the construction stages. Finally, the information embedded in the model can be used in operation and maintenance BIM uses. The said utilization of information from conception to OM is the essence of BIM.	Prevention of repetitive input of information Accurate information retrieval	(Goedert and Meadati, 2008)
BU5	Site Analysis	A BIM use wherein GIS tools are utilized along with the BIM software. This is usually performed to determine the optimal site location for a project. Site data collection is done prior to selection of site.	Efficient evaluation of an existing or potential site in relation to the development program Increase energy efficiency Improvement on hazard related and environmental issues Cost-savings on utility demand and demolition	(CICRP, 2011, Kumar and Shaikh, 2013, Zimmerman, 2000)
BU6	Programming	Spatial programming is used in this BIM use. It enables assessment of design performance with regard to spatial requirements. The BIM model provides visualization which allows the planning team to analyze space and understand the local regulations. Most of the critical	Aids in visualization which projects better analysis and understanding of the space standards and regulations Provides easy alternatives for owners when needs and options are discussed Easier allocation of	(CICRP, 2011, Epstein, 2012, Manning and Messner, 2008)

		decisions are made which bring the most value to the project.	spaces for utilization Time and cost savings for man-hours usually spent on manual site investigation Embedded data in elements enable simultaneous design and check for compliance (Epstein, 2012)	
BU7	Design Reviews	This BIM use generates collaboration among the stakeholders when considering their designs. Design review is also called collaborative production environment (Sullivan, 2007). Evaluating of the project, previewing spaces, setting criteria, and etc. are some of the aspects included when considering this BIM use. This is usually done with the help of a computer software, virtual mock-ups, or immersive laboratories. This BIM use goes hand in hand with Design authoring (Sullivan, 2007).	Cost and time savings from constructing traditional mock-ups Real-time variations based on stakeholders' feedbacks Efficient criteria evaluation based on owners' needs Easier communication of design intent to other stakeholders Coordination and collaboration increase leading to better decisions	(CICRP, 2011, Sullivan, 2007)

BU8	Code Validation	This BIM use allows the users to check the models with respect to codes and constraints set by the local government (e.g. building code) and user generated constraints. A model checking software is used to input such constraints and automatically check and generate reports of the desired structure.	Enables internal quality assurance to check if its BIM models are properly modelled and if the design conforms to local standards and regulations Enables contractors to validate models submitted by trade contractors Allows efficiency on multiple checking for code compliance Enables visualization which reduces time in actual site visiting Early detection of code errors, omissions, and oversights	(AECmag.com, 2013, Choi et al., 2014, CICRP, 2011, Nawari, 2012, Tsai et al.)
BU9	Sustainability (LEED) Evaluation	This BIM use allows the use of the model for sustainability evaluation such as LEED, BREEAM, and EEWH which originated from the US, UK and Taiwan, respectively. The structure, when desired to have sustainable attributes on it, adopts sustainability design and is evaluated. Evaluation can be done by satisfying required criteria in which can be directly, semi-directly, or indirectly be documented from the model (Azhar et al, 2011).	BIM-based sustainability software could generate results quicker than traditional methods Enables collaboration among stakeholders to discuss about sustainability of the structure Allows variation and selection of sustainable design alternatives Projected reduction in operational costs due to optimized energy management Increases emphasis on sustainable and environment-friendly designs	(Azhar et al., 2011, CICRP, 2011, Kubba, 2012, TAS, 2014, Wu and Issa, 2010)

BU10	Structural Analysis	The BIM use which can be used to automatically calculate the structural specification based on the 3D model developed. The information generated from this could be utilized and handed over to owners/facility managers for maintenance. Moreover, the intelligent applications available for engineers would catalyze better decision making.	Automation and real-time variation of structural design alternatives Faster documentation and management of changes that occurs in the design stage. Efficiency in performing multiple structural analysis by being a "one stop" analysis software without updating the current model	(CICRP, 2011, Wyatt, 2007)
BU11	Facility Energy Analysis	This BIM use utilizes energy simulation programs to adjust the model based on the assessment of the current design.	Ensures energy standard compatibility Enables optimal utilization of facility based on the energy generated Future lifecycle cost benefits due to informed decisions in the beginning.	(Azhar et al., 2009, Bynum et al., 2013)
BU12	Engineering Analysis	This BIM use help visualize and generate object-based engineering elements. Moreover, the simulation capabilities enable the engineering analysis of such thus leading to informed decisions prior to project construction.	Performance analysis of engineering elements prior to construction Visualization of engineering systems	(CICRP, 2011, Xie et al., 2011)

