THESIS

ADOPTION OF BUILDING INFORMATION MODELING IN DEVELOPING COUNTRIES:

A PHENOMENOLOGICAL PERSPECTIVE

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ABSTRACT

ADOPTION OF BUILDING INFORMATION MODELING IN DEVELOPING COUNTRIES

A PHENOMENOLOGICAL PERSPECTIVE

Building Information Modeling (BIM) is a cutting edge technology that has addressed prominent challenges in the Architecture, Engineering and Construction (AEC) industries in most of the developed countries. Construction industries in developing countries due to identified challenges and unavailability of the clear understanding of best practices, are dithering whether to adopt this technology. The scope of this study was how to facilitate BIM adoption in developing countries.

A phenomenological design approach was considered to seek early adopters' and BIM professionals' lived experiences on similar situations and how did they triumph over the hindrances against BIM adoption and made its implementation successful.

A total of six participants with extensive BIM experience and first hand BIM application knowledge were interviewed. The result confirms BIM adoption issues similarities in both developed and developing countries. Recommended best practices for new BIM users in four categories of education requirement, infrastructure requirement, sound practices, and working with partners with no previous BIM experience is represented in chapter five.

The study limitation was the inability to reach out BIM professionals in developing countries therefore, considering the similarities of BIM adoption issues, five of the participants selected for this study were from the United States whereas one participant was selected from developing countries. The study concludes with recommendation for further study in this field.

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Chapter One: Introduction

Due to the contemporary sophistication in construction contracts, building design and the resulting demand for the construction of quality infrastructure, the constructability challenges many construction companies face are very sophisticated and cannot be addressed and solved easily without the help and application of technology. One technology that has emerged over the last decade and a half is Building Information Modeling (BIM). This technology has enabled designs to become more sophisticated as the technologies supporting BIM have evolved. Currently the modeling industry in developed countries can support not only 3D models but the construction management areas of scheduling, cost control, estimating, safety training, and sustainability. The focus of this study is to identify what issues/problems one may face when adopting BIM in a developing country. Prior knowledge of potential issues/problems could be the difference between successful adoption and a failure to adopt BIM in a timely and cost effective manner.

Benefits of BIM Application

There were no significant changes in the building design methods observed until the mid-nineteenth century and engineers were used to describe their design by traditional methods (pen, paper, and ruler) (Yan & Damian, 2008). With the advances in technology, building materials and mathematics, the design process within the construction industry experienced a robust and dramatic change. BIM has been highlighted by the Architecture, Engineering, and Construction (AEC) industry as a powerful design and management tool that has significant advantages over the building life cycle, design and management (Yan & Damian, 2008).

BIM or 3D modeling has resulted in an abrupt reshaping of the AEC industry in the areas of technology and process. National Building Information Modeling standards (NBIMS) committee in the United States (US) defines BIM as a digital representation of physical and functional characteristics of a facility (Azhar, Khalfan, & Maqsood, 2012). Different people and organizations have different definitions for BIM based on its particular use and the various ways they work with BIM. Therefore, most of the benefits BIM offers are included in its definitions. The National Institute of Building Sciences states that "Building Information Modeler BIM, utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project/life-cycle information, and it is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility" (Abbasnejad & Moud, 2013). Another definition of BIM proposed by Van Nederveen is: "A model of information about a building that comprises complete and sufficient information to support all lifecycle processes and which can be interpreted directly by computer applications. It comprises information about the building itself as well as its components, and comprises information about properties such as function, shape, material and processes for the building life cycle" (Abbasnejad & Moud, 2013) Considering the business case for adopting this technology, BIM has attracted researchers', professionals' and practitioners' attention while more cost-benefit information will further convince and motivate professionals to adopt this new technology. Based on a survey conducted by Yan & Damian in US and the UK the benefits of BIM were reported as, creativity, sustainability, improved quality, reduced human resources, and reduced cost and time (2008). BIM is a shared knowledge resource for information about a facility forming a reliable basis for decision making during its life cycle from the conception to demolition (Azhar et al., 2012). A basic premise of BIM is the collaboration by

different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder.

According to Azhar (2011), Adaption of BIM will benefit construction firms in the following aspects but not limited to:

- Cost estimating: BIM software has the ability to perform quantity take off and automatically adjust and accommodate any changes occurring throughout the design and construction processes.
- Fabrication/shop drawings: With the help of BIM, developing shop drawings are simple for different systems of buildings.
- Construction sequencing: BIM will also help in sequencing and coordinating fabrications, materials order and delivery schedules for project components.
- Conflict and collision detection: Since all the models in BIM are created in proper scale in a 3D space, the software has the ability to call out any conflicts between building and utilities elements.

After gathering data on 32 major projects, Stanford University's Center for Integrated Facilities Engineering reported the following benefits of BIM (Azhar, 2011).

- Diminishes changes up to 40% by early problem detection.
- Compared to traditional methods of estimation, BIM produces estimates within 3% of accuracy.
- Reduces cost estimation time by 80%.

Almost all the benefits realized through the adoption of BIM in some way affect and enhance the overall control of the construction project. There has been extensive research conducted on the benefits BIM can offer (Figure 1).

LONG-TERM BIM BENEFITS	SHORT-TERM BIM BENEFITS
- Fewer Claims/ Litigations - Reduced Construction Cost - Increased Profits - Reduced Project Duration - Marketing New Business	- Reduced Conflicts - Better Understanding of Design Intent Among Team Members - Enhanced Project Quality - Decrease in Number of RFI's - Better Construction Cost Predictability
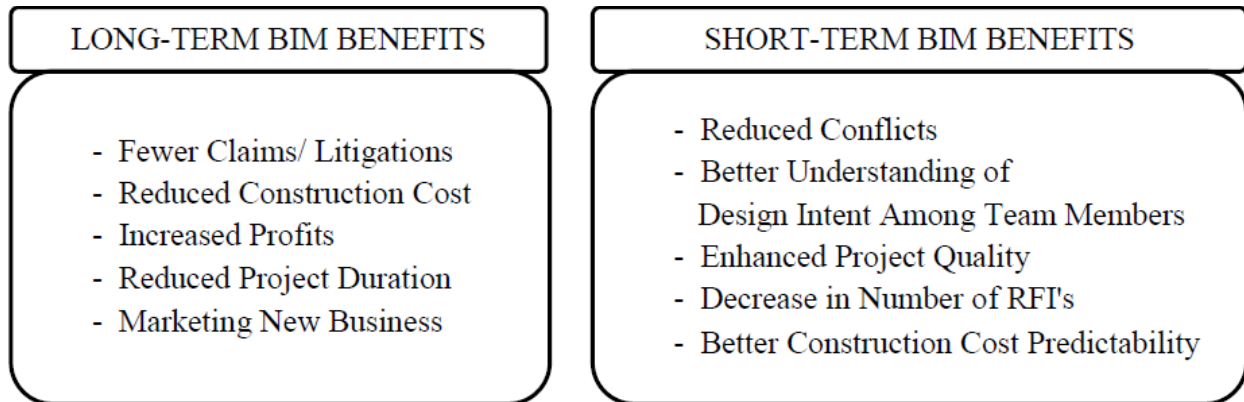
Figure 1: *BIM benefits. Source: Nanajkar, 2014 from McGraw Hill Construction, 2012*

Design issues during the construction phase could result in delays due to re-design. Based on the work that is in place when a design issue is identified there could also be multiple rework items that may further delay the project while increasing costs. Additional studies show that the impact of a design error on the schedule may further delay the project resulting in much larger economic impacts than the rework itself (Won, Lee, Dossick, & Messner, 2013b). A case study on return-on-investment (ROI) based on the use of BIM in design validation and prevention of cost involved with rework due to design errors found that a total of 709 individual design errors were recorded during the design validation of six medium and high raise buildings by BIM (Won et al., 2013b).

BIM is a tool and a process and assists in the geometric modeling of building performance while promoting efficient management of construction projects. According to Bryde, Broquetas, & Volm (2013) the most frequent benefits of BIM use resulted in cost reduction, time savings and more efficient control throughout the project life cycle.

Adverse Effects of BIM on Construction Industries:

Although the BIM implementation and adoption processes are accompanied with challenges, hindrances, and interoperability issues relating to the program itself, very few negative impressions of BIM are reported in the present literature. The majority of the studies and research consensually reveal benefits and analogous encouraging outcomes through adoption of BIM within the AEC industries. Although, most of the studies and research merit industry transition to BIM, there are still augmentations to be made in BIM programs and its application processes. Companies need to either train their staff or hire new BIM professionals prior to transitioning practically to BIM to ensure that critical projects are not negatively impacted due to a lower level of BIM expertise; an issue that could prove costly. Based on a study by Batcheler (Batcheler, 2007), BIM can cause hazard to the project team members as any changes to an object ripples throughout all correlated elements and objects. This could result in many unintended changes throughout the model from the single intended change. To mitigate the impact of such occurrences, a just in time Q&A procedure needs to be in place to identify and respond to such unintended changes.

It appears that BIM will temporarily continue with the imposition of more challenges to the companies that have not yet adopted this technology. From the owners and/or project sponsors' perspective, there is increasing demand for using BIM within the AEC industries. Therefore, companies that lack BIM capacity will find themselves at a competitive disadvantage with companies that have already applied BIM to their projects and satisfied a requirement from the owner/sponsors perspective. These challenges will reach an end as BIM application proliferates and becomes pervasive throughout the AEC industries.

Construction Industries and the Overall Impact of BIM

Although construction firms in developed countries face BIM related challenges, they work hard to resolve these issues using internal or external resources. Some of the most common challenges include: excessive change orders, poor scheduling, inaccurate estimates, scope gap, poor building design, and unqualified labor force (Caldas, Kim, Haas, Goodrum, & Zhang, 2014). Most of these challenges have been addressed through the leveraging of technology to identify modern solutions. However, challenges in the construction field continue to evolve due to increased building design demands and new technologies. From a user's perspective these challenges have supported the emergence and adoption of BIM in developed countries. Batcheler (2007) used case studies to identify the benefits realized from BIM adoption in the US construction industry. The benefits most frequently reported include: clash detection, consistent and accurate drawings set, early involvement of stakeholders and other project team members, coordinated planning, design, and construction, generation of a prefabricated model for accurate and realistic models, and extensively supporting lean construction techniques. Becerik & Rice, (2010), used a survey and found that BIM was used in Architectural firms for design related functions such as, building design, visualization and building programming and massing studies. Contractors use BIM mostly for clash detection, visualization and generating as built models. Benefits of BIM also encompass the direct fabrication and sustainability aspects of buildings (Becerik-Gerber & Rice, 2010).

Fortner et al. (2008), documented the importance of BIM in the design and construction of the National Park Stadium project in Washington DC that had an definitive completion milestone. The construction team representative reported the main reason behind the project's success was the use of BIM. The use of BIM advanced representation of the project model which resulted in a

shorter schedule and being on budget. With little room for delays and errors the number of RFIs was reduced to 100 versus 1,000 to 10,000 for typical projects that used traditional project management methods. Instead of designing the foundations and concrete work first, followed by steel stands, the stadium was built in circular style from one end to the other resulting in construction schedule that was six months shorter that that originally anticipated.

Based on the trends identified in the literature it is evident that BIM promised, and delivered, solutions for schedule and cost overruns including improved coordination and communication processes on construction projects. The results of BIM adoption appear to be similar in other developed countries. A series of studies undertaken in Canada, Germany and Australia all show that the construction firms enjoyed business advances by embracing and adopting innovative technological approaches to solve construction related needs (Manley, McFallan, & Kajewski, 2009). The benefits of construction technology have not been limited to the developed and industrialized countries throughout the history of construction industry. Ofori (1994) argues that the diffusion of construction technology from industrialized countries to developing countries has long been addressing prominent technological problems of developing countries.

Developing countries on the other hand are sharing the same chronic challenges of project delays and cost overruns as industrialized countries. However, to some extent, profound issues have been addressed via adopting technologies from developed countries like Auto CAD, scheduling software, and other design programs resulting in significant time savings. Technology transfer from industrialized countries has focused on addressing the lower level technological development of the developing countries over the last several decades (George Ofori, 1994). For example, scheduling software disseminated from developed countries has helped developing

countries construction industries develop more reliable and efficient construction schedules and control processes.

Although, technology adoption has helped developing countries alleviate the intensity of challenges, there is still a long lists of issues that need immediate attention. Long et.al (2004) found that incompetent designers/contractors, poor estimation, change management, social and technological issues, construction site issues, improper techniques and tools are key factors of construction problems in Vietnam and other developing countries. Also, inaccurate time estimating, excessive change orders, resource shortages (including obsolete technology), organizational culture and kickbacks, inaccurate cost estimating, improper planning and scheduling, lack of involvement through project life, and impractical design are ranked consistently as high frequency occurring problems in developing countries' construction industries Long et.al (2004).

Won, Lee, Dossick, & Messner (2013b) looked at the ROI based on use of BIM in design validation and prevention of cost involved with rework due to design errors. They found that a total of 709 individual design errors were identified using BIM during the design validation of six medium and high raise buildings in Korea. Additional studies show that the impact of design error on the schedule delay results in a much larger negative economic impact than rework (Won, Lee, Dossick, & Messner, 2013a). Therefore, it is important for developing countries to embrace contemporary technologies like BIM to enhance their capacity in order to respond to issues that impact the overall building process success. If not addresses these issues will continue to hinder the development process in developing countries' construction industries since other contemporary technology has not sufficient addressed efficiency issues.

Since most of the studies conducted suggest that construction companies in developed countries are facing challenges when embracing BIM, companies in developing countries are hesitant to consider its adoption. While this may be the case in the past practice and the literature, an understanding of the best practices of BIM adoption may help temper the fear of BIM adoption in developing countries. In order to overcome these challenges, lessons learned from early adopters of BIM, and its preceding technologies, may provide valuable lessons for those wishing to introduce BIM in a developing country. The aim of this study is to identify challenges that early adopters of BIM faced, how they overcame those challenges, and what lessons and best practices could be applied by those in developing countries in BIM adoption.

Need for Studying the Adoption of BIM in Developing Countries

BIM is an emerging technology that has been embraced and highlighted by the AEC industries in developed countries starting as early as 1992 (Eastman, Eastman, Teicholz, & Sacks, 2011). This study explores one overall BIM adoption question and 10 initial sub-questions. During the analysis of the data the initial 10 sub-questions were consolidated into 4 new BIM adoption sub-questions to better fit the data. The overall research question was, are there similarities in BIM adoption issues in developed and developing countries that have/are trying to adopt BIM? If so, what lessons can be learned for those wishing to adopt BIM for the first time in developing countries? The four new sub-questions support the answer to the main research question. First, why was BIM adopted in developed countries? Second, what problems were encountered by industries in developed countries during the adoption process of BIM since its inception? Third, what developing countries have adopted, or are currently trying to adopt BIM and what adoption issues did they face? Finally, are the adoption issues the same today for developing countries that have adopted BIM as they were for developed countries when they adopted BIM?

An in-depth literature review suggests that BIM emerged as supporting technology was developed and was used to address the growing and complex challenges of modern day AEC industries that could not be handled with traditional technologies. The most common challenges throughout the adoption and implementation of BIM in developed countries, according to the existing literature, appeared to be technology, people and processes. Subsequently it appears that some of the construction firms in developing countries that are working to implement BIM are sharing similar challenges even though most developing countries' construction industries are using traditional technologies disseminated from developed countries.

Therefore, it is important to identify similarities of issues regarding the adoption of BIM in both developed and developing countries, and learn from BIM professionals with first hand BIM implementation experience. The lessons learned from early adopters in developed countries may provide enough encouragement to support the successful adoption of BIM in developing countries construction industries.

A Review of BIM Implementation Benefits and Challenges

According to Kumar & Mukherjee (2009) contemporarily, buildings are more complex than ever before and require more resources to operate them. However, the complexity of these buildings resulted in more errors in design and construction due the manual and none intelligent relationship between lines and texts in software other than BIM that are still used. As previously mentioned the main difference between CAD and BIM is that CAD system produces 2D documentation made up of components that are not interrelated and intelligent. BIM creates an interactive form containing its own properties, dimensions and other characteristics integral to the specific component. BIM links all the component related data where CAD does not.

Research by the Construction Industry Institute in 2004, noted that the U.S construction industry wasted almost $75 billion of direct cost due to rework; about 5% of total installed costs (Hwang, Thomas, Haas, & Caldas, 2009). Such a waste of money and time inspired developed countries to focus on a more robust technology that can respond to such issues.

According to Yan & Damian (2008) BIM primarily emerged to satisfy the design automation needs by building a model that represents the actual elements and components of a building. The design automation achieved by using BIM also increases the accuracy of related areas like: estimating, schedule progress and tracking, green building rating system compliance, energy performance, safety plans, and developing reliable baselines for control. BIM is also used for clash detection in early design stages and saves a significant amount of time in error omission and drawing updates. According to Khosrowshahi & Arayici (2012) survey respondents from the UK construction industry specified some of the issues BIM can address including: reducing error, rework and waste, improved sustainable design and construction, improved risk management, more reliable facility and asset management, better coordination of client changes to the design. Love & Smith (2003) used a questionnaire to ask 100 AEC practitioners and academics in UK and US what the benefits of BIM were. They found many of the same items as in the previously mentioned study: increased creativity, reduced time, and cost, improved quality, and improved sustainability. Since its emergence, through continuous studies and efforts, BIM has been highlighted by AEC industry as a solution to the pattern of problems and issues of developed countries' construction industries.

Although the adoption of BIM is accompanied with quick payback, Love and Smith (2003) identified a few of the early drawbacks to adoption in the UK and US: A resistance to new technology, people refuse to learn, copyright issues and training costs, and a waste of human

resource and time. In that study 52% respondents from UK and 78% respondents from US reported that BIM will become widely used and popular in the future considering the potential it has. Khosrowshahi & Arayici (2012) identified the perceived barriers to BIM adoption nine years after Love & Smith's study. They found that the use of BIM in UK construction companies were inhibited by:

1. Firms are not familiar with BIM use,
2. Firms are reluctant to initiate staff training and revised work flow,
3. Benefits realized from BIM do not overshadow its implementation costs,
4. Benefits are not tangible to warrant its use,
5. BIM is more risky to warrant its use,
6. Organization culture change,
7. Lack of demand for use of BIM.

Most of these barriers suggest a lack of business benefit and risk reduction from the adoption of BIM. It is not very obvious as to what extent these perceptions reflect reality.

When one looks at construction projects in developing countries that still use traditional technology they find that projects in those countries are experiencing challenges within their construction industries. One study shows that construction projects that have not exploited technology are encountering interruptions in data flow throughout the project life cycle in Pakistan (Masood, Kharal, & Nasir, 2014).

In a study of BIM adoption in India, Yan & Damian (2008), identified a strong acceptance potential for BIM. BIM, with its limited use in construction companies in India reveals its potential in communicating and integrating information across the different trades resulting in smoother and

efficient work processes and better decisions. The efficiency of BIM in comparison to Auto CAD in Indian industry is depicted in the Table 1 (Yan & Damian, 2008).

