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Inducing BIM-Based e-Procurement into the Construction Industry

Yeabsira Menna
E-mail address: johanyeabsira@gmail.com

Abstract

Most of the contractual issues for the actualization of a construction work begins at procurement; which makes it the gate for many aspects of engagements made to be followed within the whole construction lifecycle. The parties to be involved in a certain construction project are either selected, compromised, or even rejected at this point of engagement. This study tried to investigate the current practices procurement system in construction projects; beginning from the overall construction design information management system establishment by a consulting firm. The fragmentation of construction information is wrongly matched and interpreted across the various disciplines, being the main source of inefficiency in time and cost; which has been observed as a problem of concern. This study contextualize the design management and construction project procurement practices in the construction industry of Ethiopia. The managerial and technical barriers associated with design management practice with respect to information management and the administrative ground for digitalization of the procurement system have also been identified with respect to transparent modality. The proposed technology and/or process discussed is BIM-based e-procurement. The advancement of public procurement to e-procurement is one wing of the study, whereas establishing a well-advanced information system platform of BIM technology as a base for e-procurement is the other wing. Thus, the main objective of this study is to induce BIM-based e-procurement technology/process in to the Construction industry of Ethiopia as a potential solution to the current inefficient construction management practice. A quantitative research method with a questionnaire survey was developed for data collection. A multi-stage random sampling method was used to select respondents for the survey. Relative weight analysis for the descriptive part and Factor analysis for the inferential statistics have been carried out to meet the specific objectives. The overall results supported the proposed research model to evaluate the perceptions of professionals on the assessment made in assessing the potential of BIM-based e-procurement in improving the fragile system of procurement and information management. These research findings are expected to pave the way and increase initiations for developing countries in adopting BIM-based e-procurement and boost the motivation towards further detailed study in the subject matter. This study demonstrated a level of intent to adopt BIM-based e-procurement having a positive and significant effect on the reduction of current managerial problems observed in the industry that may help government officials in developing countries decide to tackle construction management and procurement related transparency problems. The main contribution of this study is that it provides a new body of scientific knowledge for governments, practitioners, and policymakers in their endeavors to create an efficient platform for government construction management and procurement processes.

Keywords: BIM Technology, Building Information Modeling, E-Procurement

1. Introduction

Innovations and adoption of new technologies have become a concern in the construction industry; especially for less developed countries. The process of welcoming, supporting and incorporation of new technologies into an exisiting work process or system or inducing technology can be seen as a process of incorporating technology from one physical/geographic location to a point of application resulting in a technologically advanced arena. It is all about how innovations and technological advancements can be exploited for the betterment of the construction industry.

The construction industry needs a tangible and considerable backup from the ongoing transformation of technology. There are many areas where such a backup can be initiated. Focusing on managerial issues, each element of technical activities starting from design phase requires technology. Design & construction management practices with the emerging of information modelling technology such as BIM and the role of procurement from all aspects of management, within a context of inducing technology has gained vital attention. The fact that the procurement process of construction works is the beginning of the engagement of stakeholders to work together in changing a design to a product. Thus, a certain level of requirement by legitimate professionals can be induced as to what type of technological capabilities is needed to engage in the construction work.

Procurement is all about the activities needed to get a product or service from a supplier to the one in need. These activities has purchasing function, stores, traffic and transportation, incoming inspection, quality control and assurance, and salvage and environmental issues (Van, 2002). When the service becomes a construction work, these activities align with all that is needed to run a construction project with qualified professionals & method of work, specified material supplies and standardized management of work. The qualifications that are set to do a procurement of construction work is initiated by an owner and design consultants; as per the expected quality of work. Setting the quality expectation to the extent where there can be an exchange of building information for construction similar to the one used in a design management practice; is the level of quality assumed in this study.

There is information used as an assessment criteria for prequalification of construction companies; though the strength of consideration might differ from one to another. This information can be used as a platform of assessment to include the necessity of certain levels of technological capabilities as criteria, which can be done by either adding other information for assessment or redefining already existing information for facilitating the use of technology. Contractor pre-qualification and bid evaluation procedures currently used involve the development and consideration of a wide range of necessary and sufficient decision criteria to evaluate overall suitability of contractors. Five elements are used as common factors in contractor selection process for all types of procurement arrangements; Project Packaging, Invitation, Pre-qualification, Shortlisting &and Bid Evaluation (Zedan, 1996).

Among various factors, cost and price has been the main evaluation factors that has a stronghold to affect the selection of a contractor. Yet, some modifications to the lowest bidder system were made, such as reasonable bidder, public interest, and prequalification list which opened the door to other evaluation methods. All valuations are done beforehand with a prequalification method, which allows an owner's bid evaluation team to focus on the specific elements of a project, without being distracted by other considerations. In short,

prequalification is pre-tendering procedure that allows one to choose the most appropriate candidate from those declaring willingness to participate in the bid.

Within the advancement of technology for development and industrialization, least developed countries seem to be unable to engage in a decisive role to plan effective strategies for technological transformation (Hamid, 2001). Many developing countries do not appear to have established the necessary procedures and criteria to choose effective technology transfer policy for rapid industrialization and technological development. Yet, in the last few years, the emergence of several innovative technologies in the construction sector appears to create an increasing need to reduce waste and improve performance.