BU13	Lighting Analysis	This BIM use is used to analyze the design developed in the design authoring tool based on different lighting scenarios (e.g. indoor and outdoor lighting sources) and helps manipulate the current model to a more efficient one in terms of proposed lighting systems.	More efficient buildings in capturing natural/artificial sunlight Optimization of lighting systems to ensure wide captured areas Automation and better informed decisions through simulation of lighting Better visualize the effect of different lighting options for the facility Generate more efficient options based on the results of lighting simulation	(CICRP, 2011, Kota et al., 2014)
BU14	Design Authoring	This BIM use is utilized to generate actual representations of facility elements of the proposed structure. This also goes hand in hand with design review as well as most of the BIM uses. This provides the first step of BIM wherein each discipline starts to generate models specific to their fields. The elements can be embedded with information which can be used for other BIM uses	Visualization of actual facility elements Faster revisions when changes occur	(CICRP, 2011, Eastman et al., 2011)

BU15	Options Analysis	This BIM use utilizes visualization and automatic cost estimation capabilities of BIM. Options analysis contributes to better decision making in choosing the appropriate structure depending on the location. Many factors can help decision-making through BIM simulation such as costs, lighting, area, and etc.	Better decision based on owner/client's requirements Optimize decision by selecting the most economical design based on various options Efficient process compared to traditional methods Improved visualization and marketing effort	(Azhar et al., 2012)
BU16	3D Coordination	This BIM use promotes coordination with various stakeholders wherein clash detection is done to investigate the conflicting building elements.	Coordinate all models for clash detection Minimization of possible errors expected in construction Allocation of responsibilities for conflicting problems Visualization of conflicts	(CICRP, 2011, Eastman et al., 2011)
BU17	Phase Planning/Scheduling	This BIM use incorporates the element of time in the 3D model, thus making it 4D. This is utilized to plan the phased occupancy of the structure being constructed or retrofitted.	Visualization of the construction process and steps Phasing plans to manage space conflicts Proper allocation of resources (manpower, equipment, and materials) for better schedule and cash flow Pre-identify and resolve space and workspace conflicts Marketing and publicity	(BIMWIKI, 2009, CICRP, 2011, Hartmann et al., 2008, Kang et al., 2013, Kim et al., 2013)
BU18	Supply Chain Management	This BIM use is considered as the last paradigm as explained by Taylor & Bernstein (2009). BIM can be integrated in the supply chain (e.g. pre-cast/pre-fabricated elements) which	Improved accuracy/precision in building elements Efficiency of processes due to automation Improved	(Aram et al., 2013, Wisuthseriwong and Likhitruangsilp, 2014)

		revolves around automation and seamless production.	communication and collaboration Integration and reuse of information created by diverse resources Detection of clashes and constructability issues Visualization Accurate cost estimate Improved logistics through utilizing 4D schedules	
BU19	3D Control and Planning	This is a BIM use which utilizes information model to automate control of equipment's movement and location.	Decrease layout errors by linking coordinates Improved efficiency and productivity Reduced rework Increased accuracy and precision	(CICRP, 2011)
BU20	Digital Fabrication/Shop Drawing	The utilization of this BIM use promotes automation of digital fabrication and shop drawings. Traditionally, shop drawings are created manually with a drafting software or with a special detailing software. The information from the BIM model can subsequently be used and exported to detailing applications, thus preserving information and providing efficiency from design to manufacturing.	More efficient construction process which enables design-to-manufacturing capabilities Controlled project outcomes Accurate information Improved collaboration and delivery schedules Fewer rectifications and RFIs	(Autodesk, 2008, CICRP, 2011, Eastman et al., 2011, Taylor and Bernstein, 2009)
BU21	Construction System Design/Virtual Mock-Up	This BIM use is utilized to present virtual mock-up of facilities especially those with complex building systems.	Increased constructability of complex systems Visualization of complex systems Increased planning and communication	(CICRP, 2011, Cao et al., 2015)
BU22	Site Utilization Planning	This BIM use is utilized to assist in construction site layout	Improved communication among	(Kumar et al., 2015, CICRP, 2011)