Table 1: *Efficiency difference between CAD and BIM, Source (Kumar & Mukherjee, 2009)*

The Efficiency Difference Between CAD and BIM Applications for Particular Project in Different Phases				
Task	CAD (Hours)	BIM (Hours)	Hours Saved	Time Savings
Schematic	190	90	100	53%
Design Development	436	220	216	50%
Construction Documents	1023	815	208	20%
Checking and Coordination	175	16	159	91%
Totals	1824	1141	683	

Although technology adoption can face many sources of resistance the improvements made from adopting the new technology are typically worth the efforts. According to Kaner, Sacks, Kassian, & Quitt,(2008) formal BIM training of the personal on a project resulted in elevating the productivity by more 600%. The study concludes that BIM unequivocally improves the quality of precast engineering designs and fabrications and erections are error free with drastically lesser efforts required for checking drawings.

Discussion and Need for Adoption of BIM in Developing Countries

The emergence of BIM has significantly enhanced the overall construction practices of the companies that have adopted BIM in industrialized countries while the barriers of BIM implementation are still persistently inhibiting the adoption process. The US is the leading country in adopting BIM followed by UK although neither of these countries AEC industries have fully adopted BIM. Although developed countries have been focusing on a holistic approach in order to have BIM fully adopted, there are still many barriers that hinder the adoption process. The barriers and challenges to BIM adoption in industrialized countries are, organizational cultural resistance

to change, lack of knowledge about BIM benefits, software and training cost, and benefits to the many companies are not tangible enough to warrant its use. In order to address the problems and issues being experienced, industries need to embrace new technologies to address persisting problems (George Ofori, 1994). To explore the potentials and reasons why BIM was adopted in developed countries a detailed literature review will be conducted to explore the full picture of its application and barriers against adoption.

The trend of construction shared problems within the developing country's construction industry may be a good indicator of a vital need for innovation in developing countries' construction industries. According to Manley et al. (2009) unanimity is on the rise regarding how the innovation processes contribute to improved business outcomes for construction. Construction industries in developing countries need to pay attention to almost all aspects of their current construction practices to increase efficiency. Technological change is merited as a key contributing factor in the development of economies. In industrialized economies, many studies have shown that more than 50% of long term economic growth stems from technological changes that improve productivity (Kim, 1980).

Similar barriers are identified in developing countries AEC industries including: software and training cost, organizations and owners not familiar with BIM, companies lack technical BIM expertise, and owners do not request the use of BIM for their projects.

A further exploration of questions like what issues did the construction companies in developed countries face when adopting BIM. What issues are impeding the adoption of BIM in developing countries?, and what lessons can be learned by companies wanting to adopt BIM in developing countries based on lessons learned from adoption of BIM in both developed and developing

countries, will increase the understanding of why impediments are faced by developing countries in BIM adoption. Addressing these questions will provide sufficient feedback that could help developing countries merit the application of BIM and become educated to take responsive measures against challenges towards adoption of BIM. Further literature review ensuing this chapter will provide enough understanding of the up-to-date status of BIM within both developing and developed countries' construction industries

Chapter Two: Literature Review

In order to effectively assess the potential issues/problems that may impede the adoption of present-day construction management technologies by the AEC industry in developing countries, it is essential to understand the adoption history in countries already experiencing BIM adoption. In this chapter a detailed literature review will be conducted on why BIM was adopted, what challenges BIM adoption encountered, what construction management technology developing countries have adopted and what BIM adoption challenges are experienced so far and finally an overview of the similarities of barriers and challenges against BIM adoption between industrialized and developing countries.

Why Was BIM Adopted?

BIM emerged as a way to create a virtual depiction of a construction project prior to the start of the actual construction work in order to detect, simulate and analyze potential problems and factors of delay encountered throughout the construction phase of the project (Liu, Xie, Tivendal, & Liu, 2015). As BIM related software has progressed the initial use has extended into scheduling, cost control, safety, green certification, and operation and maintenance including infrastructures such as bridges and stadiums.

In order to understand the significance of BIM adoption in developed countries' construction industries, it is necessary to one needs to understand the impact on economic growth that can result from technology adoption The US construction industry supports both local and the national economy. The adoption of BIM to help construction managers increase productivity has enticed practitioners and researchers' to focus their attention to improving and expanding BIM

into other management areas. The benefits of this technology has in turn supported the wide spread adoption of BIM in the US and UK construction industries.

Construction and Economy:

Entrepreneurship is one of the main focuses of researchers and policy makers as they view entrepreneurship as a crucial part of a countries' economic growth and development, driving employment and innovation whereas all scholars consensually believe on different levels of entrepreneurial activity across the countries (Simón-Moya, Revuelto-Taboada, & Guerrero, 2014). In 2008, construction had the highest entrepreneurial rate among all industry groups in the US followed by the services sector (Fairlie, 2009). The development status of a country has an intrinsic relationship with the role and size of construction industries (Lewis, 2009a). Construction brings major socio-economic development through delivering productive infrastructure and facilities (George Ofori, 2007). Ofori also states that construction is an honest sector of the economy that makes up a significant portion of country's national economy.

The positive impact of technology on the construction sector can be observed in Singapore. Ofori (1994) found that as a result of embracing new construction technology in the AEC industries, Singapore's construction industry experienced a seven fold increase between 1984 and 1992. Technological potentials have always been a core element of economic success and welfare in construction and other businesses (Archibugi & Coco, 2004).

Although construction has always been an active contributor in the nation's economic and social development, further technological support will significantly enhance its potential for offering easy solutions to the complex problems.

In view of the construction industry as a main contributor in the nations' economy, developing countries have an urgent focus on innovation in all strata of their construction industries. Lewis (2009b), found that construction has a great impact on the early stages of a countries economic development, and as the economy improves, the impact of construction on the economy regresses. Lewis further notes that in developing countries construction accounts for 60% of the total capital formation while this number falls within 25-30% in developed countries.

There is a close similarity in the results of several studies on the impact of construction on the economy in developing countries. While developed countries experience an upsurge in economic growth as a result of technological improvements and investment, developing countries that do not improve technologically continue to experience negative economic impacts from these decisions. The inability or unwillingness of a developing country to embrace technology could have a direct impact on a country's construction costs.

Focusing on the vital role the construction industry plays on the economy it is important to explore the contemporary construction technology that seems to have realized all the benefits previous researches were calling for. The BIM concept appears the have met these criteria and some aspects of BIM will be discussed in the following sections.

Use of BIM in Sustainable Construction Practices:

BIM has the ability to allow multi-disciplinary information to be superimposed within one model, and enhances the opportunity for that information to be incorporated early in the design stages (Azhar, Brown, & Sattineni, 2010). Azhar, et.al further states that studies merit BIM for complex performance analysis to ensure optimized building design and the generation of documentations used for certifications such as LEED. As such sustainability is an emerging

concept with BIM and its dissemination is rapidly being adopted in a majority of countries. Important decisions in sustainable practices are made early in the design stages and BIM supports sustainable design and the required documentations for green buildings. Limited research has been conducted to support how BIM will affect sustainable construction practices (Bynum, Issa, & Olbina, 2012). Within this context, BIM will best fit in resolving a majority of the energy efficiency design problems (Azhar, Brown, & Farooqui, 2009). BIM is believed to be capable of providing a better transition from the design to the construction phase of the project. Azhar (2011) suggests that the use of BIM for building orientation, analyzing building skin options, site location and daylight studies, will augment the concept of sustainability in early design stages.

Bynum et.al conducted a survey to approximate the diffusion of BIM within the AEC industries and its effects on enhancing sustainability concepts, the result showed that 91% of respondents agreed on BIM's utilization in support of sustainable design and construction (Bynum et al., 2012). The survey also concluded that BIM will be one of the vital tools used for sustainable design and construction in the future. Azhar et al.(2010), conducted CO_2 emissions research on a 52,300 SF LEED GOLD certified building one year after its construction and found that the BIM model predictions for CO_2 emissions and the actual use data were very similar. . However, the authors point out there are future risks and challenges in BIM application include:

1. Lack of interoperability between various BIM based applications.

2. No heartily welcome to BIM by mechanical design communities in BIM based energy analyses and the use of non BIM based software

3. California energy commission has not certified any BIM based energy analyses applications

According to Laine, Hänninen, & Karola, (2007), although there are available software's for accurate thermal simulation for building projects, they are not widely utilized by practitioners because they require an enormous amount of manual data input. With BIM, the data that is initially input into the model can be used to perform a thermal analysis that verifies building thermal performance in various phases and processes.

Use of BIM in Built Environment:

A study conducted by RICS (2014) concluded that BIM has the potential for many direct and indirect benefits to the built environment sector. The benefits include improved information sharing across the entire value chain, time and costs savings, improved quality, transparency and accountability in decision making, increased sustainability, and improved end-user/customer satisfaction. BIM enhances the academic vision of a project team beyond 3D (only drawings), encompassing time, cost, and sustainability as four, fifth and sixth dimensions where other dimensions involved within the project are also considered.

Becerik-Gerber, Jazizadeh, Li, & Calis, (2011) found that BIM is facilitating real-time data access for facility management personnel to make effective decisions when they are conducting preventive and predictive maintenance activities. This is important since buildings account for approximately 72% of electricity consumption, 38% of all carbon dioxide pollution and 39% of total energy consumption (Becerik-Gerber et al., 2011). BIM can be also be used to run building operation scenarios in an effort to find the optimum performance requirements based on external parameters.

Volk, Stengel, & Schultmann, (2014) performed a review of 180 recent publications and found there was little literature on the implementation of BIM in the existing built environment

due to issues such as (1) Higher level of effort required in converting the existing building data to a BIM object, (2) Information update in BIM, (3) dealing with uncertain data and their relations in existing buildings' BIM models. BIM is not only used industry wide in the built environment and existing buildings, it has potential functionalities for facility management and deconstruction operations.

Other Benefits of BIM:

Kalinichuk (2015), reviewed a study conducted by Stanford University's Center and identified the following savings through the use of BIM at Stanford:

1. Elimination of unbudgeted changes up to 40%.

2. Most accurate cost estimation (up to 3% accuracy).

3. 80% time savings in cost estimates.

4. Up to 10% of the total contract value savings due to clash detection potentials.

5. Reduces project time approximately by 7%.

6. An upsurge in the field productivity rate by 20-30%.

7. RFIs and charge orders reduced by tenfold or greater.

According to Wu & Issa, (2013), studies show that in North America, the BIM adoption rate in the construction management industry has increased from 28% in 2007, 49% in 2009 to 71 % in 2012 in the construction industry. The same study quotes from NBS (2012:9), that in the UK, construction professionals using BIM more than doubled (from 13% to 31%) in number between 2010 and 2011. The hasty proliferation of BIM supports the ROI in the construction business through the use of BIM. Yan & Damian, (2008), noted that BIM initially emerged to satisfy the design automation needs by creating a model that represented the actual elements and

components of a buildings. The design automation through BIM can also be used to create building estimates, schedule progress and tracking, green building rating, energy performance, safety plans, and developing reliable baseline for control. BIM also has the potential for clash detection in early design stages that saves significant time in error omission and drawing updates. Khosrowshahi & Arayici, (2012) surveyed the UK construction industry and found that some of the issues BIM can address include: reducing errors, decreased rework and waste, improved sustainable design and construction, improved risk management, more reliable facility and asset management, better coordination of clients' changes to the design and their effects, and many other benefits of technology use within the construction management field. Therefore, technological advancement has been one of the historically rooted concerns of scholars (Tatum, 1988). BIM enticement and utilization is rapidly becoming pervasive as a vital requirement in construction business. Wu & Issa, (2013) quotes Yori (2011) who warned the industry that "Business-as-usual" may eventually turn into "no BIM, no Business".

What Problems and Issues Were Encountered When Adopting BIM in Developed Countries

Due to the adoption of BIM most of the companies in developed countries are in the apex of their competence in the market. However, there are still barriers that hinder the application and adoption process for the rest of the companies in developed countries. According to Khosrowshahi & Arayici (2012) the barriers and challenges against the use of BIM in UK construction companies include:

1. Firms are not familiar with BIM use,
2. Firms are reluctant to initiate staff training and revised work flow,

3. Benefits realized from BIM do not overshadow its implementation costs,

4. Benefits are not tangible to warrant its use,

5. BIM is more risky to warrant its use,

6. Organization culture change,

7. Lack of demand for use of BIM.

The barriers observed, reflect a lack of understanding the potential business benefits and risks associated with BIM adoption; it is not very obvious as to what extent these perceptions reflect reality.

A study conducted by McAuley, Hore, & Deeney (2013) found that the Irish construction industry is lagging behind its international colleagues in BIM application. The reason behind this is lack of resources, lack of awareness, ignorance, and misunderstanding of the diversity of BIM uses. The study merits further investigation of the international construction industry in regards to the adoption and application of BIM in order to understand if BIM can help the Irish construction industry tackle its existing construction challenges. The Irish construction industry may follow the transition undertaken towards BIM adoption by the international construction industries. This will help Irish construction industry to migrate to BIM with less challenges and disruption.

A survey regarding BIM adoption by Khosrowshahi & Arayici, (2012) found that in the UK, 60% of the respondents' were to receive the following regarding BIM adoption: a clear understanding of BIM benefits and how they outweighed the cost and other impeding factors, required training and know-how transfer to their firm and staff, workshops to elevate their knowledge about BIM, software and hardware recommendations, project driven support and

implementation, group effort among the construction stakeholders, and how to populate the databases and identify the investment risk involved with BIM adoption.

Based on Ku & Taiebat, (2011) a study in the U.S identifies several barriers to BIM adoption: 1- Learning curve and in-availability of skilled personnel. 2- Less company investment (cost). 3- Reluctance of the architects, engineers and subcontractors. 4- Inexistence of standards and collaborative work process. 5- Interoperability. 6- Legal issues and contractual agreements.

Thomson & Miner (2006) argue that designers are not necessarily given additional compensation for all the savings and efficiencies attributes to utilizing BIM technology which lessens the motivation for designers to use BIM to its full potential.

What Technology Have Developing Countries Adopted and What BIM Adopting Challenges Do they Face?

Ofori, (1994) argues that the diffusion of construction technology from industrialized countries to developing countries has long been addressing the prominent technological problems of developing countries. According to (Oyelaran-Oyeyinka & Lal, 2004), technologies such as CAD/CAM and CNC machines are not dependent on online connectivity which is why firms in Nigeria and Uganda have adopted these technologies. Ofori's study was conducted in Nigeria, Uganda and India using a semi-structured questionnaire during 2002 and 2003 and suggests that small and medium enterprises (SMEs) have found learning by doing, the most effective style of technological knowledge acquisition.

In order to signify the impact of technology like BIM on construction industries, it is important to look into the importance of the construction industry in developing countries, its

contribution in overall economy and the existing gaps and challenges that may require more innovative solutions.

Construction Industries in Developing Countries

When construction companies expand into developing countries the list of potential issues may broaden to include things like socio economic stress, resource shortage, environmental concerns, globalization, construction industry development, and organization culture (G Ofori, 2000). These challenges continue to rigorous and intimidating to BIM adopters. The literature suggests that the majority of problems relating to delays within the construction industries seem to be similar and persistent in many developing countries. Therefore, the construction industries of Jordan, India, Malaysia, and Vietnam were selected to further explore the chronic challenges of developing countries' construction industries.

Construction Industry in Jordan

The construction sector in Jordan is growing at a fast pace (G. J. Sweis, Sweis, Al-Shboul, & Al-Dweik, 2015). (G. Sweis, Sweis, Hammad, & Shboul, 2008) found that similar to other developing countries, the construction industry plays the main role in Jordan's economy leading to employment and wealth. While the construction industry contributes in the country's economic development, construction projects still experience delays which typically results in unreasonable inflation of the original time and cost (G. Sweis et al., 2008). One of the main causes of construction delays was identified as the contractor's financial inability to fund the project and excessive change orders by the owners. A study on over 130 public projects in Jordan conducted by Al-Momani, (2000) shows that the origin of delays in construction projects can be traced to poor design, increases in material quantities, change orders, site conditions, and economic

conditions. Al-Momani, (2000) also identified similar findings in a study of construction project delays in Saudi Arabia: preparation and approval of shop drawings, payment by the owner, design changes and the slow decision making process of the owners. Studies suggest that further investment and motivation towards the use of IT in the construction sector will increase the quality of the project throughout all phases of the construction (G. J. Sweis et al., 2015)

Construction Industry in India

The Indian construction industry has been one the fast growing industries in the region (Laskar & Murty, 2004) and accounts for most of the major investments in India. Based on Interiors (2015), the total construction industry value in India was $126 billion as of 2013 with a total construction spending of $427 billion, the third highest in Asia. The growth of the construction industry in India from 2000-2013 averaged 11 percent of Indian GDP (Interiors, 2015).According to Laskar & Murty, (2004) the construction industry is the second largest industry of the country significantly supporting the overall economy while providing employment opportunities. The use of technology and the deployment of project management skills and techniques has resulted in the successful completion of mega scale projects in India (Lasker & Murty, 2004). According to Chatterjee (2013) based on the international counterparts' cooperation with Minister of State for Housing, Mining & Industry, a technology program has recently been launched within the construction sector of Indian government. It is further stated that the recent technology launched is Building Information Modeling and this is supported by Tekla Structures. This will enable architects, engineers and MEP professionals work more efficiently (Swarup, 2007).

A study by Vyas (2013) in India, concludes that the major elements impacting delays include equipment issues, employees, decision making power, team work and coordination, and a

lack of strategic planning. Delays caused by equipment included a shortage of the right tools for the work, the use of classical tools as a result of organization culture, calibration of equipment, and installation problems. Delays caused by employees include a random approach by employees on how to execute the construction process, a lack of discussion between teams, interpersonal skills, decision making power, weak feedback to the project teams, and a frequent change of manpower.

   Malaysian Construction Industry

   There are different arguments by scholars whether construction is an important driver of the country's economy whereas, it surely contributes in providing necessary infrastructure that stimulates economy and national development (Olanrewaju & Abdul-Aziz, 2015). Abdul-Rahman et al (2006) argues that the Malaysian construction industry vitally contributes to the country's economy. Rahman et.al further introduces the causes of delay in construction projects as variations and planning issues (2006). As a result of a survey conducted, most of the participants believe that owners are the main reason behind project delays and that they never cooperate with making decisions in a timely (Abdul-Rahman et al., 2006). Sambasivan & Soon (2007), studied the Malaysian construction industry and identified ten important causes of construction delays. These causes are, (1) Contractors' Weak planning, (2) contractor's poor site management, (3) inadequate contractor experience, (4) inadequate client's finance and payments for completed work, (5) problems with subcontractors, (6) shortage in material, (7) labor supply, (8) equipment availability and failure, (9) lack of communication between parties, and (10) mistakes during the construction stage (Sambasivan & Soon, 2007). The impacts of the delays are listed as time overrun, cost overrun, disputes, arbitration, litigation, and total abandonment of construction projects in some cases.