		planning (CSLP) in terms of planning and collaboration.	stakeholders Visualization of complex site layout Easier identification of space conflicts	
BU23	Project Progress Monitoring	This BIM use is utilized to integrate BIM concept to typical project progress monitoring.	Efficient monitoring process Collaboration between project participants Easy extraction of information for owners	(Losavanh and Likhitruangsilp, 2015, CICRP, 2011, Tsai et al.)
BU24	Quality Control Checks	This BIM use is to integrate BIM with quality control checks. This is mainly utilized for real-time automation and identification of defects in building elements.	Improved work efficiency in quality inspection Facilitates easy inspection through automatic identification of defective building elements Improved communication and collaboration with sub-contractors	(Chang et al., 2013, Losavanh and Likhitruangsilp, 2015)
BU25	Record Modeling/Production Data Delivery	This is a process used to represent the accurate/actual physical condition, environment, and asset of the facility. It contains, but not limited to, main architectural, structural, and MEP elements. It also contains information regarding fabrication models and other useful information to be handed-over to the owner/facility manager.	Easier modelling for renovation Improved documentation for future use Benefits future permit processing in case of revised codes (e.g. building codes) Linkage with FM applications Visualization of actual structure Data-rich environment for easier maintenance and warranty information	(CICRP, 2011, Eastman et al., 2011, Jung et al., 2014, Cerovsek, 2011)

BU26	Safety/Disaster Planning	This process utilizes BIM for facilities management, specifically in emergency management. In the event of natural disasters, internal disturbances, attacks, and other force majeure events, the data from the model can be useful for emergency management. Spatial data, which is usually embedded in the model, would be useful for FM applications.	Visualize locations for hazards Efficiently inform and contact emergency responders in locating and identifying potential emergency problems Accurately pinpoint through graphical representation of actual building elements Better and informed decision making in case of emergency	(Becerik-Gerber et al., 2012, CICRP, 2011)
BU27	Space Management and Tracking	Another application of BIM in FM which is used to manage, forecast, and assign facility space for optimal use. The movement of occupants can be streamlined to the spaces which benefits productivity of people. The information in BIM can be used for space management and allow improved decision making for future expansions.	Optimize the utility of physical space and related assets Productivity of employees in optimized spaces Streamlining of move process which leads to efficiency Automation in managing space and placing identifiers for fetching and displaying space attributes	(Becerik-Gerber et al., 2012, CICRP, 2011)
BU28	Facility Management	This process involves creating and updating digital assets from BIM to the FM application. Traditionally, after a structure is completed, digital assets are input manually to facility management systems (FMS) (e.g. work order management, repair, and maintenance). Linking BIM to supply these information would provide utilization of information from the as-built drawing/model to the FMS.	Increased efficiency of automatic update of assets/building elements Accurate information utilization Automated processes for inputting building components' information to FMS Consistent information from various sources	(Becerik-Gerber et al., 2012, CICRP, 2011)

BU29	Building Systems Analysis	This BIM use directly relates to energy usage of the facility. The graphical interface provided by BIM is seen as a solution to the lack of desired level of detail provided by some BAS applications (Becerik-Gerber et.al, 2012). The model is used to provide information regarding occupants' use of the facility's system for tracking, monitoring, and predicting facility performance. This BIM use also relates to sustainability issues which is directly related to the facility's energy consumption	Visualization for monitoring and updating of floor plans and equipment Avoids repetitive entry and inconsistency of graphical data Real-time monitoring and automated control Simulation for different energy configurations in determining most efficient solutions Controlled energy consumption Tracking of historical energy usage	(Becerik-Gerber et al., 2012, CICRP, 2011)
BU30	Building Maintenance Scheduling	This BIM use focuses on the maintainability of facility elements. This is usually done to optimize performance throughout the life cycle of a facility with a minimum life cycle cost (Becerik-Gerber et al. 2012). Information regarding maintenance which are related to accessibility, sustainability of materials, and preventive maintenance are crucial with this BIM use. Proper schedulling and noticing of these issues would benefit owners in terms of savings throughout a facility's operation and maintenance.	Proactive maintenance activities and allocation of maintenance staff Scheduled inspection for facility elements Automate checking process through the use of geometric and non-geometric information	(Becerik-Gerber et al., 2012, CICRP, 2011)

CODE	BIM USE	REQUIREMENTS				OUTCOMES
		INFORMATION	INFO SOURCE	TOOL	MODEL	
BU1	Existing Conditions Modeling	Actual existing conditions gathered through (1) contact or (2) non-contact technique Photos of the site Floor plans As-built drawings/model	O	BIM modeling software Laser scanning point cloud manipulation software 3D Laser scan Surveying equipment	N/A	Laser scan model Existing conditions model
BU2	Quantity Take-Off/Cost Estimation	Cost reports Analysis Method Cost Database	E,C	Model-based estimating software Design authoring software	3D model	BOQ Cost estimate of the project
BU3	Visualization	Organizational template	A,E,C	Design authoring software Model checking software	3D model	Blowups Elevations 2D drawings
BU4	Database Information Management	Non-geographic information of facility elements	A,E,C,O	Design authoring software	3D model	
BU5	Site Analysis	Site information (Slope, road proximity, land use/cover, land value, geological information, utility distribution, planning and zoning ordinance, etc.)	O,E	Design authoring software GIS software		Site analysis model
BU6	Programming	Site data	O	Design authoring software	Site analysis model Existing conditions model	Programming model
BU7	Design Reviews		A,E,C,O	Design authoring software	Design model	Design review information

				Model checking software		
BU8	Code Validation	Company implementation standards User-specific constraints Local building code	A,E,C	Model checking software	3D model	Code validated 3D model Code validation report
BU9	Sustainability (LEED) Evaluation	Sustainability rating background	A	Design authoring software Building performance analysis software Application development software	Design model	Sustainability criteria information
BU10	Structural Analysis	Local structural code and requirements	E,C	Design authoring software Structural analysis software	Architecture model	Structural model
BU11	Facility Energy Analysis	Local energy code Local weather information	E	Energy simulation and analysis software Design authoring software	3D model	Energy analysis model Predicted energy consumption information
BU12	Engineering Analysis	Local building code and requirements	E	Design authoring software Engineering analysis software	Architecture model	Various engineering models (mechanical, electrical, and plumbing)
BU13	Lighting Analysis	Design standards and codes related to lighting	A	Design authoring software Lighting analysis software	3D model	Lighting analysis model
BU14	Design Authoring	Parametric Modeling Content Existing 2D plans and specs	A,E,C,O	Design authoring software	Program model	3D model
BU15	Options Analysis	Spatial information Area-based costs	A,E,C,O	Design authoring software Model-based estimating software	Schematic model	Optimal schematic design

BU16	3D Coordination	Company implementation standards Contract requirements	A,E,C,O	Design authoring software Model review application	Design model	Information exchange requirements Coordination model Compiled coordination model
BU17	Phase Planning/Scheduling	Productivity information of labor and materials Historical schedule data	C	Design Authoring Software 4D Modeling software Schedule developing software	3D model	Project schedule 4D model
BU18	Supply Chain Management	Bill of quantities Project schedule	C	Design Authoring Software	Design model	
BU19	3D Control and Planning	Coordinates	O	Surveying equipment GPS enabled equipment		
BU20	Digital Fabrication/Shop Drawing		C	Design authoring software Model checking software Steel detailing application Model-based estimating software		Shop drawing
BU21	Construction System Design/Virtual Mock-Up	System design	C	Design Authoring Software 3D system design software	Design model	Virtual mock-up
BU22	Site Utilization Planning	Site layout plan Equipment/machinery information (e.g. location) Material delivery schedule	C	Design Authoring Software Cloud-based platform Schedule developing software		Site layout model
BU23	Project Progress Monitoring	Project schedule	C	Design Authoring Software Schedule developing software Field BIM software Mobile computer device	Design model	Project progress update

BU24	Quality Control Checks	Punch lists	C	Design Authoring Software Field BIM Software Model review software Mobile computer device	Design model	Defect documentation
BU25	Record Modeling/Production Data Delivery	As-built information	A,E,C	Model review software Design Authoring Software	Design model Construction Model Subcontractor Fabrication Model	As-built model
BU26	Safety/Disaster Planning	Fire/emergency exit plan As-built information	O	Model review software Building automation system (BAS) Computerized maintenance management system (CMMS) Electronic document management system (EDMS)	As-built model	
BU27	Space Management and Tracking	As-built information Spatial information	O	Model review software Building automation system (BAS) Computerized maintenance management system (CMMS) Electronic document management system (EDMS)	As-built model	
BU28	Facility Management	As-built information Manufacturer/vendor information Equipment and system information Maintenance manual and test reports	O	Model review software Building automation system (BAS) Computerized maintenance management system (CMMS)	As-built model	