Afghanistan Construction Industry:

Although the construction industries in Afghanistan have been one of the largest contributors in creating jobs and has been a major driver of economic growth, the construction practices and technologies used within the industries are the same old fashion methods except for the technology used for basic design purposes. Most of the high level and complicated design works are being performed in foreign countries (USAID, 2012). Gidado & Niazai (2012) state that due to plethora of reasons in Afghanistan, construction projects do not meet their baseline and original finish milestones. These delays usually are followed with unpleasant consequences resulting in the donor investor's reluctance to continue funding thus slowing the development process. After an in-depth study and survey, it was identified that the poor qualification of contractors, security, poor site management and supervision by contractor, slow decision making, poor risk management, unforeseen site conditions are some of the leading causes in construction projects delay (Gidado & Naizai, 2012). Gidado & Naizai (2012) also found that a study on high raise buildings in Indonesia shows that schedule overrun was less severe than cost overrun in Indonesia. The significant factor leading to cost overrun was material fluctuation and inaccurate material estimation and complexity, therefore, Afghanistan as a developing country shares these challenges in its construction industry. Initiatives have been taken in order to enhance the capacity of the construction industries in Afghanistan while this initiative may need to expand further and introduce industries to new technology for better planning, design and overall construction management.

Construction Industry Challenges **in Vietnam**

Vietnam's construction industry is a fast growing industry that heavily contributes to the country's economy (Ling & Bui, 2009). The study finds that the Vietnam construction industry

is providing AEC firms with tremendous opportunities since economic growth demands a proliferation of built facilities. Although construction seems to be a successful business, it still experiences communal problems similar to those of other developing countries. Based on Le-Hoai, Dai Lee, & Lee, (2008) more than 57% of construction projects are experiencing overruns due to recurring delays. The study further explains that in Vietnam, construction projects have regularly faced delays and cost overruns. Also poor site management and supervision, financial difficulties, design changes, unforeseen site situations, inaccurate estimates, shortage of material, design errors, and others were identified as factors resulting in project delays and cost overrun. Ling & Bui, (2009) highlights that cost overruns and delays are not unusual in Vietnam construction projects. Further problems found in the Vietnam construction industry are reported as incompetent designers, poor estimates, change management, obsolete technological and social issues, and improper techniques and tools.

Barriers to the Adoption of BIM in Developing Countries

As noted in the literature many of the challenges and problems within the developing countries' construction industries are ultimately leading to cost and schedule overrun and the same was the result of challenges within the developed countries' construction industries. Therefore, some of the companies in developing countries are trying hard to overcome these challenges by adopting innovative technologies such as BIM. Masood, Kharal, & Nasir (2014) conducted a study on the Pakistan construction industry regarding the application of BIM, the result of the survey reveals that BIM practitioners in Pakistan perceive two major benefits of BIM, cost saving and time saving in construction projects. The study further explains that barriers to BIM implementation seem to have been shattered due to a pervasive level of BIM awareness among companies. Although, the barriers are reported to be near to none, there are very few companies

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using BIM in their projects meaning that companies still require adequate support in terms of guidance and process of BIM application and adoption. A study conducted on Nigerian construction industry by, (Abubakar, Ibrahim, Kado, & Bala, 2014a) reveals the barriers to the adoption process of BIM. The barriers were assigned relative importance index to identify their level of importance and resistance (Table 2).

Table 2: *BIM adoption barriers in Nigerian construction industry. Source: (Abubakar et al.; Abubakar, Ibrahim, Kado, & Bala, 2014b)*

Barriers to the Adoption of BIM in the Nigerian Construction Industry		
Barriers	RII	Rank
Social and Habitual Resistance to Change	0.824	1
Legal and Contractual Constraints	0.791	2
High Cost of Training	0.783	3
Lack of Enabling Environment (Government Policies and Legislations)	0.697	4
Lack of Trained Professionals to Handle the Tools	0.665	5
Clients Not Requesting the Use of BIM on Projects	0.657	6
No Proof of Financial Benefits	0.648	7
High Cost of Integrated Software/Models for all Professionals	0.64	8
Lack of Standard to Guid Implementation	0.579	9
Poor Internet Connectivity	0.555	10
Frequent Power Failure	0.477	11
Lack of Awareness of the Technology Among Industry Stakeholders	0.408	12

Based on a survey by Yan & Damian (2008), the respondents had different perspectives in regards to the reasons and barriers to BIM use within the Indian construction industry (Figure 2).
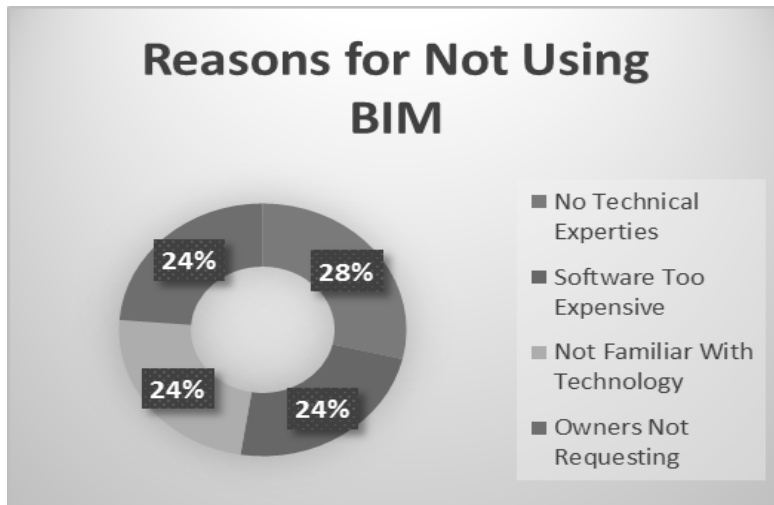
Figure 2: *Reasons for not using BIM. Data source(Kumar & Mukherjee, 2009)*

In order to seek innovative solutions to the chronic challenges they face, the Malaysian construction industry is focused on innovation to the existing construction systems; as a result, preliminary Building Information Modeling adoption is being tried (Pour Rahimian, Ibrahim, Imoudu Enegbuma, Godwin Aliagha, & Nita Ali, 2014). Since the BIM model's successful adoption is reliant on the collaborative contribution of project teams, challenges such as people, processes and technology may slow the adoption rate by the Malaysian construction industry. Most of the scholars are in the process of carrying out researches on helping industries to prepare and raise their awareness regrading BIM adoption by the construction industries (Pour Rahimian et al., 2014). As suggested by the literature, most of the BIM adoption/application challenges are similar in developing countries' construction industries with slight differences from country to country.

Are BIM Adoption Issues the Same for both Developed and Developing Countries

As observed in the literature, industrialized countries are struggling with seeking holistic approaches toward fully adopting BIM in their construction industries. On the other hand some of the developing countries are lagging developed countries in BIM implementation while others have started with raising the awareness about BIM technology within their construction

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industries. Looking at the trends of barriers to BIM adoption in both industrialized and developing

similarities can be observed. Some of the perceived barriers in both developed and developing

countries (Table 3).

Table 3: *Comparison of Barriers against BIM Adoption in Developed and Developing Countries. Sources: (Yusuf Arayici, Khosrowshahi, Ponting, & Mihindu, 2009), (Kumar & Mukherjee, 2009), (Abubakar et al., 2014b), (McAuley et al., 2013)*

Comparison of Barriers Against BIM Adoption in Developed and Developing Countries			
Barriers in Developing Countries	Country	Barriers in Developed Countries	**Country**
Lack of awareness regarding technology among industry stakeholders	Nigeria	Lack of awareness	Ireland
No technical expertise	India/Nigeria	Learning curve and unavailability of skilled personnel	USA/UK
Software and training cost	India/Nigeria/ Malaysia	Software and training cost	UK
No proof of financial benefits	Nigeria	Benefits are tangible to warrant its cost	UK
Social and habitual resistance to changes	India/Nigeria/ Malaysia	Firms are reluctant to initiate staff training and revise work/organization culture change	UK/Ireland
Not familiar with technology	India	Lack of resources	Ireland
Owners do not request its use	India/Nigeria	Lack of demand for use of BIM/ Less company investment (cost)	UK/USA
Legal and contractual constraints	Nigeria	Legal issues and contractual agreements	USA
Lack of enabling environment (Government policies and legislation)	Nigeria	Inexistence of standards and collaborative work processes	USA
Clients not requesting the use of BIM in projects	Nigeria/Malaysia	Reluctance of the architects, engineers and contractors	USA
Lack of standards to guide implementation	Nigeria/Malaysia	BIM is more risky to warrant its use/Interoperability	UK/USA
Poor internet connectivity	Nigeria		
Frequent power failure	Nigeria		

What deserves attention is that companies who have adopted BIM are fully satisfied

with its proven benefits and no major drawbacks reported by them. However many companies

with lesser experience are reporting drawbacks and barriers during BIM implementation. Since

construction firms do not have a clear understanding and best practices of BIM available to them,

most of the firms vacillate on adopting this cutting edge technology and building their capacity for

better production, efficiency and competition in the global market (Y Arayici et al., 2011). The

absence of clear guidance and clearer process of implementation as a hindrance may be true for developing countries' construction industries.

Need for the Study

The literature suggests that BIM is in a rapid and pervasive dissemination stage within the industrialized countries' construction industries. It was welcomed for its potential to address the chronic challenges that traditional construction technology could not address. BIM emerged as a result of struggles to automate and further elaborate construction and design practices over time. Although BIM is an ideal approach to more sophisticated solutions for a large number of challenges in construction industry, there are still barriers and hindrances along its implementation. When compared to its predecessor construction technologies, BIM is not only a program software but both a program and process which sets a unique perimeter of conditions for its implantation. Companies willing to adopt BIM are facing both new learning and work processes simultaneously. BIM as a process requires team members work more collaboratively than ever before. This collaboration in turn requires a robust information sharing processes. Collectively, barriers to BIM adoption in developed countries comprise, but are not limited to, a lack of awareness, associated costs, people's attitudes, changes in work flow, a lack of sufficient information in return on investment, limited skills within the industry and legal aspects of contracts involving BIM.

Some of the developing countries are sharing a majority of the same challenges within their construction industries as those in developed countries relating to cost and time overruns. As a result industries in developing countries, to some extent, are using BIM to address these problems. The literature suggests that, although some of the companies in developing countries have experienced surprising benefits of BIM use, adoption barriers have been reported by some

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others. Reviewing the construction industries from a few different countries, adoption barrier similarities were observed within those countries. The similar barriers include: lack of awareness, lack of technical expertise, habitual and social resistances, program and training costs, clients not requesting use of BIM, and legal aspects of contracts involving BIM.

Further comparison of the barriers to the adoption of BIM noted that not only there are distinct similarities of barriers to the adoption of BIM between industrialized and developing countries' construction industries, but also majority of these hindrances are shared between both developing and developed countries.

It is important to know that the companies who have fully adopted BIM are in their apex of competencies and success while others with a lower level of adoption or no implementation experience at all, are reporting barriers and hindrances during the implementation process. The literature does not provide information on why these two different categories of companies (companies with full BIM adoption & Companies with lower level of implementation or no BIM experience) and individuals (BIM professionals who have adopted BIM & individuals with no BIM experience and knowledge) have different perceptions regarding BIM adoption and may require further study.

In a summary the literature identifies similarities between barriers to the BIM implementation in both developed and developing countries. The literature also indicates that developed countries are adopting BIM at a more rapid pace than developing countries, therefore, it is important to further explore the experiences of risk takers or early adopters of BIM to provide industries in developing countries with in-depth information on processes followed for successful BIM adoption by the early adopters. This study will provide lessons that can be learned from early

BIM adopters in terms of implementation process, expected challenges along the implementation process and implemented solutions. It appears that companies that are willing to adopt BIM in developing countries, if provided with lessons learned from successful adopters, will benefit and be will equipped for successful BIM adoption within their companies.

Chapter Three: Methodology

The adoption of BIM in developing countries is an area of importance to ensure that when BIM is adopted, potential issues/problems are known and can be addressed prior to starting the adoption process. The literature review found that there are likenesses to the adoption of BIM in both developed and developing countries.

The aim of this research is to examine early BIM adopters lived experiences to identify potential issues and trends a construction company in a developing country may encounter while adopting BIM. The lived experiences of early adopters appear to be the best data source for this type of study which seeks to identify potential problems in BIM adoption in developing countries based on actual experiences in developed countries. These lived experiences are invaluable to a construction company in a developing country as they may help identify and mitigate a problem prior to adoption of a BIM related software. According to Creswell (2013) the problems for which the understanding of individuals' lived experience and phenomena is essential, are the best suited problems for phenomenological research. Therefore, phenomenological research mythology is considered the best approach for this type of research.

The identification of potential participants for the study was the biggest obstacle for this study. There are several iterations of BIM type software dating back to the early 1990's therefore finding people who have not only used this software's but taken them to the next level was critical to this study. These early adopters understand the need for interoperability between software's, the need for increased computing power, and the need for some type of standardization in the industry. They also understand the limitations of what early software versions of BIM could and could not do relative to supporting infrastructure. The process of finding potential participants

started with the identification of complex early projects that were built in the U.S. using BIM which enabled those projects to be constructed. Once the projects were identified the identification of individuals that worked on the modeling of the projects was undertaken. This was done through a network of individuals known in the industry and the graduate program the author attended. Once several key individuals were identified the process of recruiting the individuals for the study was done.

After obtaining permission from the Institutional Review Board at Colorado State University arrangements were made to interview the participants in person whenever possible and by phone in other instances. The data was collected through an unstructured in-depth interview with the research participants. In all cases the interviews were recorded, with the permission of the interviewee, to be transcribed at a later date for analysis. The participants were also given a chance to review the transcripts to ensure that they were comfortable with the information they had provided and provide feedback in cases they may view as an incorrect transcription of the recording. At the end of the interview each participant was asked to identify anyone they thought could benefit the research process; a snow ball sample as illustrated in the diagram in Figure 3.
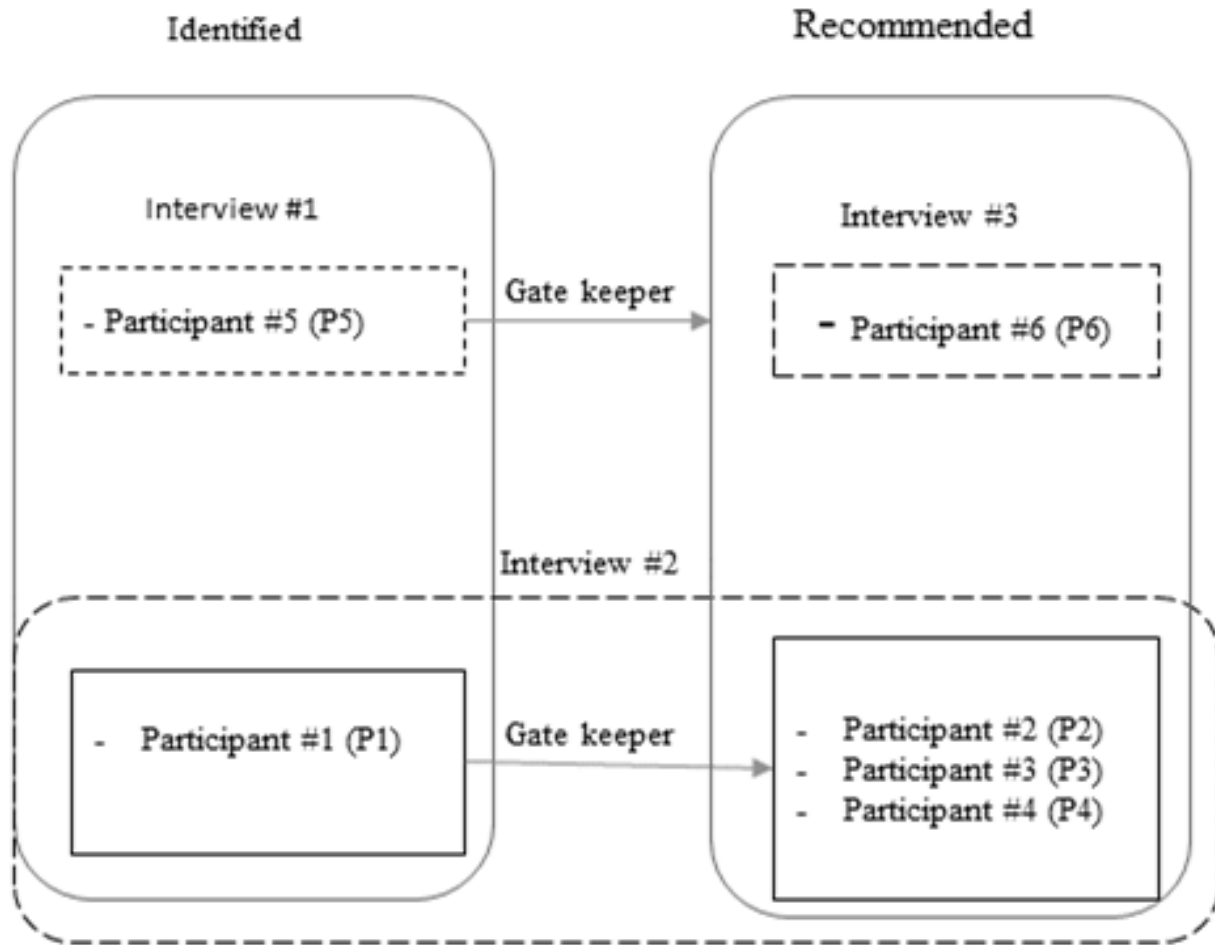
Figure 3: *Initial Participants Snowball Identification Diagram*

Each interview was assigned a code to avoid the use of individual identifiers throughout the study (e.g, participant P1, P2…etc, July, 15, 2015). Field notes were the secondary data storage method in this research since memories are short and human minds tend to forget quickly; field notes are crucial in qualitative/phenomenological research. Groenewald recommends four types of field notes for phenomenological research (Groenewald, 2004):

1- Observational Notes: Also called the 'what happened notes' are deemed important to emphasize the use of all the senses in making observations.

2- Theoretical Notes: 'attempts to derive meaning' as the researcher thinks or reflects on experience.

3- Methodological Notes: 'Reminders, instructions or critique' to oneself on the process.

4- Analytical Memos: End-of-a-field-day summary or progress reviews.

Once the data is gathered, Hycner's (1999) explication process was followed as suggested by Groenewald (Groenewald, 2004):

1. Bracketing self-presupposition: No position is taken for or against researchers' presupposition. Researchers' theoretical concept, meanings and interpretations are to be avoided from entering the unique world of participant. It is basically bracketing researcher's personal views and preconceptions.

2. Delineating units of meaning: in this stage, the data and statements informative to the researched phenomena were extracted. While bracketing self-suppositions, considerable amount of judgment calls were made while units of similar meanings were extracted

3. Form themes by clustering of units of meaning: Grouping the units of meanings formed cluster of themes. The meanings of clusters were further interrogated to establish central themes which in turn, expressed the core of these clusters.

4. Summarize each interview individually and validate the information by the informant: A validity check was conducted by returning to the informants to make sure the fundamental nature of interview was captured accurately and fully.

5. In this stage, general themes for all the interviews were included in a composite summary.

This process provided a wide spectrum of data pertinent to the phenomena of the individual similarities of issues relating to the early adoption of BIM in a country. The analysis of this data

will result in the identification of best practices and lessons learned that can be used to anticipate issues/problems that could interfere with BIM adoption in a developing countries construction industry.

Data Sampling and Validation

The selection of the participants is one of the initial steps taken towards data gathering and sampling. Determining the proper sample size for this research was the next step. Englander argues that small sample sizes, probably no more than 10 participants, are most suitable for this type of research while the minimum number of participants is limited to three (Englander, 2012). Large samples can become unmanageable therefore, in this study a total of six (6) participants were selected for data gathering purpose. Five participants contributed to the study are all currently working with construction firms in different states in the U.S. while the sixth participant is a professor in Vietnam. All the participants have the first-hand knowledge and experience of BIM applications in construction projects and construction companies going back to the first iterations of BIM type software. This process resulted in selecting informants that appear to be a representative sample of early BIM adopters from which to interview. Participants (P5 & P6) were interviewed over the phone since travel to meet with them was not an option due to funding issues. Four informants (P1, P2, P3, and P4) lived close enough to the author to allow for a face to face interview at their place of employment.

Developing the open ended questions to start the interview was another important step in preparing for the interview. The questions developed for this research were all open ended unstructured questions with the goal of starting the conversation where the interviewee tells about their BIM related adoption experiences. They were also used to prompt additional information and

detail as needed throughout the interview process. In phenomenological research it is important to contextualize the context of the phenomena that is being studied to capture the interviewees lived experience (Englander, 2012). Following the introduction of the topic and the informed consent process, the participants were asked the following open ended unstructured questions:

Interview Questions:

1. Why did you choose to adopt BIM?

2. What problems/issues did you encounter when you first adopted BIM?

3. If you were adopting BIM is a developing country, what issues would you anticipate needing to overcome to make that adoption successful?

4. In your experience do you think that BIM adoption issues would be the same for everyone that wants to adopt BIM irrespective of working in a developed or developing country?

5. Please tell me about your experience about adopting BIM for the first time in your projects and when your first time occurred?

6. In your role as a GC, how easy or hard is it to work with local contractors, either in developed or developing countries that have not used BIM previously?

7. Excluding the potential lack of physical infrastructure in developing countries, what challenges do these developing countries face when adopting BIM for the first time?

8. If you were working with companies/people in developing countries to adopt BIM for a project, how different do you think the challenges are in this scenario with that of adopting BIM in one of the industrialized countries

9. When your company works on projects where BIM is used what are the minimum requirements for infrastructure: equipment, programs, worker knowledge, etc.

10. If you are working on a BIM driven project with subcontractors that do not use BIM, how would you structure your processes to accommodate this situation?

These types of unstructured open ended question helped start the conversation with the interviewee allowing them to relive their experiences in great detail as experienced in the real life application as a BIM early adopter. Interviews were recorded while the same time notes were taken to record the important ideas or phrases that interviewee's imply through their facial or vocal expressions.

All interview records and notes for specific participants were clearly labeled and dated using the coding scheme previously identified. Once data collection was done, all recorded interviews were transcribed thoroughly before any analysis. All transcriptions were then returned to the participants for validation to make sure nothing is taken out of context in the written notes or expressed different than participant's original view and thoughts in order to capture the pure phenomena. Soon after the participant validation process, the data analysis was conducted via putting all general and unique themes into a composite summary.

Analysis Process and Composite Summary

According to Creswell (2013, p. 180) "Data analysis in qualitative research consists of preparing and analyzing the data (i.e., text data as in transcripts or image data as in photographs) , then reducing the data into themes through a process of coding and condensing the codes, and finally representing the data in figures, tables, or a discussion. Across many books on qualitative research, this is the general process that researchers use."

After the data collection completion, the analysis process was started with listening to the interview recordings multiple times to make sure the author had a full understanding of the

interview discussions prior to undertaking the transcribing process. The author then started with the transcription process while browsing through the transcriptions for full understanding of the first impressions as suggested by Creswell (Creswell, 2013, p. 180),. In addition, the author also took notes during this process as suggested by Creswell   underlining any noteworthy statements and or speech marks that impart understanding of how the participants experienced the phenomena by browsing through the data collected; a process called horizonalization. All the transcriptions, together with the interview recordings, were then imported to Nvivo software for facilitating the analysis process. Meanwhile, the interviews transcriptions were tabulated according to the answers given to the specific interview questions for all three interviews in order to compare the overall experiences and ideas of the interviewees for each question. As suggested by Creswell (2013), once the data organization is completed, the author performed a continuous analysis to gain an in-depth understanding of the data in hand. Following this process helped the author in the coding process as having a general understanding of the data helped the researcher index the data in a more comprehensive manner (Figure 4). During this process the author was able to pre-identify comprehensive themes and indexes that were later used for the data in hand. After a full understanding of the data and all the essential notes taken, the answers from all three interviews to each specific question was coded.
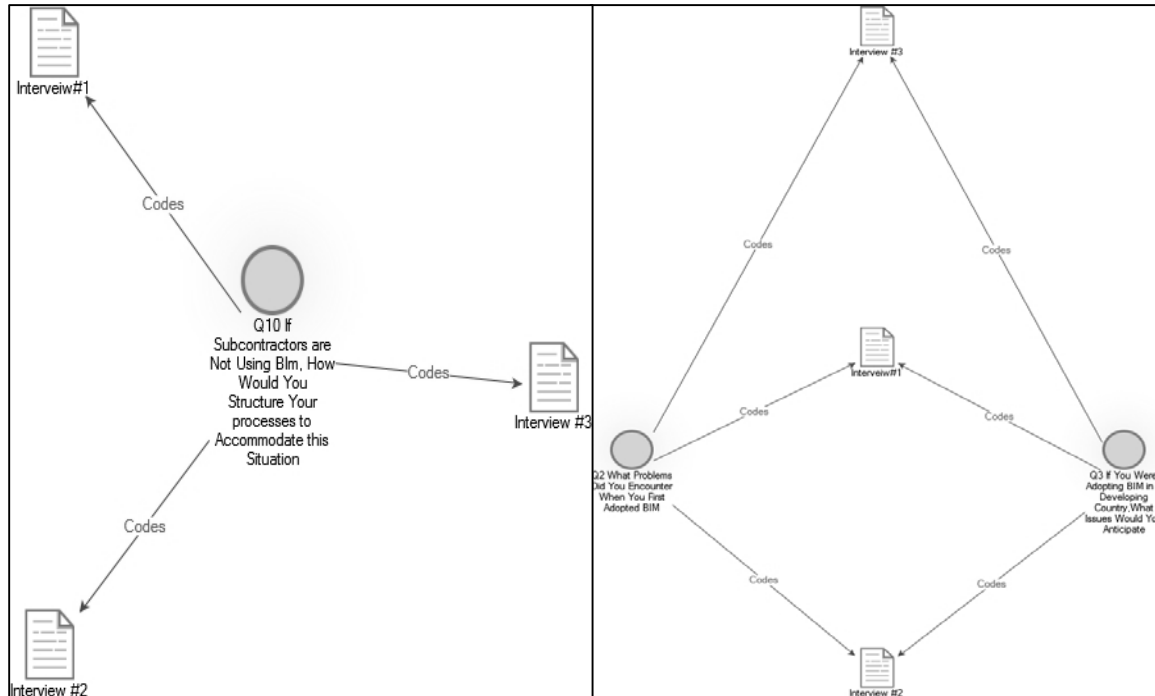
Figure 4: *Coding Process. Source: (Nvivo)*

The step following the memoing and reading the data was forming codes and categories which is the aggregation of the data into small pieces of comprehensive information as suggested by Creswell (Creswell, 2013, p. 183). The coding or indexing process was started with reviewing and pondering over the research question and then transforming the research question to a focus prompt (a phase that guides the generation of codes to represent the relevant information in the data). All the codes were generated after fully understanding the data as a whole, whereas in cases new themes were emerging, the researcher kept adding new codes to represent the new emerging themes. Different approaches were undertaken to select code names for instance, some of the code labels were selected as "in vivo codes" or "code labels" the researcher composed to best describe the information as suggested by (Creswell, 2013, p. 185).

Once a significant amount of information was labeled, the author started to classify the labeled information into themes as suggested by (Creswell, 2013, p. 185). A sufficient number of

themes were generated to the best of the author's knowledge in order to assimilate enough information to answer each question where all themes relevant to the questions were clustered or aggregated into a single category under each interview questions (Figure 5).
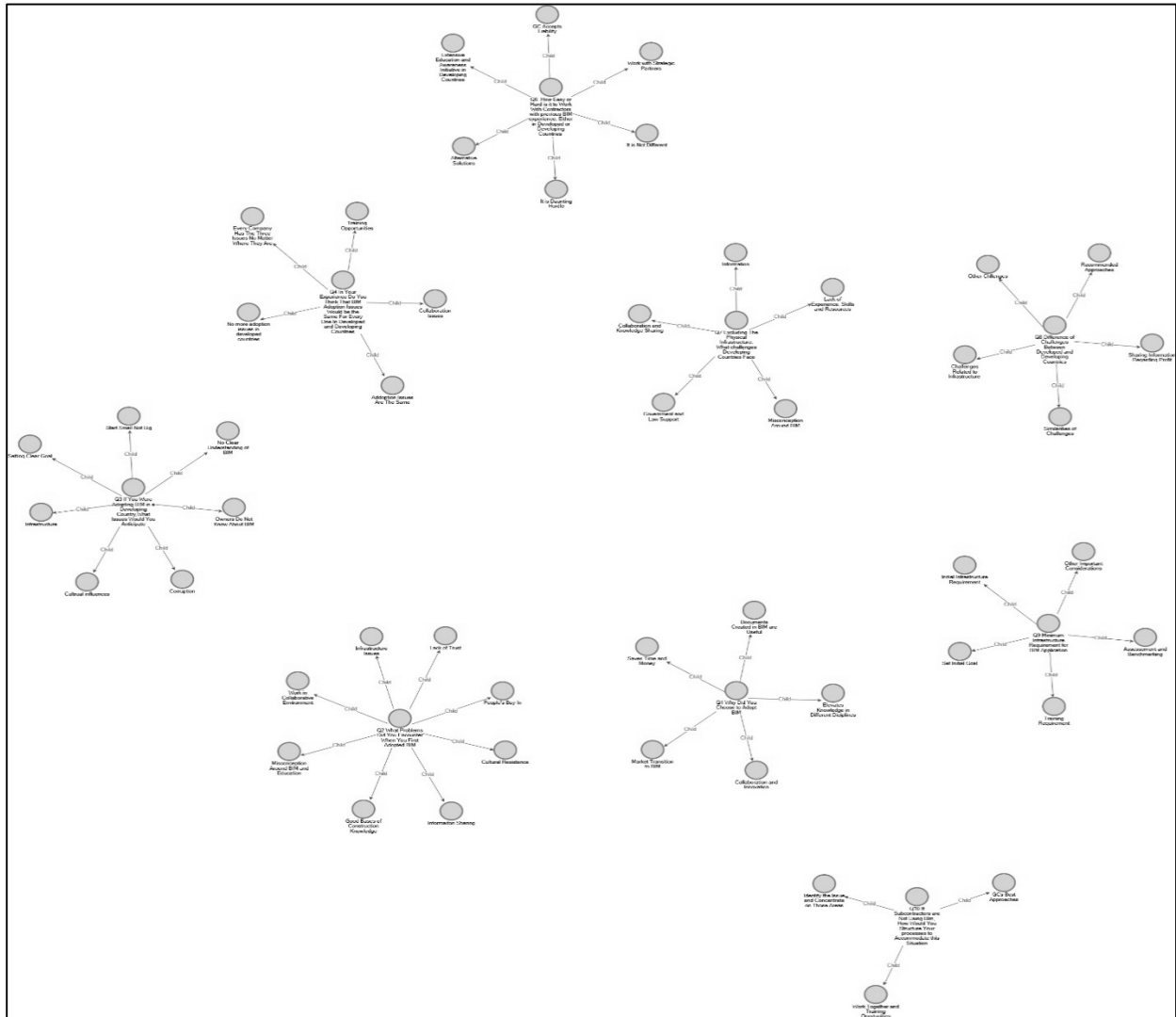
Figure 5: *Categories and Themes Illustration. Source: (Nvivo)*

Following the process of arranging the data into a family of themes or categories for each question, the author started interpreting the data. Following Creswell's (2013, p. 186) format, when conducting qualitative research, the researcher employs data interpretation which involves

making sense of the data as lessons learned. Therefore, the researcher initiated organizing the themes into larger units of abstraction to make sense of the data for each question.

In the final phase, the data was represented as packages of findings in text and visual, created in Nvivo formats as suggested by (Creswell, 2013, p. 187). A graphic of the overall process is represented in (Figure 6).
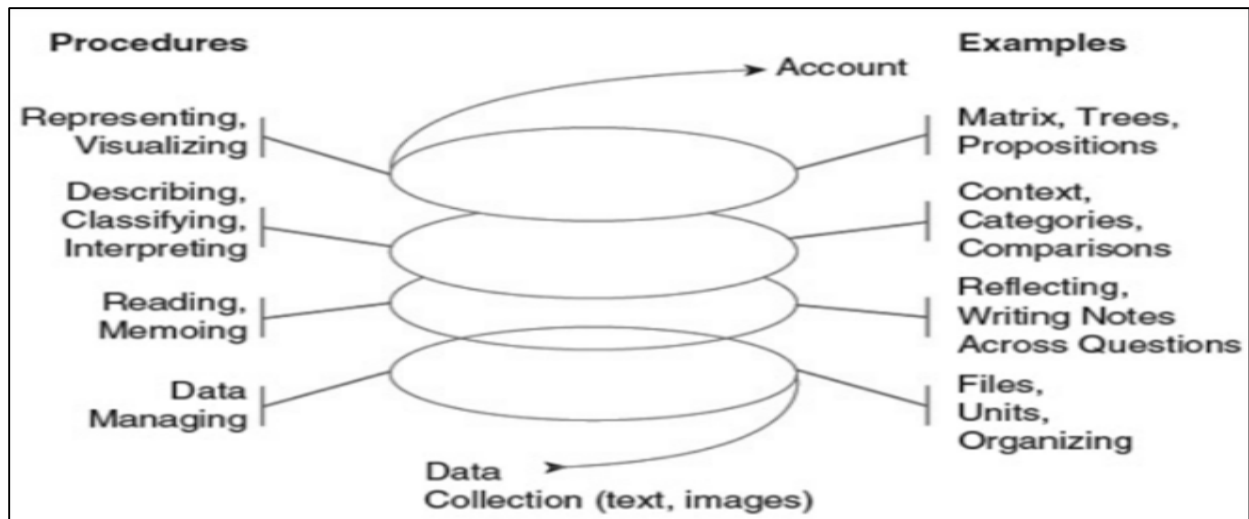
Figure 6: *Data analysis spiral, source (Creswell, 2013, p. 182)*

Limitations to the Study:

The majority of the participants were from developed countries; the U.S. in particular. Through the snowball sampling method one participant was recruited from Viet Nam. While this could be construed as a limitation the purpose in using phenomenology to learn about peoples lived experiences is to look for those participants that have the lived experiences of early BIM adoption. Since most of the early adoption of BIM took place in the U.S. the participant selection meets the criteria of this methodology. The international participant did bring additional insight to the study regarding early BIM adoption in Viet Nam.

The indexing (coding) process was conducted by the author while constantly trying to bracketing self-suppositions to avoid introducing any bias to the analysis process. Considering the smaller data sample, acceptable in this type of research, the data was sent to the participants for validation prior to writing the final version of the paper. This process took the place of using multiple people to code and analyze the data; a process known as inter-rater reliability. Based on this process the author has provided sufficient safeguards into the data collection and analysis process to ensure a high quality study.

Chapter Four: Analysis

The purpose of this study was to identify the challenges/issues one may encounter when adopting BIM in developing countries. The data collected to answer this question came from early BIM adopters in developed countries; specifically the U.S, and one developing country, Viet Nam (Table 4). Through their lived experiences these early adopters can help those wishing to adopt BIM in developing countries plan for and anticipate potential barriers they may encounter when adopting BIM in their country. The insight from the early adopters with first-hand knowledge in BIM adoption is a valuable resource for individuals and construction companies willing to adopt BIM. The main criteria for selecting the participants was first hand BIM experience, from an early adopters perspective, on construction projects in both developed and developing countries and a solid understanding of BIM or BIM expertise. Having these criteria in mind, the researcher was able to identify 6 individuals who had not only extensive BIM knowledge but also have adopted BIM in their companies in the United States and an individual with first hand BIM knowledge in Vietnam.

Table 4: *Participants Attributes*

Participant	Reviewed transcripts	Developed Country
P1	Yes	Developed Country
P2	Yes	Developed Country
P3	Yes	Developed Country
P4	Yes	Developed Country
P5	Yes	Developed Country
P6	Yes	Developing Country

The reason for setting such criteria for the research participants was to conduct interviews with them in order to capture their lived experiences relating to the adoption of BIM in their company. Since this study is a qualitative phenomenological research, the interviews are the main source of data where participants are sharing the pure phenomena they have been through and what they could have done differently for better results of their BIM application experience. The informants who participated in this study come from different but interrelated backgrounds such as architecture, construction and civil engineering. All the participants have an extensive background of using BIM (**Figure 7**). One participant has used BIM since 2011, two of the informants have used BIM since 2008, one participant started using BIM in 2006, one participant started using BIM in 2001, and the earliest adopter started using BIM in1997. The term BIM was not coined at that time and the most commonly used program was Bentley Tri Forma.
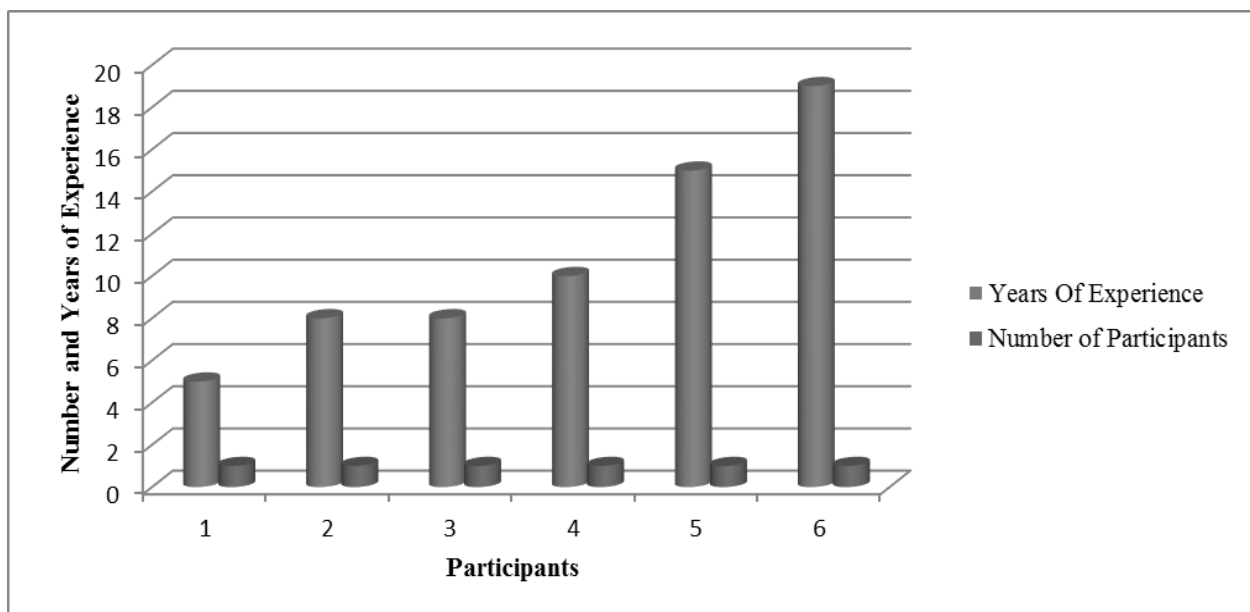
Figure 7: *Participants by number of years of BIM experience*

All the interviews were recorded by the researcher, with participant consent, for transcription at a later time. All the participants were given the same open ended or unstructured

interview questions since they all were BIM experts with applied first hand BIM knowledge. Three

interviews took place; the first and third interviews were conducted over the phone, each with one

(single) individual. The second interview was conducted with four participants as a group in a face

to face setting. Most of the participant's responses were labeled with the participant's names when

taking notes to make sure the researcher will accurately recognize the recorded voices in order to

assign accurate identifiers to each individual's comments for analysis purposes. The interview

transcriptions were also sent back to the participants for validation and accuracy confirmation.