				Electronic document management system (EDMS)		
BU29	Building Systems Analysis	As-built information Equipment information and maintenance	O	Model review software Building automation system (BAS) Computerized maintenance management system (CMMS) Electronic document management system (EDMS)	As-built model	
BU30	Building Maintenance Scheduling	As-built information Maintenance manual	O	Model review software Building automation system (BAS) Computerized maintenance management system (CMMS) Electronic document management system (EDMS)	As-built model	

APPENDIX E
RISK – BIM USE PURPOSE CATALOGUE

Risk event	Risk Center	Risk Factor	Simplified Risk Factor	Primary Purpose	Purpose
Design changes	Design	Vague requirements by clients	Client	Communicate	Visualize
		Erroneous drawings and specifications	Drawing insuffcency	Communicate	Draw
		Incompatible design and site condition	Site	Gather	Capture
		Improper planning and space utilization	Planning	Generate	Arrange
		Inflexibility of consultants	Consultant	Generate	Prescribe
Delay in design	Design	Delay from other consultants	Consultant	Generate	Prescribe
		Tideous 2D design process	Drawing insuffcency	Communicate	Draw
		Vague requirements by clients	Client	Communicate	Visualize
Deficiencies in specifications and drawings	Drawings	Human error	Drawing insuffcency	Communicate	Draw
		Lack of communication between stakeholders	Communication	Communicate	Transform
		Consultant's incompentency	Consultant	Generate	Prescribe
Difficulty in choosing proposals	Proposals	Vague requirements by clients	Client	Communicate	Visualize
		Owner's lack of knowledge to evaluate proposals	Client	Communicate	Visualize
		Too many proposals to evaluate	Numerous proposals	Communicate	Visualize
		Clients are undecided	Client	Communicate	Visualize
Unable to get approvals	Approvals	Insufficient time to prepare tender documents	Documentation	Communicate	Document
		Owner's lack of knowledge in construction and tender	Client	Communicate	Visualize
Changes in quantity/scope of work	Scope	Clients are undecided	Client	Communicate	Visualize
		Uncertain scope of work	Scope	Communicate	Analyze
		Erroneous quantity	Quantity	Analyze	Quantify
Inadequate quality of work and need for correction	Work	Low quality of materials	Material	Generate	Prescribe
		Lack of quality checks	Inspection	Gather	Monitor
		Disregard of local building code	Bureaucratic	Analyze	Validate
Difficulties/delays in labor, equipment, and material availability	LEM	Low quality of materials	Material	Generate	Prescribe
		Import of materials	Material Import/Transportation	Communicate	Document
		Transportation problems	Material Import/Transportation	Communicate	Document
Safety/Accidents	Safety	Lack of safety inspection	Inspection	Communicate	Visualize
				Gather	Monitor
		Unforseen accidents/hazards on site	Site	Gather	Capture
		Lack of safety measures	Planning	Generate	Arrange
				Generate	Prescribe
Coordination with suppliers/subcontractors	Coordination	Lack of communication with subcontractors	Communication	Communicate	Visualize
			Communication	Communicate	Document
		Incompetent subcontractors	Subcontractor	Generate	Prescribe
Constructability	Constructability	Incomplete design review	Inspection	Gather	Monitor
		Overlooked conflicting items	Drawing insufficiency	Analyze	Coordinate
		Clashes with engineering system	Drawing insufficiency	Analyze	Coordinate
		Owners are unsure if contractor's method statements or shop drawings are accurate	Client	Communicate	Document
				Communicate	Visualize
Inconsistent design and construction work	Inspection	Overlooked items in quality inspection	Inspection	Gather	Monitor
		Interruption of client's consultants regarding design	Client	Communicate	Document
				Communicate	Visualize
Difficulty in inspection for progress payments	Inspection	Misjudged cost estimate	Drawing insufficiency	Analyze	Quantify
				Communicate	Transform
		Difficulty in quantifying actual works done	Drawing insufficiency	Analyze	Quantify