The open ended questions were developed such that the participant's perspective and

actual story of the phenomena they experienced were drawn out. The researcher, aside from taking

notes during the interview, was repeating any previously undescribed or vague portions of the

interview during the discussion to make sure they fully understood the phenomena; in essence the

author continually asked for clarification of thoughts during interview.

Interview Response Analysis:

The initial step of the analysis was to come to a complete and profound understanding

of the interview discussions. The researcher re-listened to the interview recordings in full, multiple

times, to gain a better understanding of the lived experiences and to better understand each

individual interview as whole. The goal while listening was to hear and understand the exact

meaning of what participants were saying. This not only helped the author gain a profound

understanding of the individual interview data but also led to a more accurate transcription of the

interviews. The actual writing process also contributed a lot to the analysis because of the

additional time spent on the subject and discussion around it. In order to avoid personal

identifications, participants' names were assigned codes from P1 to P6 where P1 indicating

participant #1 and P6 indicating participant #6. The interview transcriptions were sent to participants for validation and to confirm their accuracy after transcription.

Why Did You Choose to Adopt BIM?

This question was aimed to find out about the participants' perspective on incentives motivating companies or individuals to adopt BIM. Pondering over the answers, there seems to be similar patterns of ideas observed between five participants reasoning that BIM fosters an environment of collaboration and innovation. P5 mentioned that BIM applied to a project is the best thing ever from a designer's perspective. P1 further explained that with BIM, different areas of specialties could be explored, from site logistic coordination for projects to visualization and finally doing estimates even for people coming from an architectural background. BIM therefore facilitates a collaborative work environment while elevating individual's skills in variety of areas in construction management, design and architecture. This participant also believes that BIM as any other technology, alone will not solve any issues; it facilitates how to work collaboratively and innovatively.

P2 believed the adoption of BIM within the company they were working for was totally reactionary to the trends of BIM application in the market in 2007. The concept instilled to the CEO at that time was "no BIM no business in the future". The reactionary behavior of the company's CEO towards adoption of BIM implies the history of BIM in the market and its enticement potential for the business owners before 2007 which bolsters the arguments of scholars that BIM implementation and adoption process has been slower than anticipated. P1 highlights that their company did not adopted BIM until 2007 making them late adopters as the rest of the market had adopted BIM in 2000. P2 during the interview felt that the inherent characteristic of

the use of BIM as a tool today generates processes that aid in building a building faster and more efficiently thus enticing companies adopt it.

The participants' responses to the question depend on the view of the participants from the experience and phenomena they have been through. Observing the response from P6, the benefits inherent with the use of BIM resulting in participant's transition to BIM is that, BIM saves a lot of time and money. The participant further explained that documents created through the use of BIM are very useful and can easily be understood by clients and the team. The phenomenon explained by this participant aligns with the reported benefits of BIM in the existing literature. For example, one of the reasons that P6 likes to use BIM was that many impractical requests by clients now can easily be coordinated and dropped from consideration due to the easy understanding and depiction of the client's requests in early stages of the design as well as the use of 6D BIM in facility management. Overall, it was observed that participants in developed countries are more transitioned towards collaborative and multigenerational working environments which is best supported through the application of BIM whereas the participant from a developing country highlights the inherent benefits that BIM technology can offer rather than the processes generated by BIM.

A word frequency query was generated separately for each question in Nvivo to identify words most frequently used by participants. The frequency of the words would imply two concepts, one, the word is either used by all participants and/or the participants were repeatedly insisting on a concept or concepts. The contexts in which these words were used was examined to draw a general understanding of participants' agreement on these concepts. In the word frequency query, the higher the frequency of words used, the larger the words are depicted in Figure 8. The

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words frequency queries emerged from the themes identified in Nvivo while the grouping of words was limited with synonyms.

Figure 8: *Word Frequency Query for this question: Source (Nvivo)*

As depicted in figure 8, in response to this question, participants had used collaboration in the context of BIM is fostering collaborative environment whereas this factor emerges as one of the resistances against the use of BIM as well. The different specialty areas like mechanical, visualization, preconstruction estimates and coordination are some of the benefits participants realized through the use of BIM. P6 mentioned "understanding" in the context of products produced by BIM are more comprehensive and that clients' increased understanding of the product gained from BIM is a significant factor in the success of BIM application in developing countries. P6 also mentions BIM saving time and money. This was a unique response that other participants

did not touch on thus not visualized boldly in the word frequency query whereas this incentive has been reported by other studies repeatedly.

What Problems/Issues Did You Encounter When You First Adopted BIM?

The question was intended to highlight the phenomena standing out as a preliminary challenge to early adopters. Interestingly, it was observed that one of the challenges that still persist in most of the companies represented in this study, even in developed countries, emanates from work habits like being used to doing things on a regular basis. Four of the participants expressed that a collaborative work environment, inherent with the use of BIM for successful results, was a challenge until people got used to BIM and working collaboratively. P1 feels that collaboration and working together with people in order to receive their buy-in is essential. Most importantly, these collaborations require ample effort from BIM users to constantly validate their work to receive the buy-in needed from parties vital to the project. Lacking collaboration skills and a complete understanding of their work will result in others rejecting the use of BIM. P3 elucidates that collaboration becomes a hurdle when everybody within the team is not using BIM or if only a few people are using it. P2 notes that a lack of collaboration between the experienced people that are not using technology with the newly out of school-students results in an information gap. To ensure that BIM information flows downstream constant coordination needs to be maintained. P1 confirms that the habit of working in a transparent and collaborative environment inherent with the use of BIM is challenging for most of the people as it takes time to transition from old to new habits.

Another hurdle discussed by the participants was the misconception around BIM. Four of the participants stated the misconception around the term BIM was a hurdle. P2 explained that

a lack of education seems to have resulted in a misconception about BIM. A majority of the people using Revit perceive that they are doing BIM just because they use Revit and Revit means BIM. In other cases people claim to know what BIM is as they know what BIM stands for. Unfortunately, BIM needs profound understanding of the tool and process not a simple definition. This idea seems to be further exemplified by P3 stating that

> *(P3)- "So, there is something lost in translation where design teams and a lot of people are not really looking into the issues that they should be finding because they think the model is going to find it for them and it is not happening."*

Understanding any tool or program, obviously is important in order to select the right tool for the right purpose. In regards to BIM, this understanding seems to be transitioned to individuals' perceptions that can play a deterrent role toward the adoption of BIM. The participant in the third interview highlighted that there is a lot of misconception around BIM in both developed and developing countries. P5 explains the phenomena that when in graduate school, they were not supported in use of BIM as their employer thought BIM would take them away from the design process. This highlights a scenario where the concept of BIM was surrounded by misconceptions that played a blunting role in the adoption process.

Another deterring factor in successful BIM application was brought up as information sharing. Two of the participants during the second interview believed that information sharing is something like extrapolation of successful results of BIM implementation. P2, experienced BIM implementation hard without all possible partners doing it and sharing the information generated from the model; information sharing is vital for doing BIM correctly. P1 explains that a BIM model needs to be a shared platform that everybody contributes to; they state that this is an ongoing deterring factor in a robust and advanced market. The reason behind not sharing all kinds of information is a lack of trust and companies and designers are afraid of misuse of their proprietary

information. In order for information to be shared in its entirety, it needs to start in the design level and be shared and evolved throughout the life of the project.

BIM continues to be a robust AEC cutting edge technology, and requires good operators with construction knowledge for effective utilization, said by P1. They added that people with 2D drafting experience might be able to use BIM for 3D visualization whereas for individuals with better knowledge of building systems, things in BIM mean more to them and it may be easier for them to do it right. P1 noted that most of the people with 2D drafting experience use most of the Autodesk products. However, when it comes to BIM, they get confused in how to put different trades together in the BIM even though a lot of the information comes from the same source software (Autodesk). Therefore, this scenario may imply a lack of construction fundamental knowledge. As brought up by P5 throughout the discussion, selecting random individuals for training is not a wise decision and that benchmarking and assessment is crucial in selecting the right resource since BIM is very organic and people using BIM need to be creative to benefit from the suppleness of BIM in terms of its creativity. P6 also point out that besides the clear understanding of BIM, prior knowledge of the subject for which BIM is utilized is crucial therefore the successful use of BIM requires a good understanding of the construction knowledge.

Hesitation regarding reliance on new technology may not be something new in the market until used, tested, and the results observed by the future users. The concept of using a BIM, due to the sophisticated and advanced nature and performance of BIM, seem to be more resistive than normal. P5 explained that with BIM you always have to convince people and obtain buy-in from them as you continually sell the benefits of the process; you need to market and sell your work. This is a challenge because if you do not continuously market your work and fail to collaboratively go through your work with new adopters, it could become a turn off to people.

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As observed in the Figure 9, collaboration was the word used by participants in different contexts referred to as both a benefit and a hurdle for BIM users. This inherent characteristic of BIM sets the baseline for successful BIM adoption while encouraging information sharing that in turn leads companies to the highest level of accuracy and coordination of different trades possible when properly used. As seen in Figure 9, "understanding" and "misconception" were words used by participants in different contexts. Some of the participants believe that it is important to understand what exactly BIM is capable of and how it can be used otherwise people's expectations may differ on what BIM is actually capable of. P6 also highlighted that gaining proper BIM knowledge requires extensive education and experience that comes over time and that BIM trainings need to be considered in phases in accordance to its specific use. Doing so will help individuals train well in specific areas and gradually build a complete knowledge of BIM.

Figure 9: *Word Frequency Query for this question. Source: (Nvivo)*

If You Were Adopting BIM in a Developing Country, What Issues Would You Anticipate Needing to Overcome to Make that Adoption Successful?

The aim of this question was to seek the participants' observation on critical issues one may encounter when adopting BIM in a developing country. Interestingly, two of the participants (P1 and P2) not only identified fundamental issues that appear to be dominant, but also continue recommending approaches needed to overcome these challenges. P4 started with noting that one of the main issues is the large amount of data sharing and transfer that may require high speed internet access; dial up type networks may not serve the purpose. P3 recommended work arounds when high speed internet is not available and that issues related to slow networks can be overcome through scheduled and structured meetings when coordinating with different groups or individuals

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working on the project. It is important to note that none of the participants mentioned issues of any kind that cannot be dealt with in regards to the application of BIM in developing countries.

Based on their experiences everyone suggested parallel solutions and approaches for a new successful implementation of BIM in a developing country. P1 suggested that one of the first things to set up would be a protocol on how the building is to be modeled showing how it can be segregated into smaller pieces. This would allow for easy information sharing and transfer and show that these smaller pieces can be put back together once the information is shared. They further explained that not everything needs to be modeled in BIM, especially interiors as that model usually does bring value back over the resources needed to create the model. P2 share their view as to setting a goal for specific jobs in the beginning by helping people understand what will be accomplished by using the tool.

They further prescribed starting with smaller pieces of the job rather than allowing its use companywide. For example, in the first job using BIM, while it might be a large project start with a BIM application for mechanical room to make sure all parts and pieces come together. In the next job this scope can be expanded to include more areas of the project including scheduling and so on and probably on the third or fourth job you would be able to fully utilize BIM throughout your projects. P1 believes that starting small would allow for more manageable processes for new users.

P6 has somewhat of a different perspective in regards to BIM application issues for the new users in developing countries that may be ingrained from people's understanding and level of awareness in developing countries. P6 observes that the vital issue is a clear understanding of BIM and it's challenging to distinguish with traditional 2D CAD use in some cases. This conveys

their perspective on people's perception about BIM and what BIM is really capable of. This information gap and general awareness about BIM may instill a negative perception about BIM throughout construction industries in developing countries. A salient factor for a successful adoption they think is the need to elevate the owners' knowledge about 6D BIM and how the information can significantly impact owners as part of the facility management. They further remarked that owners' buy-in would result in having the designers apply BIM in their designs which is a great initial place to start with BIM adoption on a project.

P5 sees the BIM adoption issues from a technology and human perspective in developing countries. They believe that challenges associated with culture and behaviors vary throughout different geographical regions. For instance, in Asia working in a collaborative and transparent environment would be a challenge because BIM results in a very transparent process that may jeopardize peoples or stakeholders' benefits. P5 further added that corruption may be a salient factor why designer, engineers and other stakeholders do not want to implement BIM. Also, from the technology perspective, they suggest that resources may not be a hurdle as there are big companies from the U.S outsourcing their design work to some developing countries. They further noted that some of the big companies have branches in developing countries. This means that there are talents in developing countries working for the big names therefore; it is as if developing countries have the opportunity to utilize these tools.

The interview data of all three interviews for this question was coded in Nvivo in order to observe the word frequency participants have used. As observed in the Figure 10, the word repeated most often by the participants is "gear". Observing the context, it is supporting the participants' view and suggestion that a successful BIM implementation should start with a small

project or piece of a project and then gear all the efforts towards developing the process to achieving that goal.

Not starting small was brought up as a deterring factor by participants. Companies or individuals not having a smaller and clear goal as their initial start may experience failure as the amount of effort required for bigger job and or for bigger projects with no goal may become unmanageable for early BIM users. The word small was used alternatively as little in most of the contexts to suggest that when first time users achieve their first small goal, in the next job they can add a little more scope in order to gradually increase their knowledge, experience, and physical infrastructure. The word "understand" was used in the context of understanding what you are using the tool for and setting that as your goal. It was also used by one participant in the context of BIM users needing to understand BIM explicitly and that the owners need to become award of the usefulness of BIM 6D in facility management so that they would require designers apply BIM in their projects. The words data, transfer and internet were also used repeatedly by owners to signify the requirement of initial infrastructure when starting BIM for the first time.

Figure 10: *Word Frequency Query for this question. Source: (Nvivo)*

In Your Experience Do You Think that BIM Adoption Issues Would Be the Same for Everyone that Wants to Adopt BIM Irrespective of Working in a Developed or Developing Countries?

Considering the approaches and steps discussed within this question, five participants aligned in a positive view of BIM adoption. P4 stated that although downfalls and curves would be encountered during the adoption process, overall adoption issues would still be the same in both developed and developing countries. They reasoned further stating that all companies who have adopted BIM have experienced the same infrastructure and knowledge development process and that the same approaches are taken no matter where. P1 confirms this idea and adds that no matter which geographical location an adopter is in; we validate cost benefit analysis of the adoption. Therefore, we always encounter resistance on investing in something doing the same job we have done without it.

Another generic barrier they mentioned was information sharing. P3 gave an example of a struggle as obtaining everyone's buy-in by proving its worth it and that the first job would always be a mass of challenges; this would be a generic issue everywhere. This scenario requires a firm commitment of someone in a higher position in the company pushing through the struggles and believing that BIM adoption is the right way and will result in significant savings at the end. P2 believes that every company has the three same issues regarding this technology adoption; it is technology, culture or processes. For instance, you have the technology or not, you have the culture and how easy that allows for adoption, or if you have the processes for what you are going to do. They exemplified that for a company doing clash detection where they do not have the processes; it is an automatic turn off.

The participant from the developing country (P6) also reflected on such issues being the same in both developed and developing countries. They further stated that they have been to many developing countries and found that some of the developed countries adoption challenges are the same. However, in U.K, due to pervasive dissemination of BIM throughout the construction industry, the challenges compared to other countries are less as the adoption and application of BIM is strongly recommended and supported by the government entities. P5 believes that adoption issues and resistances no longer exist in developed countries and that most of the developed countries are accepting and demanding the use of BIM. Unfortunately, many developing countries still have their ways to go regarding challenges associated with BIM adoption. They remarked that in developed countries if you are not using BIM, you are behind. Pondering over this perspective, it may imply that there were challenges to BIM adoption in developed countries whereas they can be overcome gradually as is probably the case with the organization the participant is working with. This scenario was further supported by stating that the adoption issues in developed countries no longer exist and the current hurdle is how to collaborate and what is next or in the future.

The responses from all three interviews to the question were analyzed through conducting a word frequency query to see what words had been repeatedly used by participants. The words with larger frequency also support the themes developed through comparison of the interviewee's responses. As observed in Figure 11, the word "same" was used mostly in the context of BIM adoption issues and the processes followed toward BIM application are the same irrespective of being a developing or developed country. Some of the other words like "technology", "people" and "processes" were utilized in the context of generic issues inherent with BIM application everywhere. The words "adoption" and "developing" ware used most repeatedly as they represent the core concept that discussion was circling around within the question.

Figure 11*: Word Frequency Query for this question, Source (Nvivo)*

In Your Role as a GC, How Easy or Hard it is to Work with Local Contractors, Either in Developed or Developing Countries that have Not Used BIM Previously?

This question was discussed with participants to get their insight on real world scenarios typically found in the construction business, in companies that work collaboratively in large projects as contractors, and with subcontractors where BIM can be utilized to its fullest potential. Based on five participants' experiences, this phenomenon was explained to be one of the daunting hurdles that can be overcome as a result of significant efforts, wise decision making and taking a feasible approach to adoption. This part of BIM application may be perceived as negative towards BIM application for most of the companies; five of the participants had experience in this area and discussed interesting lessons and remedies to this issue.