Lack of value management	Value Management	Low working morale Contractor taking advantage of owner Uncertain specifications of materials	Contractor Contractor Material	Gather Gather Communicate Communicate Analyze	Monitor Monitor Document Document Quantify
Exceptionally inclement weather	Weather	Adverse weather conditions	Weather	Analyze Gather	Forecast Qualify
Unforeseen site conditions	Site Condition	Uncertain subsurface conditions	Site	Analyze Communicate Gather	Coordinate Visualize Capture
Site access/right of way issues	Right-of-Way	Unidentified right of way issues Lack of knowledge on local regulations Contractor's rights-of-way due to particular method of construction	Right-of-way Inspection Method of construction	Analyze Communicate Analyze Communicate Gather Communicate Analyze	Coordinate Visualize Validate Visualize Monitor Visualize Validate
Bureaucratic problems	Bureaucratic	Delay in requesting permits	Bureaucratic	Gather Communicate	Qualify Document
Inconsistent warranty information and as-built drawing	Warranty and as-build drawing	Use of low grade materials Lack of informationon building elements Warranty on facility performance is mishandled	Material Information Information	Generate Gather Gather Communicate Communicate Generate Generate	Prescribe Qualify Monitor Capture Document Prescribe Prescribe
Difficulty in property management and maintenance	Property management	Lack of communication with end users Lack of automation Maintenance of building systems	Communication Communication Maintenance	Communicate Realize Gather Communicate	Visualize Control Qualify Document

APPENDIX F

GUIDELINES ON UTILIZING BIM USES FOR RISK MANAGEMENT

Constructability Risk

Project Phase: Pre-Construction and Construction

Facility Elements: Substructure, Shell, Interiors, Services, Special Construction and Demolition

Responsible Parties: Contractor

	Risk Identification	Risk Response	Risk Monitor
Existing Conditions Modeling			Along with visualization, this BIM use can automatically gather actual locations and geometry which would help monitor clashes that were identified before construction
Visualization	The parametric modeling capability of BIM can show actual representations which can determine clashes during modeling process	After clash detection, project members can visualize the actual clashes happening in the digital models which would subsequently occur in construction if not responded	
Database Information Management		Clash detection processes can document and inform project participants of their engineering systems that has problems	
Design Reviews	The design review would help stakeholders identify erroneous designs which would have problems in the future.		
Options Analysis		After design review and 3D coordination, various options on how to respond on the clashes can be chosen to provide optimal solution to the problem	
3D Coordination	This BIM use can identify overlooked conflicting systems prior to construction of the facility	Clashes with engineering systems can be assigned to respective stakeholders in charge of the modeling of the involved element	Repetitive conduction of clash detection would help the project team continuously monitor the facility elements upon addition of new elements.

Inadequate quality and need for correction risk

Project Phase: Construction

Facility Elements: Substructure, Shell, Interiors, Services

Responsible Parties: Contractor

	Risk Identification	Risk Response	Risk Monitor
Programming		Conducting special planning through design authoring and programming BIM use would enable A/Es to allocate and optimize spaces, thus reducing the rework when changes occur.	
Design Review	The project stakeholders would be able to investigate the BIM upon checking all design options and resolving the issues prior to the construction or pre-fabrication of an element	Through visualization and design review, project stakeholders can visualize and respond to current problems through virtual mock-ups once they are identified.	
Code Validation	Through rules-based or model checking tools, local codes can be set as limits when modeling the elements, which can avoid future code related rework		Applying this BIM use to existing buildings would help owners and facility managers with monitoring building compliance through as-built building models.
Sustainability (LEED) Evaluation	Through combination with other BIM uses such as quantity take-off and design authoring, sustainability issues can be identified if desired to have a specific target LEED rating		
Project Progress Monitoring	Similar to traditional process, BIM-based project progress monitoring would identify punch lists which can be swiftly responded.	Recent developments utilize advanced point clouds and aerial drones to monitor project progress and help in responding to delayed facility elements during construction.	Those elements that are identified to be behind schedule or punch listed can be automatically monitored, rather than implementing time consuming traditional methods.

Quality Control Checks	Identified through model-checking software; the quality, in terms of compliance to the code and owner specifications would help identify future issues during design.

Design Change

Project Phase: Pre-Construction and Construction

Facility Elements: Substructure, Shell, Interiors, Services, Equipment and Furnishings

Responsible Parties: Contractor

	Risk Identification	Risk Response	Risk Monitor
Existing Conditions Modeling			The usage of existing conditions modeling technology, e.g., laser scanning tools and point cloud manipulation software, would enable stakeholders in monitoring changes made in the design. This benefits efficiency in inspection.
Visualization	The parametric modeling makes it easier to distinguish elements, especially those that are exposed to the risk.	In the event of design changes, this BIM use can help the contractor in visualizing the changes that are needed to be done. This is usually implemented with the design authoring BIM use.	As the construction progresses, changes made with the design can easily be monitored through adding information to the affected elements.
Site Analysis	This BIM use can be implemented in detecting sites that are incompatible with the designs. For instance, debris and other blockades can be avoided and/or manipulated with the design intent of the designers.		
Programming	The program model would aid in visualizing areas to optimize the value of the facility. It aids in the pre-construction through visualizing the proposed facility and avoiding changes in the future.		
Design Authoring		This BIM use can be implemented to avoid human error such as drawing errors	

		done in 2D CAD. The generation of families incorporated with parametric modelling prevents the users to avoid design errors which can lead to design changes.	
Options Analysis		In the event of design changes, options analysis BIM use can be implemented when selecting the appropriate designs. Along with other BIM uses such as quantity take-off, better informed decisions can be made.	
Phase Planning/Scheduling	This BIM use can aid in identifying potential problems related to design especially other factors such as weather, labor, material, and equipment are involved. It also reflects to the owner when an owner wants to expedite a facility and would require some design of facility elements to change.	This BIM use can aid in project management in managing the schedule once the design change occurs.	The 4D scheduling BIM use enables the contractor to expedite the process in terms of monitoring the project timeline.
Supply Chain Management	This BIM use, along with 3D coordination, enables the users to identify potential problems in elements prior to prefabrication. This prevents changes to be made which would then be costly if the conflicts were identified during production.		
Construction System Design/Virtual Mock-Up	The virtual mock-up of complicated elements identifies areas that need design changes prior to construction. This benefits structures with complex geometry and connections. The visualization		

	benefit incorporated with this BIM use enables the stakeholders, especially trade contractors, to visualize and work on problems prior to their occurrence.		
Quality Control Checks		Contractors could respond immediately and inform stakeholders the changes that are required.	Real-time monitoring and updating of site information can help in monitoring the elements that were rectified.

Deficiencies in specifications and drawings

Project Phase: Pre-Construction and Construction

Facility Elements: Substructure, Shell, Interiors, Services

Responsible Parties: Contractor

	Risk Identification	Risk Response	Risk Monitor
Visualization	The visualization BIM use can benefit in identifying this risk especially when contractors are converting 2D drawings from consultants (e.g. from Case 3). Lacking information are detected early on and can be responded prior to construction.		
Design Authoring		This BIM use can be implemented to mitigate design- and drawing-related issues. The automatic generation of drawings aid in visualization of the facility.	
3D Coordination	In the event of this risk, implementing the 3D coordination/clash detection BIM use would enable the contractors to identify facilities affected. Usually, contractors working with non-BIM consultants transform the 2D drawings to 3D for clash detection purposes. The 3D coordination would then aid in identifying elements at risk.		
Supply Chain Management		Implementing BIM for supply chain management also benefits with delivering precise and on-time products.	

Supplier' and subcontractors' failure due to poor performance

Project Phase: Pre-Construction and Construction

Facility Elements: Substructure, Shell, Interiors, Services, Special Construction and Demolition, Site work

Responsible Parties: Contractor and Subcontractor

	Risk Identification	Risk Response	Risk Monitor
Existing Conditions Modeling	The automatic generation and identification of constructed elements can easily be inspected using this BIM use. Therefore, any inconsistency in works from the subcontractors can be identified and resolved.		
Visualization		This BIM use would convey instructions and relatable scope of works to the subcontractors. The collaboration and increased communication benefits of BIM would mitigate any miscommunication that might occur during the construction phase.	
Site Analysis	The efficient evaluation of potential site characteristics prior to construction enables the identification of future complications of site-related problems with subcontractors.		
Programming		The added visualization benefit of this BIM use provides better understanding and allocation of spaces. This BIM use can aid in minimizing the risk related to subcontractors by the increased collaboration in the beginning of the project.	
Design Authoring	Implementing this BIM use would enable identification of erroneous facility elements.		The embedded information used in a collaborated model can be used to monitor