P2 described their experience in working with partners with no previous experience as difficult. They indicated that as a general contractor (GC) making the choice to adopt BIM was difficult but when it came to convincing subcontractors to use BIM they ran into resistance if the subcontractor did not see any value added to their bottom line. This resulted in the GC's decision on being reimbursed by subcontractors when they were required to do the modeling for subcontractors. The participant further explained that for most of the jobs, the GC would accept the liability for getting the job done efficiently and quickly. P1 shared their experience of working with a BIM enabled subcontractor as being the most efficient and reasonable option for them. They further explained that with subcontractors that do not have previous BIM experience, they fight through the subcontractor frustration and help them enable and elevate their capacity.

The participant also believes that in developing countries dealing with this challenge may require extensive education and awareness initiatives. Another remedy suggested by the participant was that some of the modeling efforts can be outsourced and this option will prove more efficient if the outsourcing is done with companies in different time zones. For example, if you send something at the end of the day to a company located in different time zone, early the next day you will have the product back as companies located in different time zone are working when you are not. P2 further explained that in developing countries working with strategic partners is a good strategy. On projects where the developing country firm is performing most of the work it is always wise to reach out to the strategic partner for information and knowledge. This strategy allows for sharing the cost of training; an acceptable strategy to increase the overall performance of the current and future projects. P3 suggested that if companies do not have in-house capabilities, they can hire someone do it for them.

It was also noted in the second interview that it's always daunting to work with partners not capable or in the same level where you are. P5 believes that it is going to be hard to work with companies with no previous experience with BIM use, but it is something that can be overcome. They further explained that the sophistication and frustration involved within this scenario would be similar in both developed and developing countries. P6from a developing country shared their experience that working with such companies and people is extremely hard. They further explained that sometimes companies pay for the training of their staff and in some cases the trained individuals cannot show success and the companies lose money and a potential barrier to further adoption is created. These scenarios may need further study to determine if companies have a high level assessment and benchmarking process for selecting individuals for training.

The frequency query for this question shows the most repeated words by participants are "companies" and "model", Figure 12. This highlights the interrelationship of the words; similar to how companies use BIM and BIM is used by companies. The most important word found was "hard" in the context of it is hard to work with companies with no previous BIM experience and to make the decision of whether the GC needs to do the modeling for the subcontractor, have them do it themselves, or find a third party for doing it. This decision is hard as outsourcing the BIM function could be demoralizing to the company without experience. If companies put in enough effort and work with their strategic partners persistently, they can achieve the level of success needed to perform better in future projects. The words "strategic", "possible" and "done" are also used in the same context of supporting the idea of "possibility" and dealing with scenarios where a partner company does not have previous experience of BIM. As observed in Figure 122, The most repeated words by study participants were "together" and "efficient" and were mostly used in the context of companies being more efficient if they work together with their partners.

Figure 12: *Word Frequency Query for this question, Source (Nvivo)*

Excluding the Potential Lack of Physical Infrastructure in Developing Countries, What Challenges Do These Developing Countries Face When Adopting BIM for the First Time?

This question was intended to seek participants' observations on different issues other than the obvious issues of physical infrastructure in developing countries in order to identify specific issues inherent to BIM application in developing countries. Three of the participants (P1, P3, and P4) pointed out the lack of experience and skilled resources. P1 explained that besides a lack of experience and resources, the confidence in the outcome would be a challenge as people initially doubt what you are doing. P3 added that turning the final product or models into something useful for field crews is also something companies struggle with.

P5 seemed to agree that the lack of experience and resources is a more prominent issue than others whereas P5 viewed those issues a bit differently. They explained that people in developing countries are more resistant to working in a collaborative environment and knowledge sharing due to a lack of soft skills. They did not see technical skills to be an intense challenge or different than developed countries if the skills and resources are provided to support collaboration and knowledge sharing.

P6 pointed out the misconceptions surrounding BIM and noted that both legal and social supports are the prominent determining factors. Based on this view it could be suggested that any misconception about BIM is an outcome of lack of experience and knowledge about BIM as observed in views of participants from the second interview.

The word "collaboration" was the most repeated word by the study participants, Figure 133. Although, in both developed and developing countries, collaborative work environment is a prominent impediment, the level of resistance based on participants' views would be higher in developing countries. The word "collaborative", Figure 13, was mostly used in the context of less collaborative and going over the information with subcontractors collaboratively. People in developing countries are less agreeable to work in collaborative environment. The word "information" is also used repeatedly in the context of companies' and peoples' resistance to sharing information and that it is important to turn the information in the BIM model into useful information for people in the field. The word "knowledge" was equally mentioned in the context of knowledge sharing as a resistance, the challenge is not the technical knowledge but, of how to work together. Also, the words skills and experience are used in the context of having skills and experience to fight the initial resistance to the use of BIM. As stated previously, a transparent work

environment and corruption in developing countries were the two challenges highlighted by the participant from developing country.

Figure 13*: Word Frequency Query for this question, Source (Nvivo)*

If You Were Working With Companies/People in Developing Countries to Adopt BIM for a Project, How Different do You Think the Challenges Are in This Scenario with That of Adopting BIM in One of the Industrialized Countries?

P1 felt this situation would be more challenging due to factors like the first cost of developing the infrastructure, enabling technology and obtaining the proper resources in those countries. P4 added along that recruiting experienced people is different in developing countries where the candidate pool might not have the baseline knowledge or experience and would need to be educated as a beginner level. P3 explained that as part of explaining to people what you are doing, companies may need to develop lessons learned for training purposes; this requires a

resource commitment by the company. P01-Int02 added to the discussion that people asked to implement BIM for the first time will ask for evidence or cases that clients and owners have realized profit through the use of BIM. This is usually a hurdle because even people in U.S are not willing to share proprietary information that may impact their profitability. They further explained that in developing countries, you need to show examples of work products to show people how you do it and what the benefits are in order to have people buy-into the application of BIM.

As part of the suggested solution, P4 added that when selling your products, it is better to show people product examples similar to what you are planning to do as in scaling a sophisticated or large product down to the level of product you are trying to sell would be challenging for people. P2 added the suggestion that when implementing BIM in developing countries, share your plans with Autodesk and they will help you succeed with your BIM implementation as they have great plans and resources available.

P5 believed that there will be no difference in the application of BIM between industrialized and developing countries. Of course there are challenges but they are going to be the same as challenges for industrialized countries that can be overcome as was the case for developed countries. P6 felt that in developed countries, because of the laws and government support, challenges are not as intense and persistent as is for developing countries. They further explained that some of the developed countries strongly support BIM and it is hard for most people with no BIM experience and knowledge to find satisfying jobs in the industry. The most used word identified in the analysis of this question was "infrastructure" that encompasses the physical and knowledge infrastructure, which was highlighted as a challenge in developing countries (Figure 16). Reasons involved with the infrastructure challenges was highlighted as the initial cost of technology and trainings.

Some of the participants used the word "hard" to express their feeling of BIM adoption in developing countries as being harder in comparison with developed countries (Figure 14). Some of the participants felt that BIM adoption would be harder in developing countries while some others felt it would be the same as in developed countries.
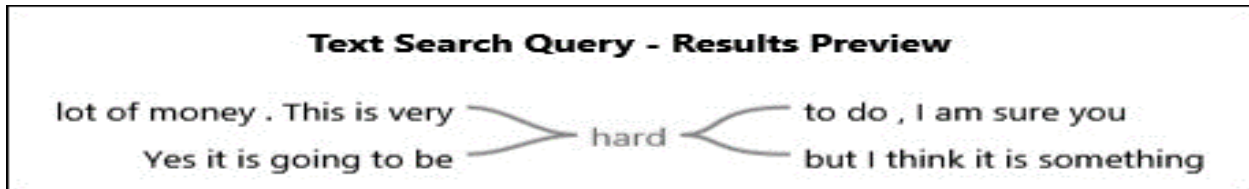
Text Search Query - Results Preview

lot of money . This is very ⟶ hard ⟵ to do , I am sure you
Yes it is going to be ⟶ hard ⟵ but I think it is something

Figure 14*: Text Query with Participant's example, Source (Nvivo)*

The word "show" was mostly used in the context that companies do not want to show or share their profit realized from the use of BIM; they don't want others seize the opportunities (Figure 15). Also, the word "show" was used in the context of showing people the success of using the tool to encourage them and companies in developing countries how BIM can work by using similar projects as encouragement.

Text Search Query - Results Preview

it , sell them the project similar to what you
you would want to have a work product to ⟶ show ⟵ them and what is your outcome . Because if you
#1 : you will get the question a lot that ⟶ show ⟵ people to say , here is what we want to
me the case study where it saved the owner
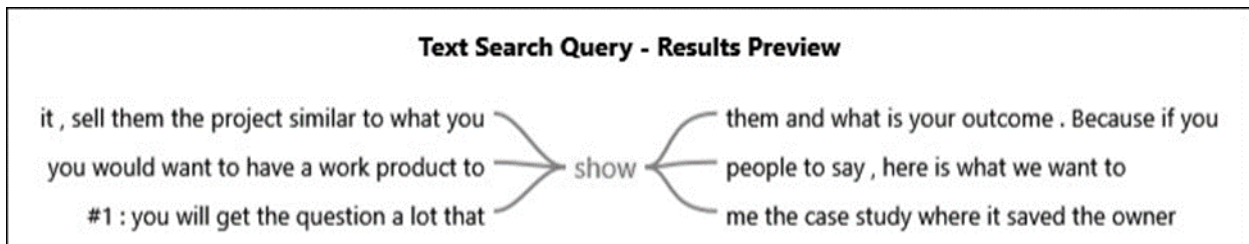
Figure 15: *Text Query with participants' example, Source (Nvivo)*

Figure 16: *Word Frequency Query for this question. , Source: (Nvivo)*

When Your Company Works on Projects Where BIM is used what are the

Minimum Requirements for Infrastructure: Equipment, Programs, Worker

Knowledge, etc.?

This question aims to identify, based on lived experiences, the basic infrastructure requirements that every company has to provide prior to implementing BIM. P1 and P2 both commented that an initial successful step towards selecting any BIM related infrastructure would be to identify what you want to do with the tool. This initial step would streamline the process of determining the software programs required for the initial goal you have set. P2 provided the example that if someone's first objective for BIM application is only visualization, the Revit software program will suffice the purpose. P1 contributed that doing the first step based on a

desired goal would result in less immediate infrastructure requirements. Whereas, if the first step selected is pre-construction coordination, far more staff, product, training and bigger computers will be required. P2 further explained that with a smaller initial goal, a middle to high level computer with at least 4G ram and Revit software would be all that needed to start with. However, the complexity of the project would impact this baseline equipment requirement. When doing visualization as the initial step a very attainable goal would be to start with the exterior/shell animation; the foundation and interior partitions do not need to be modeled for this step. This goal requires a lot less effort, is going to be more manageable, and can be done with Revit which helps keep the costs low. Once the initial goal is achieved, you may want to add in some clash detection system coordination software like Navisworks. This addition will increase the storage capacity requirements and impact computing speed. P2 went to a more detailed level of information for clarity by giving an approximate cost of $13,000 USD to start with a very low level of BIM implementation.

P1 further explained that human resources are also important. If a company does not hire someone with BIM experience they will need to support the training of a person(s) and that will take time to gain a proper level of understanding the tools. P2 clarifies the process towards full BIM adoption and that it might be the fourth job when the original midlevel computers will no longer serve the purpose and the company needs to either upgrade their system or provide super high level computers. P3 added to the discussion that it is always better to provide computers with capacity a bit over the minimum limits set by Revit to allow for unknown needs. This idea was supported up by P1 reasoning that it is important to make sure computers are fast; a slow and inefficient machine will frustrate people and impede implementation.

P5 also believes that it is important to set people with right equipment necessary to perform the job as a way of ensuring success. They also believe that BIM specialists, maybe from outside the company, need to figure out what they need and coordinate their requirements with the company. Based on their experience it is also important to train people to be flexible with use of BIM and focus on what it is that they are trying to produce. Prior to starting any draft, it is important to conduct team discussions and identify all the deliverables and set expectations. In their opinion identifying expectations is more important than the tools used to achieve the expectation.

P6 also believes that the minimum requirement for adopting BIM includes a computer, software, and server and that outsourcing the add-in in developing countries is important in order to expand the capability of the software. They further stated that proper training for BIM operators may take over a hundred hours making it important for trainers and companies to adjust their trainings in different models or levels to meet the needs of the BIM team.

Several words were frequently used in the discussion of this question: Revit, software, tools, Server, and resources, were all used to describe the initial infrastructure required to start with BIM (Figure 18). The word "first" was the most repeated word in the figure followed by the word "goal". The word "first" was used synonymously in different contexts such as, what you want to do first, my first piece of BIM is, start pretty simple, what I want to do is the first step, and do the first step before you start drafting (Figure 17). In reviewing the context and subsequent explanation by the participants of this high reference to "first", it is important to "first" identify that what you are going to do with BIM. Doing so will not only determine the software program

you may require but also help ensure that the BIM application or adoption process is going to succeed with a very low first cost.
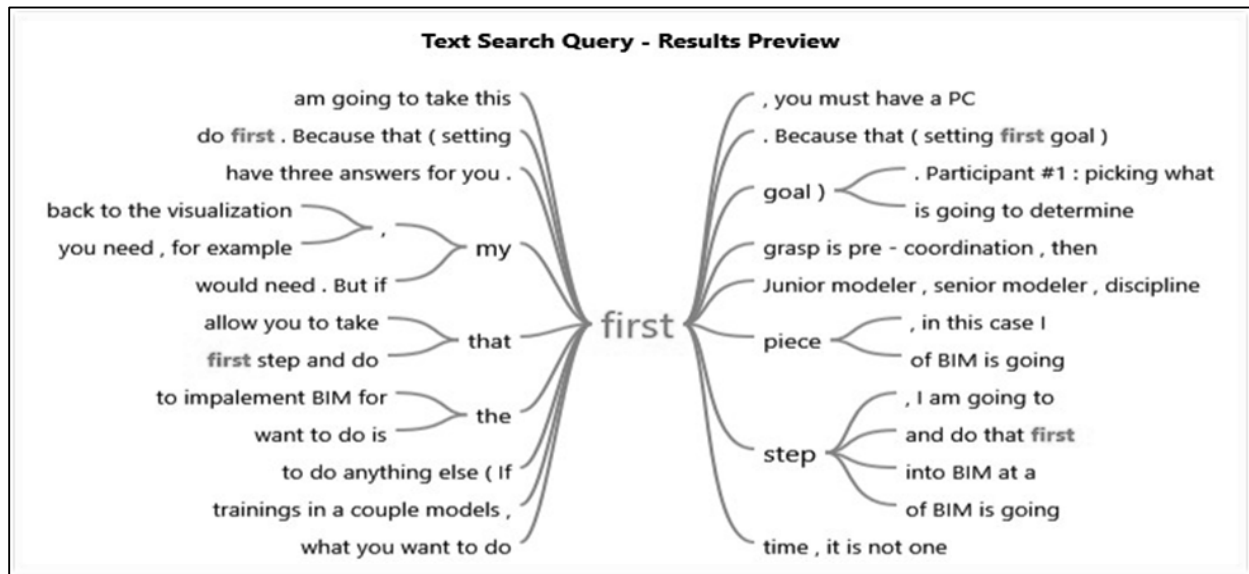

Figure 17*: Text Query with participants' example, Source (Nvivo)*

Another important theme that emerged during analysis was pertinent to setting goals. Most participants strongly believe that setting an initial goal is one of the most important concepts in adopting BIM. This in turn, will determine how much and what software or other infrastructure you require to achieve that initial goal successfully. Other comments that could impact a successful adoption and full implementation of BIM in both developed and developing countries include workarounds, determination of the deliverables and outsourcing.

Figure 18: *Word Frequency Query for this question, Source (Nvivo)*

If You Are Working on a BIM Driven Project with Subcontractors that Do Not Use BIM, How Would You Structure Your Processes to Accommodate this Situation?

This question sought participants' view on dealing with situations where the subcontractors and partners are not BIM enabled as is typically the case in developing countries and to share their experience on successful handling of this situation. P4 described that this circumstance requires additional work on the general contractor side as this necessitates decisions on whether you want to model what they cannot, and the identification of critical areas where general contractors are willing to help the subcontractors by building the model for them. P2 also supported the idea of identifying the critical areas and only paying attention to those areas of concern. If this is not done the GC may expect the subcontractors to do the whole model and that

will be vexing for them. P1 shared their experience that although they do not model for the subcontractors, they bring the subcontractors together in the same room weekly and use 3D visualization. During this process the subcontractors pay attention and share with them where each elements of electrical, plumbing and mechanical routs are going to go. They further stated that this has been very beneficial exercise for all parties to better coordinate and solve problems and meanwhile help train the subcontractors. P3 explained their experience on a project where the subcontractors were unable to do the clash detection. They indicated that they did the modeling with too many clashes detected and then gathered the subcontractors and went through the model with them which was painful but resulted in no problems during installations. P2 clarified that for contractors it is Building Information Management as they are managing the information and model whereas the subcontractors are required to do the modeling for them.

P5 shared the view that it is important to reach out subcontractors and analyze the situation in order to figure out a reasonable approach for a solution. They further stated that they have long term trainings for their subcontractors to educate them on how to coordinate and collaborate better since both parties rely heavily on each other and therefore it is worthwhile long term Investment. P6 explained that in these scenarios, it is better to model in 2D in early stages for subcontractors' technical use and remodel only for clash detection.

The word "model" was highlighted as most commonly used by the participants in the context of finding out if the GC is going to do the modeling for the subcontractors, having the subcontractors do the modeling, or if subcontractor will hire someone to do for them. The answer to this question influences the GC's decision-making process (Figure 21).
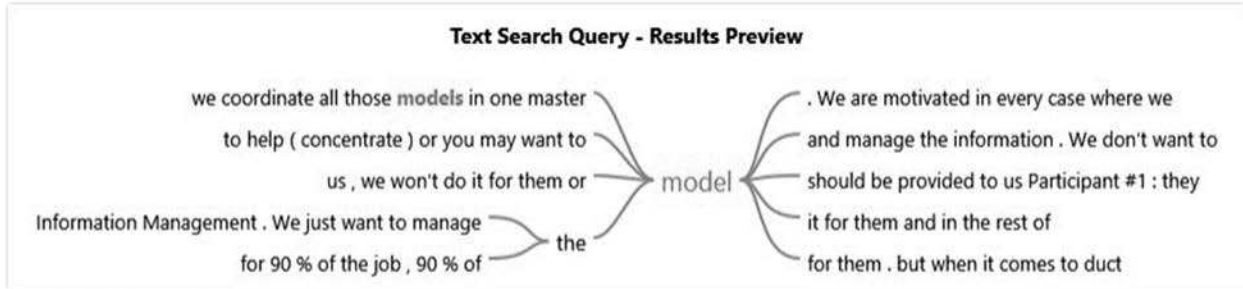
Text Search Query - Results Preview

we coordinate all those models in one master
to help (concentrate) or you may want to
us , we won't do it for them or
Information Management . We just want to manage
for 90 % of the job , 90 % of
→ model ←
. We are motivated in every case where we
and manage the information . We don't want to
should be provided to us Participant #1 : they
it for them and in the rest of
for them . but when it comes to duct
the

Figure 19*: Text Query with participants example comments. Source: (Nvivo)*

Participants, as illustrated, strongly suggest coordination and information sharing with subcontractors as given in the examples, coordination will result in problem identification meanwhile significant training to the subcontractors in terms of collaboration and knowledge enhancement (Figure 20).

Text Search Query - Results Preview

walk through it would be essential . Participant #2 : The
to duct routing and plumbing and all ; a typical
coordination ←
and identifying the area of trouble (critical) and concentrating
for us is that we are getting together weekly

Figure 20*: Text Query with participants' example. Source (Nvivo)*

The other word used most repeatedly in the query is "area", this word was used in the context of identifying the areas of problem, critical areas and the areas that need concentration by the GC.

Figure 21: *Word Frequency Query for this question. Source: (Nvivo)*

Chapter Five: Summary of Results and Discussion

The goal of this study was to provide answers to the sub-questions established to support the main question of the study "Are there similarities between BIM adoption issues in developed and developing countries? If so, what lessons can be learned for Construction Companies in developing countries that want to adopt BIM". The main question of the study was narrowed to a total of ten (10) sub-questions to collect sufficient data required to answer the main research question. In order to address the first part of the main research question "Are there similarities between BIM adoption issues in developed and developing countries?" the (10) sub questions were further synthesized into four new sub questions following the analysis of the ten sub questions. The new four sub-questions are more generic and encompassed the responses from all (10) sub-questions. The four new sub-questions then resulted in a comprehensive response to the first part of the main research question "are there similarities between BIM adoption issues in developed and developing countries?" (Figure 22)

In order to provide lessons learned from early adopters' experiences to the companies wishing to adopt BIM in developing countries, all the best practices, remedies, suggestions and approaches that early adopters have either practiced or merited were extracted from the analyzed responses. The summary responses were condensed into four naturally occurring categories of lessons learned or best practices (Figure 22). At the end of this chapter, lessons learned or best practices will be outlined as a result of condensing the analyzed interview responses into four categories: education requirements, basic infrastructure requirements, sound practices and working with no previous BIM experience partners.
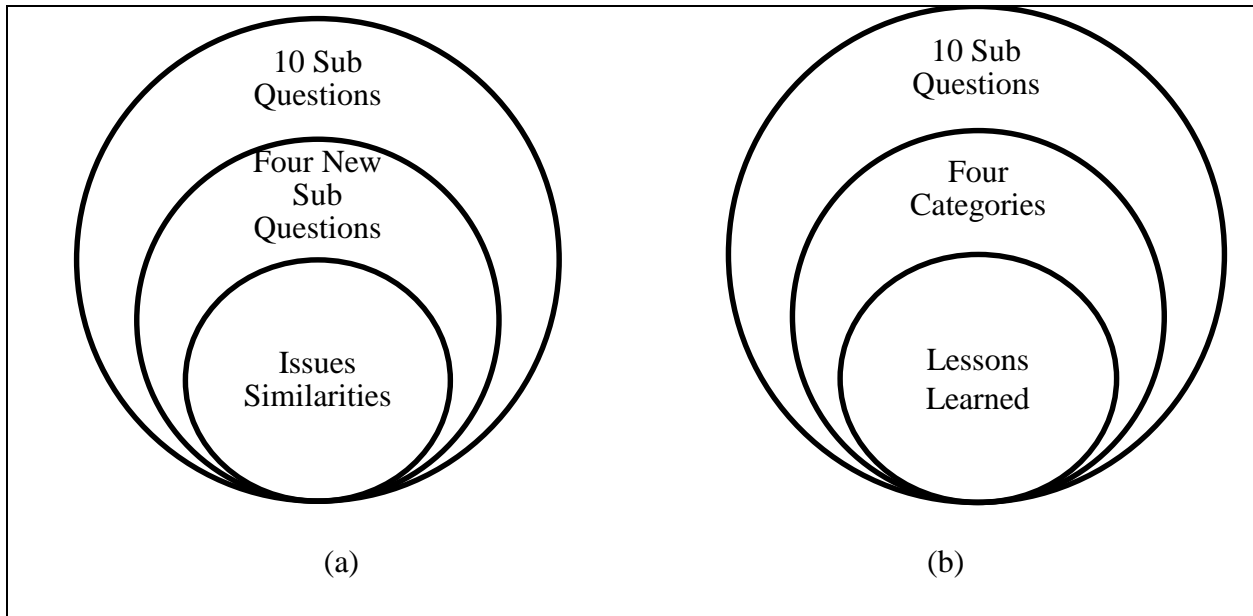
Figure 22: *Breakdown of the data into two main parts: part A and B of the main research question.*

Summary of results

Why Did You Choose to Adopt BIM?

While discussing this question with participants, there were no divergent views observed whereas, based on the individual experiences, somehow unique reasons were given by informants to explain their experience on that view (Table 5). It is interesting to observe the uniqueness of reasons, benefits and overall drivers towards BIM adoption from different perspectives. Also, further scrutiny of the responses reveals a uniqueness of the phenomena, "BIM fosters environment of collaboration and innovation" and the concept of "no BIM no business in the future" from participants in developed countries. These responses not only signify the importance of BIM but also an incentivizing factor to the companies for BIM adoption. P5 denotes BIM importance in saying "BIM fosters environment of collaboration whereas adds an incentive factor of elevating knowledge in different areas of specialties and that from a designer's perspective it's the best thing ever". Pondering over all these reasons from participants'

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experiences, they align with the previous studies done on BIM benefits and that BIM potentials are vast and pervasive in regards to its use in AEC industry.

More enticing is the clear difference of notions observed between developed and developing countries' BIM professionals. Participants from developed countries seem to be transitioned towards BIM in order to further augment their construction practices to address the challenges of collaboration, coordination of different trades and to produce documents that assist the projects throughout their life cycle. The participant from the developing country looked at the BIM adoption purpose from a slightly dissimilar perspective "BIM saves a lot of money and time" and that the "documents created by BIM are more useful for the project team". Noticing this viewpoint, it can be perceived that companies in developing countries are in the stage where salient construction challenges are rudimentary traditional construction practices. Therefore, the primary step towards enhancement are efficient practices that can save time and money and that more comprehensive construction documents be produced to run construction businesses more efficiently in developing countries.

Table 5: *Summary of responses of why respondents choose to adopt BIM*

Participant	Response
P1	- BIM fosters environment of collaboration and innovation - Get to the level of accuracy and coordinate multiple disciplines - No BIM no business in future
P2	- Reactionary to the trend of BIM application in market in 2007 - BIM fosters environment of collaboration and innovation - No BIM no business in future - Saves time and money
P3	
P4	
P5	- Different areas of specialties could be explored from site logistic coordination to visualization and estimates in preconstruction phase - From a designer's perspective, it is best thing ever - BIM alone does not solve issues, it facilitates how to work collaboratively and innovatively
P6	- BIM saves significant time and money - Documents created by BIM are more useful and easy to understand by the project team

What Problems/Issues Did You Encounter When You First Adopted BIM?

Although trivial differences can be observed in participants' views regarding challenges encountering new adopters, no contradicting views were witnessed (Table 6). Therefore, it appears that when experiencing BIM application for the first time, these challenges are most likely encountered in both developed and developing countries and companies need to be aware prior to its application. Also it is important to note that the misconception around BIM stands out as the major factor that participants consensually agree upon. Scrutinizing this factor, it most likely emerges due to lack of education, lack of construction knowledge and people's expectation from BIM which ties back to the BIM education.

Collaboration is an inherent characteristic for the successful use of BIM. It stands out as a deterring factor stated by four participants in companies trying to implement BIM for the first

time. The participant from the developing country does not reference collaboration as a prominent hurdle which may imply that developing countries are in the tool learning phase rather than realizing its high level application and efficient use as a collaboration tool. It is important to notice that information sharing is inherent to collaboration and transparent work environment and this factor is also underlined by participants as a deterring factor for companies most likely due to the lack of trust or fear of misuse of information.

Lack of construction knowledge for BIM users also turns out to be an obstacle since BIM requires a sound knowledge base of construction in order to be efficiently utilized. It appears that people with a lack of construction knowledge experiences difficulties with the use of BIM. This might be due to people's unrealistic expectations of BIM or they cannot provide accurate information input to the model due to lack of construction knowledge. This issue interestingly was observed in both developed and developing countries' participants' views. Although obtaining people's buy-in was not highlighted as a hurdle by all or a majority of the participants, it still may emerge as a prominent factor to first time BIM users. This is because, using BIM for the first time requires rigorous changes in a companies' work process and people's working styles. BIM users typically need to convince people by marketing and selling their work by taking multiple approaches so that they can get people buy-in and support BIM application. Although doing so will not promote productivity and direct pay-offs, a failure to obtain buy-in may surface as essential unwillingness towards BIM application.

Table 6*: Summary of Reponses* of *what problems/issues did respondents encounter when they first adopted BIM?*

Participant	Response
P1	- Collaboration and working with people to obtain their buy-in is essential and requires ample effort - Lack of collaboration results in others rejecting the use of BIM - Collaboration and working in transparent environment is challenging for people until getting used to. - BIM model need to be a shared platform that everyone contributes to it and this is a deterring factor in a robust and advanced market due to lack of trust regarding misuse of information - Use of BIM requires a good base of construction knowledge
P2	- Lack of collaboration between experienced and new graduates - Lack of education results in misconception around BIM - BIM implementation is hard without parties sharing pertinent information of the model - When it comes to BIM people get confused how to put different trades together
P3	- Collaboration becomes a hurdle if everyone is not using BIM - People are using BIM as a crouch where they don't know where different pieces of building come together - People do not think of fining issues within the model as they think the program will find it for them and it is not happening
P4	
P5	- Collaboration and working together - Design oriented school was not supporting BIM as they were thinking BIM will take them away from design process - Selecting random individual for BIM training is not a wise decision as benchmarking and assessment is crucial prior to selecting individual for training. - With BIM you have to always convince people and you need to obtain people's buy-in and its challenging
P6	- There is misconception about BIM in both developed and developing countries - Prior knowledge of subject for which BIM is utilized is crucial therefore, successful BIM adoption requires construction knowledge.

If You Were Adopting BIM in a Developing Country, What Issues Would You

Anticipate Needing to Overcome to Make That Adoption Successful?

Observing the responses from the participants, as a first step towards BIM adoption in developing countries, it is important to know who is trying to implement BIM. If the process of transitioning towards BIM is mandated at the industry level by the government, I believe general awareness and creating opportunities for BIM specific education would serve a vital purpose in incentivizing people towards BIM use. Mandating BIM in the industry level may require a different approach that involves legal aspects and BIM standards for BIM use which is not within the scope of this study.

If the BIM adoption process is initiated in a company or individual level, the issues identified by P6, P5, and P4 along with the remedies suggested in Table 7 would be a better starting point. I believe the issues identified and the remedies suggested by participants (Table 7) may play a rigorous role in the adoption process. Setting up protocols to determine unique and manageable work packages and gearing processes in an effort to achieve that single goal is critical to successful implementation. The scheduling of structured meetings where high speed internet is not available, is a suggested feasible approach for companies or individuals in the early stages of BIM adoption.

Since the discussion in the context of this specific question was circling on personal experiences from projects that participants have worked on, I think, the approaches suggested by P1 and P2 appear to be the best fit the context of the discussion. At this point in time developing countries appear to be in an emergent juncture of BIM adoption. Companies in developing countries that are seeking to transition to BIM should start small and expand their capacity of

physical and knowledge infrastructure job by job. Until that happens, it appears that collaborating with teams seems to be more feasible with lesser effort in this scenario.

The best practice appears to be gaining support for BIM adoption, at both the company and individual levels, through increased education and an overall increase in the general awareness about BIM and what it can add to the company. In many cases this may take time to convince people within the company that a successful transition to BIM will increase the competitiveness and performance of the company. The adoption of BIM in an entire developing countries AEC industry may require more rigorous and inescapable efforts oriented to general awareness, collaboration, transparent work environment issues, and the availability of high speed internet.

Table 7*: Summary of responses for "If You Were Adopting BIM in a Developing Country, What Issues Would You Anticipate Needing to Overcome to Make That Adoption Successful"*

Participant	Response
P1	• Early on set protocol on how the building is to be modeled to allow information sharing and data transfer through segregating the model to smaller work packages and easily integrated back as a complete model • You don't need to model everything that does not bring value back • Starting small is more manageable
P2	• Consider BIM as a range of human abilities and processes • Set smaller goal and gear all the efforts and process to accomplish that one goal • Expand its use job by job
P3	• Setting up scheduled and structure meetings when high speed internet is not available
P4	• High internet speed required for sharing large amount of data
P5	• Cultural barrier of working in collaborative and transparent environment • Provide people with opportunity to use the tool
P6	• Needing to understand exactly what BIM is capable of prior to starting with BIM • Elevate owners' knowledge about BIM 6D for facility management as owners can convince designers start with BIM

In Your Experience, Do You Think That BIM Adoption Issues Would be the same for everyone that wants to Adopt BIM Irrespective of Working in a Developed or Developing Country?

Summarizing the responses given by participants, five of them believe that BIM adoption issues for people wanting to adopt BIM in either developing or developed countries would be the same (Table 8). Participants exemplified some of the issues like cost benefit analysis validation prior to making any decision to transition into a new technology, issues of culture, technology, obtaining people's buy-in, learning curve in a first job and related challenges, and other slight differences inherent to the projects. The best practice appears to support the notion that all these challenges will exist for anyone adopting BIM regardless of the development status of the country.

Although P5 believes that developed countries have long passed the adoption issues and now they are dealing with issues such as collaboration and high efficiency of BIM utilization, developing countries are still experiencing adoption challenges (Table 8, P5). On the other hand most of the studies identified in the literature review and the overall context of the interview comments in this study support the ongoing issues against BIM application even in developed countries. It does appear there are companies that have fully transitioned to BIM and may have already passed the adoption hurdles in developed countries.

Table 8*: Summary of responses to similarities of BIM adoption issues in both developed and developing countries*

Participant	Response
P1	• Adoption issues are the same as no matter where we are, we always validate the cost benefit analysis
P2	• Yes, as every company has the same issue of technology, people, and culture regarding this technology
P3	• It is the same. For example obtaining people's buy-in and expecting a lot of challenges in the first job are generic issues
P4	• Although there would be some downfalls and curves where the overall adoption issues are the same
P5	• In developing countries, adoption issues no longer exists whereas developing countries still have adoption challenges.
P6	• Adoption issues are the same in both developed and developing countries.

In Your Role as a GC, How Easy or Hard it is to Work with Local Contractors, either in Developed or Developing Countries That Have Not Used BIM Previously?

Five out of six participants agree that it is hard to work with partners that do not have previous BIM experience (Table 9). Surveillance of the responses show that participants at the same time recommend remedies to address the challenges to this scenario. As stated in the responses, companies need to evaluate the options for working relationships with companies with no BIM experience and select the most feasible one for the situation. For instance, if companies do not have in-house BIM capabilities they can either outsource or hire someone do it for them. Working with strategic partners has helped companies for better transition and lesser training costs. Working with strategic partners is another option which could result in a better reliance and work environment that in turn results in a more successful and efficient use of BIM.

It also appears that some companies do not have a benchmarking and assessment process in place to measure the individual's construction knowledge. When individuals with non-

construction related backgrounds are trained in BIM, they typically are not as successful which

could create an additional BIM adoption barrier as observed in the response from P6.

Table 9*: Summary of responses to how hard it is to work with local contractors with no previous
BIM experience*

Participant	Response
P1	• With subcontractors that do not have previous experience, we fight through the frustration • In developing countries, this challenge may require extensive education and awareness initiatives
P2	• Working with partners with no previous experience is difficult • Making the choice to adopt BIM and then do it by the subcontractor was a hard decision • It would be easy to work always with strategic partners and elevate their knowledge to where you want to be and share the cost of training with them so that you both can learn together
P3	• If companies do not have in-house capabilities, they can outsource or hire someone do it for them
P4	
P5	• Although it's hard to work with partners with no previous BIM experience but it can be overcome and the frustration is similar in both developed and developing countries
P6	• It is extremely hard to work with people with no previous BIM experience • Sometimes companies pay for their employees training, when trained individuals cannot show success, it results in creating a potential barrier to further adoption

Excluding the Potential Lack of Physical Infrastructure in Developing

Countries, What Challenges do These Developing Countries Face When

Adopting BIM for the First Time?

As observed in in participants' responses, lack of experience, knowledge and resources

stand out as more noticeable challenges that holistically can be referred to as lack of knowledge

infrastructure (Table 10). Knowledge infrastructure seems to face similar barriers for BIM

implementation in both developed and developing countries. However, developed countries have

been addressing these challenges in both the long and short terms and they are not as conspicuous as they were initially. Moreover, some of the developing countries are yet not aware of the knowledge barrier as they are as just starting the journey of transitioning to BIM. Therefore, knowledge can be regarded as a generic barrier that companies may encounter in the early stages of BIM adoption. In all countries it appears that the best practice is for companies to develop their knowledge infrastructure over time.

Collaboration is another areas of potential concern in the BIM adoption process. P5 believes that businesses in developing countries may encounter more resistance than companies in a developed country when it comes to collaboration. This situation may be influenced by factors like, cultural differences, corruption (as stated by some of the participants) where people are not in favor of transparent work environment and unwilling to share information and knowledge with others. These phenomena may still exist in developed countries but at a lower level of intensity as collaboration is an inherent requirement of BIM use.

Lack of experience and skilled resources are challenges with deeper roots in developing countries. This may stem from the time it takes to disseminate technology from developed to developing countries over time. In addition, there are typically resources in developed countries which foster experience and knowledge development. There is also the component of technology emergence as a result of the advancement of practices in the AEC industries as a whole. Based on the resources of developed countries they tend to be, more resourceful with a higher level of sophistication and expertise. Overall, when technology disseminates to developing countries, resources and knowledge do not necessarily follow at the same pace of technology dissemination.

As stated by P6, there is lack of social and legal support to the use of BIM in developing countries. Two alternatives to increase each of areas emerged in the research: government and stakeholders to support and raise general awareness regarding BIM, and the adoption of a legal framework. The later would pose its own set of issues for the industry. For instance, it would be more challenging for industries with basic BIM knowledge to fully transition to BIM. In other cases just the use of BIM would ensure failure. Therefore, a gradual transition into BIM at both the individual and company level maybe a better approach for developing countries.

Table 10: *Summary of responses to challenges faced in developing countries to BIM adoption*

Participant	Response
P1	• Lack of Experience and skilled resources
P2	
P3	• Transforming the model information into the useful product to the field crew
P4	• Lack of Experience and skilled resources
P5	• Developing countries seem to be more resistant against working in collaborative environment
P6	• Misconception around BIM • Lack of social and legal support to the use of BIM

If You Were Working With Companies/People in Developing Countries to Adopt BIM for a Project, How Different Do You Think the Challenges Are in This Scenario with That of Adopting BIM in One of the Industrialized Countries?