	This would benefit subcontractors in identifying risks not only on their work but also those that conflict with other trade contractors.		construction progress. In view of this, the contractors can monitor punch lists which reflects on subcontractors' performance.
Options Analysis		The ability of subcontractors to propose options, e.g., material, construction sequences, and methods through BIM would lead to better communication with other stakeholders.	
Phase Planning/Scheduling	The use of this BIM use can aid contractors in identifying potential problems in overlapping roles of subcontractors. It also identifies potential resource related problems.	This enables the contractor and subcontractor to avoid overlapping works due to delay. The delays that are caused by other subcontractors can affect the works of the next, e.g., finishing subcontractor works are delayed. This BIM use could generate more efficient communication which would avoid future conflicts.	The constant updating of the 4D model enables the subcontractors sharing the model to identify the construction tasks that are needed to be accomplished. From that, further delays can be avoided and constant communication be established.
Supply Chain Management		The added accuracy and precision in the development of building elements avoids conflicts that are related to specialty trade contractors.	
Construction System Design/Virtual Mock-Up	This BIM use can enable identification of possible conflicts which would be costly if left unattended. The virtual mockup also presents a way of communicating with subcontractors, which can benefit in avoiding performance related issues.		
Quality Control Checks			This BIM use can be implemented by contractors for project monitoring. The added

		benefit of on-site BIM can aid in more efficient decision and response making which would affect how subcontractors respond to those issues.

Difficulties/delays in labor, material, and equipment availability

Project Phase: Construction

Facility Elements: Substructure, Shell, Interiors, Services, Equipment and Furnishings, Special Construction and Demolition, Site work

Responsible Parties: Contractor

	Risk Identification	Risk Response	Risk Monitor
Programming	Proper allocation of spaces and optimal spatial decisions in the beginning through the programming BIM use can identify possible difficulties with regard to resources. The added visualization can also benefit in identifying possible locations for managing resources.	Implementing this BIM use can minimize possible resource problems especially with locations with limited maneuverability.	
Phase Planning/Scheduling	Using this BIM use enables proper allocation of resources. In lieu of this, it also enables identification of possible conflicts related to resources in the future.	Any changes in the planned schedule, which is inevitable, can be automatically adjusted and simulated using the 4D modelling or phase planning BIM use. It can also be used to allocate resources for better schedule and cash flow.	
Digital Fabrication/Shop Drawing		Implementing BIM for this BIM use minimizes the difficulty especially in errors. The improved accuracy, coupled with increased efficiency benefit trade contractors especially in this area.	

Exceptionally inclement weather

Project Phase: Construction

Facility Elements: Substructure, Shell, Site work

Responsible Parties: Contractor

	Risk Identification	Risk Response	Risk Monitor
Quantity Take-Off/Cost Estimation		This BIM use can aid in estimating damages caused by severe weather. This extends to a more efficient allocation of contingency budget for these types of events.	This BIM use can be used to monitor the facility after the effects of an inclement weather. Some possibilities of using this include generating schedules of operating facility.
Structural Analysis		The environmental data can be included in the structural design which could minimize adverse effects of the risk.	
Facility Energy Analysis	This BIM use can be used to identify potential problematic elements when natural disasters occur. The simulation can help suggest and provide analyses of design options.		
Engineering Analysis	The BIM model can be used to complement the energy simulation programs to simulate weather conditions. The weather data, e.g., wind, would help in simulating the current design. It would identify possible elements that need justification.		

VITA

A promising engineer, a compassionate leader and a hardworking individual – these are the words that would best describe Mervyn Jan S. Malvar. Born on August 19, 1991, he is the second to the youngest son of Fernando Malvar and Lydia Malvar. He grew up with four siblings which molded him to become the family-oriented and responsible man that he is today. He resides in Cainta Rizal, Philippines, located 17 kilometers east of the Manila.

As a student, Mervyn always excelled in his academics. He attended Don Bosco Technical College in Mandaluyong, Philippines, for his secondary education where he received several awards. His experience in this institution honed his technical skills which later led him into taking up Bachelors of Science in Civil Engineering in De La Salle University-Manila. He finished his undergraduate degree as an Honorable Mention Awardee and a Nominee for Most Outstanding Thesis.

He did his on-the-job training in one of the biggest construction firms in the Philippines. Subsequently, he started studying for the local professional licensure examinations which he passed. After which, a rare opportunity came to him as he was offered a scholarship under the supervision of the AUN/SEED-Net to study in their host institution for Civil Engineering which is Chulalongkorn University in Bangkok, Thailand. He pursued a master's degree in civil engineering. Several of his research papers were already published and presented in international Civil Engineering conferences.

Aside from Mervyn's busy academic life, he enjoys travelling and fitness. He explored ASEAN countries in his two years abroad where he learned about the differences in culture and the history of each country. Also, he spends his free time by learning how to cook healthy meals, joining marathons, and going to the gym.

Mervyn considers his achievements and successes in the field of engineering a stepping stone in his pursuit of applying his learnings in improving the construction industry in his home country.