The challenges to adopting BIM in developing countries appear to be more intense than those in developed countries based on the participants responses (Table 11). Factors that support this statement include: the unavailability of tools and services, recruiting experienced people, upgrading technological tools, education most likely starting at a beginner level, resource commitment for lessons learned and all the extra efforts to address the cultural and behavioral

barriers as well as shifting the work processes will require additional cost and effort. The factors recruitment, upgrading technology, and education are more reachable and easier to tackle in developed countries. In addition, the use of BIM in developed countries is becoming pervasive and companies with BIM capabilities are more favored to work with by general contractors and owners, therefore, use of BIM pays off its initial cost.

All these challenges were encountered long ago by companies in developed countries. Gaining experience and building complete infrastructure to support BIM use are things that will build over time. For instance, experience cannot be gained in advance of doing something therefore in the initial step, there are recommended approaches that companies follow to start with BIM for reduced effort, better managing, less infrastructure and initial capital.

Table 11: *Summary of responses to BIM use challenges in developed vs developing countries*

Participant	Response
P1	• It is more challenging in developing countries due initial cost of infrastructure and education • Prior to adopting BIM, people may ask for proprietary information effecting profitability
P2	
P3	• Resource commitment to produce lessons learned as part of training
P4	• Due to lack of experience and education, developing countries may require more education started from scratch • Show people similar product to what you are selling to them as people cannot scale up or down other product to the level of their projects
P5	• No difference • There are challenges but can be overcome
P6	• Challenges in industrialized countries are not as intense

When Your Company Works on Projects Where BIM is Used, What Are the

Minimum Requirements for Infrastructure: Equipment, Worker Knowledge, etc.?

P1 and P2 both insist on determining the primary goal of what you want to achieve with BIM as vital initial step prior to selecting or thinking of initial infrastructure needed for BIM adoption (Table 12). To reach its full potential the adoption of BIM encompasses all trades in the AEC industry. As such there is an enormous infrastructure requirement as well as the need for experience, knowledge of construction and technology, resources and modification of traditional processes already in place in the companies. The challenges of experience and knowledge, even for large companies, may be too extreme to tackle in the first job as explained by the participants. On the flip side of this scenario, all companies build up experience and knowledge over time including their physical infrastructure. Therefore, the recommendation of starting small and setting initial goals may help decrease companies in developing countries from intense frustration due to a lack of knowledge, physical infrastructure and experience. This will also help spread out the cost associated in developing the needed infrastructure for complete BIM adoption.

For the smaller initial goals, an off the shelf computer with 4 G ram, Revit software and a human resource with BIM knowledge would be all that a company needs to get started. The second step will gradually expand into training the design and management team, and providing the individuals with the right tools to perform their job. This development and training process would expand with each new project and probably by the fourth project the company might be able to fully transition to BIM.

All the participants agree on the need to provide the computer, software and tools for BIM use. However, there are a wide range of choices of computers and software that could result

in wide range of costs. In addition, there is the need for training and experience that companies may not be able to provide as new adopters of BIM. The emerging best practice is to start small with computers, software, and people and grow into additional resources in each category as the need requires.

Table 12*: Summary of responses to the minimum infrastructure requirements for BIM use*

Participant	Response
P1	• What you want to do first will determine the requirement for initial infrastructure, Computer, Software
P2	• What you want to do first will determine the requirement for initial infrastructure • Medium to high level computer with minimum 4 G ram, Revit
P3	• Provide computers with little stronger capacity Autodesk sets for its products
P4	
P5	• Right tools to perform the job (Computers & Software)
P6	• Computer • Software • Add in outsource

If you are working on a BIM Driven Project with Subcontractors that Do Not Use BIM, How Would You Structure Your Processes to accommodate this Situation?

Based on their experiences participants have taken different approaches to working with non-BIM subcontractors. The approaches typically illustrate project specific conditions and overall company procedures and processes towards efficient and unique solutions to the problem (Table 13). For instance, P1, as a GC, prefers letting subcontractors perform the bulk of modeling work and has weekly coordination meeting in an effort to visualize the model and identify any problem areas and to guide them with recommended approaches to address any issues. This approach may best fit situations where subcontractors are enabled to some extent with the use of

BIM. The early identification of critical problems in this scenario may require a high level assessment from people with sound construction and BIM knowledge. This approach may also be feasible in cases with a protocol with subcontractors that the GC will only manage the information and subcontractors are held responsible for doing the modeling work.

P2 and P4 both agree that it is hard to work with subcontractors with no previous BIM experience. A better approach to this would be to identify the project areas with critical problem and help them with modeling those areas. The recommendation from P5 also infers agreement with P2 and P4 and reaches out to the subcontractors and analyzes the situation and finds out what the problem is. These comments both infer that when subcontractors are not BIM enabled and cannot utilize BIM, modeling for subcontractor becomes a critical issue. Therefore, if subcontractors are new users of BIM, a more feasible approach would be to coordinate with them to make sure they are on the right track to prevent potential delays and model reworks while simultaneously identifying the areas of risk that may require high level experience and knowledge. This approach may result in a more controlled and conducive collaborative environment resulting in a successful implementation of the modeling process.

As suggested by P6, subcontractors with no previous experience should not necessarily be forced to do any modeling work. The project can run partially with BIM and 2D products such that the export of 2D products can be for subcontractors while the GC can use BIM models for clash detection during installation. The result will be a smoother implementation process until the subcontractors gain sufficient experience and are BIM enabled.

Table 13: *Summary of responses for a structured process for working with non-BIM contractors*

Participant	Response
P1	- We do not model instead hold weekly coordination and doing visualization to identify the areas of problem for subcontractors
P2	- Identify critical areas and pay attention to those areas of concern - For contractors it is building information management where subs do the modeling
P3	- Once we did the whole modeling and went through with subs which was painful
P4	- This situation requires additional effort in GC's part - Identify critical areas that subs need help with
P5	- Reach out subs and analyze the situation to take necessary measures
P6	

Findings of the Four New Research Sub Questions

The main purpose of the study was to answer the main question of "are there similarities in BIM adoption issues in developed and developing countries that have/are trying to adopt BIM? If so, what lessons can be learned for those wishing to adopt BIM for the first time in developing countries?" In order to validate a comprehensive answer to the first part of the main research question, the list of 10 initial sub questions was restated as (4) new sub questions after the initial (10) sub question analysis. These new questions are:

- Why was BIM adopted in developed countries?

- What problems were encountered by industries in developed countries during the adoption process of BIM since its inception?

- What developing countries have adopted, or are currently trying to adopt BIM and what adoption issues did they face?

- Are the adoption issues the same today for developing countries that have adopted BIM as they were for developed countries when they adopted BIM?

The initial merging of the initial 10 sub questions was done to consolidate the emerging trends in the sub questions. In turn the answers to these new four sub questions will support the first part of the central research question "are there similarities between BIM adoption issues in developed and developing countries?".

New Research Sub Question One: Why Was BIM Adopted in developed countries?

Based on the participant's experiences a suggested list of causes that have incentivized participants to adopt BIM in developed countries is shown (Table 14). These reasons may not be generalized to all AEC companies in developed and developing countries but may highlight the realities that most of the companies perceived to support BIM adoption.

Table 14: *BIM implementation incentives*

BIM Implementing Incentives
• BIM fosters environment of collaboration
• Get to the level of accuracy and coordinate multiple disciplines
• Trend of market "No BIM no business in future"
• Elevates knowledge in different areas of AEC specialties
• BIM saves significant time and money
• Documents produced by BIM are more useful to the team involved in project

New Research Sub Question Two: What problems were encountered by industries in developed countries during the adoption process of BIM since its inception?

A total of (10) problems were identified by participants during the course of their first BIM implementation (Table 15). These problems may not bridge all the issues companies may have encountered while adopting BIM but appear essential to understand and prepare for prior to transitioning to BIM.

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Table 15: *Problems encountered by first hand BIM users in Developed countries*

Problems Encountered by First Hand BIM Users In Developed Countries
- Obtaining people's buy-in   - Collaboration/Lack of collaboration results in people's turn off   - Working in transparent environment   - Information sharing due to the fear of information misuse or loss of benefit   - Solid base of construction for efficient use of tool   - Lack of education   - Misconception around BIM   - Use of BIM not supported by some schools due to misconception about BIM   - Selecting random individuals for pursuing BIM training by companies   - You always need to market and sell your work and convince people

New Research Sub Question Three: What developing countries have adopted, or are currently trying to adopt BIM and what adoption issues did they face?

As observed the challenges encountered in both developed and developing countries are pretty similar from the participants' perspectives (Table 16). Some of the challenges like initial cost involved in BIM application was not highlighted for developed countries. This might be due to the availability of resources in developed countries and that companies realize that "BIM pays off" and is therefore excluded from being viewed as a major hurdle. On the contrary, people may still doubt if the cost involved with BIM adoption will pay off and that perception may take a while until companies in developing countries experience the same phenomena as their counterparts did in developed countries. The rest of the issues faced in developing countries pretty much align with that of developed countries per the participants' experience and perspective.

Table 16: *Developing countries issues and current technology*

Issues One May Encounter	Adopted Technology Other Than BIM
- Initial costs of physical and knowledge infrastructure - Sharing of model and proprietary information - Resource commitment to produce lessons learned - Misconception around BIM - Lack of construction knowledge with BIM users - Lack of experience and skilled resources - Transfer model to useful information - More resistant against working in collaborative environment - Lack of social and legal support - Owners' lack of knowledge about BIM and its use in facility management	Revit and other Autodesk products

New Research Sub Question Four: Are the adoption issues the same today for developing countries that have adopted BIM as they were for developed countries when they adopted BIM?

Among all participants, only P5 does not explicitly reference the similarities of adoptions issues between country classifications (Table 17). They believe that developed countries have already passed the challenges and struggles of adoption to a point they are fully resolved. The rest of the participants consensually agree the adoption issues are the same in developed and developing countries. This concept has been repeatedly reported in previous studies as well.

Table 17: *Similarities of issues in developed and developing countries*

Responses	Similar?
Adoption issues are the same since wherever we are, we validate cost benefit analysis	Yes
Every company has the same three issues of technology, people and culture regarding this technology	Yes
It is the same. For example, obtaining people's buy in and expecting challenges in the first job are generic issues	Yes
Although there would be some downfalls, where overall adoption issues are all the same	Yes
In developing countries adoption issues no more exist where it is still valid for developing countries	Yes
Adoption issues are the same for both developed and developing countries	Yes

Summary of the Four New Research Sub Questions

Witnessing the summaries of all four new sub questions, it is explicitly observed that the issues encountered by first hand BIM adopters are similar (*Table 15 & Table 16*). This scenario was further scrutinized by observing participants' explicit views. As depicted in (Table 17), participants agree on the similarities of BIM adoption issues in both developed and developing countries. Having that said, when similar issues or hurdles are encountered by first hand BIM adopters in both developed and developing countries, the approaches and experiences from early adopters from both developed and developing countries may serve as best practices to the generic problems of BIM adoption in developing countries.

Lessons Learned

The lessons learned from the participants' views and experiences on BIM application in individual and company level was summarized in four main categories.

- Sound practices

- Infrastructure requirements

- Education requirements

- And working with partners with no previous BIM experience

The majority of sound practices emerged in response to the question "If you were adopting BIM in a developing country, what issues would you anticipate needing to overcome to make that adoption successful". This question geared participants view towards responding to the more plain and most likely issues that participants have been through or what seems to be best approach from the participants' perspective (Table 18).

Table 18: *Sound practices*

Sound Practices
- Determine what do you want to do first with BIM   - Determine the software, data storage and other infrastructure requirement after determining what you are going to do first   - Early on develop a protocol on how the building will be designed to be fragmented into manageable packages for ease of information sharing and can easily be integrated into a whole model at the end or set up structured meetings for work arounds when no high speed internet is available   - Start small or set a smaller goal to be more manageable   - Do not model everything when starting first or avoid modeling elements that do not bring in value   - Expand its use job by job

Considering sound practices for new BIM users, basic physical infrastructure is an inherent requirement. In order to start from a rudimentary level, it is important to choose the right tools that is not only cost effective but also sets the basis for sound and gradual improvement as companies expand their capacities of BIM use. Participants merit basic infrastructure for new BIM users (**Table 19**).

Table 19: *Infrastructure requirements*

Infrastructure requirements
• Medium to high level computer with at least 4 G or more ram • Software • Either high speed internet or break the model down to manageable pieces that can be put together easily at the end • Add in outsourcing • Upgrade computers as expanding the use of BIM over time or project wise

Prior to the start of BIM, companies and individuals need to consider BIM education and experience for successful implementation. In order to assure successful implementation by new adopters, companies need to make sure that individuals taking BIM education and trainings have sound construction knowledge. BIM, unlike the traditional construction technologies, require sound construction knowledge. The information in Table 20 suggests education requirements as part of the best practices for first time BIM users.

Table 20: *Education requirements*

Education Requirements
• Make sure to fully understand BIM and its capabilities • Perform high level assessment and benchmarking prior to selecting individuals for BIM training • Make sure BIM user has sound construction knowledge

Once companies consider sound practices, they can easily pick up the right tool and infrastructure while having the competent trained individuals identified within the company. Since construction business is mostly carried out cooperatively, companies mostly work with partners and business counter parts. Therefore, it is essential for companies to know dealing with the situations where partners are not BIM enabled. This scenario seems to be very challenging that takes a while for BIM enabled companies to bring their business partners with no BIM experience

to the level where BIM enabled companies are. Participants suggest some of the remedies that may help companies deal with such scenarios (Table 21).

Table 21: *Working with partners with no previous BIM experience*

Working with Partners with No Previous BIM Experience

• Decide on your effort with subcontractor
    o Do the modeling for them or have them do it
    o Outsource the model
    o Or hire experts do it for them
• Identify critical areas or areas with more risk and pay attention on those areas
    o Do the modeling of the critical areas
    o Help them through coordination and do some visualization together as well as offering solutions
• Or reach out the subs most often and analyze the situation and what they need
    o Maybe export the 2D models for their technical use and remodel for necessary visualization and clash detections to make sure all parts and pieces of a specific area comes together

I believe these lessons learned would help companies in developing countries with a smoother, cost effective and successful transition towards BIM adoption. However, these lessons may not encompass the entire aspect of successful BIM adoption whereas can be generalized in terms of vital steps towards successful adoption as most of these issues have practically been encountered by BIM professionals with first hand BIM knowledge in some of the medium to large size companies. Most of the participants contributing in this study had been through these situations in developed countries and since the adoptions issues were consensually agreed upon to be the same everywhere, the same approach would also apply to successful implementation irrelative of being in a developed or developing country.

Discussion

As observed throughout the course of analysis and summarization, the responses were re-aggregated to develop the overall lessons learned from the early adopter or risk takers perspective. An important point to be noted was to see if all the participants agree on the similarities of issues that early adopters may encounter in BIM application in developing countries. Further view of the participants although highlighted that BIM implementation may encounter intense resistance in developing countries than developed countries where remedies were highlighted from the BIM expert perspectives for expected scenarios in developing countries.

As summarized throughout the process, the most important lessons that new BIM users in developing countries may consider prior to the implementation process were, sound practices, immediate infrastructure requirements, education requirements, and working with partners with no previous BIM experience.

Since the study focused on the lived experience of early adopters, the lessons learned may be generalized to the application of BIM at a company or individual levels in developing countries. It is also important to note that legal aspects of BIM and mandating BIM application in the industry level may require further studies. The results of the study will fill the gap of starting BIM implementation in developing countries construction industries as previous studies have highlighted the unavailability of clear understanding of the best practices that construction companies would follow as a road map towards successful BIM application which has resulted in companies dithering or being hesitant to adopt this technology.

Although, it is quite challenging to avoid a personnel bias influencing the analysis process since, the author had a good understanding of the current BIM application challenges and

status in both developed and developing countries through conducting an in depth literature review. Every effort was made to bracket self-suppositions when analyzing the data in hand as the only source of information for explicating and analyzing the data. To maintain a high level of validity the author sent follow-up inquiries to the participants asking them to validate the transcriptions for accuracy and completeness of the data throughout the study process.

Significance of the Study

I believe more profound studies and researches will be required to simplify the fundamental approaches for BIM standard, and legal aspects of contracts involving BIM as these parameters may significantly differ based on different geographic locations and overall regulatory difference from one country to another. The study will add significant value by helping construction firms in developing countries successfully implement BIM by providing best practices and lessons learned by early adopters of BIM. The study will help construction firms understand.

- BIM implementation issues are the same in both developed and developing countries

- Companies in developing countries can take the same approaches taken by early adopters for successful BIM implementation

- Successful BIM implementation will help construction companies are facing

- The lessons learned will help construction firms take informed decision regarding BIM use companies in developing countries to address most of the modern day challenges construction

- BIM use in developing countries will enhance construction practices and overall company's construction knowledge that in turn will support countries' economy.

These lessons learned or best practices will help construction firms in developing countries in the process of successful gradual transition to BIM. Taking these approaches may require much less effort whereas meanwhile companies will experience a gradual enhancement in collaboration and knowledge sharing practices (Table 22).

Table 22: *Lessons Learned*

Sound Practices
- Determine what do you want to do first with BIM   - Determine the software, data storage and other infrastructure requirement after determining what you are going to do first   - Early on develop a protocol on how the building will be designed to be fragmented into manageable packages for ease of information sharing and can easily be integrated into a whole model at the end or set up structured meetings for work arounds when no high speed internet is available   - Start small or set a smaller goal to be more manageable   - Do not model everything when starting first or avoid modeling elements that do not bring in value   - Expand its use job by job
Infrastructure Requirements
Medium to high level computer with at least 4 G or more ram

- Software

- Either high speed internet or break the model down to manageable pieces that can be put together easily at the end

- Add in outsourcing

- Upgrade computers as expanding the use of BIM over time or project wise

Education Requirements

- Make sure to fully understand BIM and its capabilities

- Perform high level assessment and benchmarking prior to selecting individuals for BIM training

- Make sure BIM user has sound construction knowledge

Working with Partners with No Previous BIM Experience

- Decide on your effort with subcontractor
  - Do the modeling for them or have them do it
  - Outsource the model
  - Or hire experts do it for them
- Identify critical areas or areas with more risk and pay attention on those areas
  - Do the modeling of the critical areas
  - Help them through coordination and do some visualization together as well as offering solutions
- Or reach out the subs most often and analyze the situation and what they need Maybe export the 2D models for their technical use and remodel for necessary visualization and clash detections to make sure all parts and pieces of a specific area comes together

Further Research

The potential areas of future research identified by the author are based on the access to the data from developing countries construction industries. Since some of the known companies in developed countries are outsourcing their models to the developing countries for more economical product point of view, it is suggested that further research should be more focused on accessing a large number of construction companies in developing countries to further explore the issues and barriers against BIM implementation. In order to share the experiences of early adopters in developing countries and comparing those approaches to the result of this study would be of great value that would help construction firms choose the best suited approaches among the successful set of recommendations and practices.

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