Information & communication technologies (ICT) have disrupted traditional working methods and stimulated changes and modernization in the areas of electronic business and building information modeling (BIM). Though the progress is slow, these technologies are being integrated into the construction process, demonstrating the prospect of potential gains. The networks supported by these emerging electronic platforms capture the communication practices and provide controlled communication within the entities. The relevance of these information -sharing instruments is being progressively seen in the industry by the efficiency achieved in time and cost management.

Based on the above understanding, an innovative approach to e-procurement in the construction industry of Ethiopia that uses BIM to support the procurement process gained the focus of this study. The hypothesis behind the study is to assess BIM-based structure of information system handling (for digital procurement); in reducing negative effect of fragmentation of the construction process through integration of information across a procurement process and overall management. This is expected to be a strategic approach in procurement cycle that supports a more accurate decision-making and an integrated system saturated with necessary information capable of advanced operations to strengthen transaction relationships & collaborations throughout the chain.

2. Literature Review

According to a report by the World Bank, the delivery of infrastructure projects in several Sub-Saharan African countries lacks efficiency and are normally knotted with delay, cost overrun, low productivity, and dispute among stakeholders (Calderon et al. 2018). In addition, literature highlights that the application of change orders due to design errors and use of old construction methods in developing countries are major causes of poor performance in public infrastructure projects (Ismail et al., 2017; Koops et al., 2016).

Design information as a requirement for procurement, being transferred with traditional 2-D paper format has got the outmost vulnerability for being wrongly shared/interpreted. This inevitable transfer of information creates design negligence, omissions, conflicts, mis-calculations, and inconsistencies on drawings, specification, and other contract documentations. These problems cause frequent change orders and also contribute to disputes among owners, designers and contractors.

The increasing complexity of buildings and infrastructures coupled with competition in the industry in the past few decades has stimulated the industry to seek and adopt emerging trends to overcome challenges associated with these delivery. Firms are increasingly focusing on the area of design by applying thenologies and/or processes like BIM and prefabrication in increasing efficiency. The National Institute of Building

Sciences states that “Building Information Modeling (BIM), utilizes cutting-edge digital technology to establish a computable representation of all physical and functional characteristics of a facility and its related project/lifecycle information and is intended to be a repository of information for owner /operator to use and maintain throughout the lifecycle of a facility”. (NIBS, 2007)

In recent years, BIM has also gained a widespread acceptance across developing countries, despite its low adoption rate in developmental infrastructure projects (Ismail et al., 2017; Olawumi & Chan, 2019). For instance, Ismail et al. (2017) reported an improvement in overall BIM uptake across Asian developing countries although suggested for further extended studies. Similarly, Murphy and Nahod, (2017) call for an in-depth investigation of BIM adoption in public construction projects for successful BIM adoption and diffusion. Researchers and management professionals tried to identify gaps in the AEC industry such as teamwork fragmentation, ineffective coordination, poor communication, low performance, energy consumption, and unsustainable building. In addition, design errors & clashes, project overrun, low productivity, low building quality, poor satisfaction of stakeholders /client/users and shortage or unauthenticated data for facility management (FM) during maintenance stage are reported (Eastman et al, 2008).

Considering the business case for adopting BIM, it has attracted researchers, professionals and practitioners' attention while more cost-benefit information further convinces and motivates professionals to adopt this emerging trend. Thus, the construction industry needs to investigate techniques to decrease project cost & duration, increase productivity, and improve quality; BIM has been accepted in the construction industry as new approach. And to achieve these, it involves detailed & complete replication of a building in a digital environment with the sole goal of providing a collaborative platform for managing building information throughout the lifecycle of a facility (Aouad et al., 2014).

BIM is the process of creating a digital parametric model which represents the physical and functional characteristic of a building in full detail and further shared knowledge pool which can be used to form reliable decisions throughout the life cycle of a facility (Eastman *et al.,* 2011; Suranga and Weddikkara, 2012). It can be taken as shared knowledge resource for information on a facility forming a reliable basis for decision-making from conception to demolition (Azhar et al., 2012). A basic premise of BIM is a collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update, or modify information in supporting and reflecting the roles of that stakeholder.

Based on interviews made with higher officials in the Construction Bureaus of the MoUD (Ministry of Urban Development and Construction); the adoption of BIM in Ethiopia is at the very infant level, which is at the stage of training professionals and is in promotion stage to get into courses given at University level. In contrast, prior studies also highlighted challenges and barriers to BIM adoption in low-income countries, despite the efforts by governments & respective stakeholders in the construction sector (Amuda-Yusuf, 2018; Olanrewaju et al, 2020). These hindrances are ranging from problems associated with low IT infrastructure, financial competency of construction firms, poor collaboration, lack of BIM courses in universities and cultural barriers (Ghaffarianhoseini et al, 2017; Kekana et al, 2020).

The other new phenomenon as an extension to BIM is an innovative approach to e-procurement as an integral part of the

BIM platform. A report by Chong et al. (2009) and Wang and Archer (2007), electronic business platforms are playing an important role as communication and business process management tools; with the provision of an effective support system for collaboration, information management, and exchange. E-procurement is viewed broadly as end-to-end solution integrating many procurement processes throughout an organization. Some of the procurement processes are e-evaluation, e-notice, e-award, e-submission, e-decision, e-ordering, e-invoicing, e-payment, e-contract management & ex-post-evaluation (Vaidya et al, 2006). In a fully integrated &and paperless context, these processes are expected to be combined and relevant information are available electronically.

Duyshart et al. (2003) and Tavares (2010) argue that the use of e-procurement platforms results in a reduction of more than 3% of public expenditures without a reduction in outputs. Such a phenomenon became a reality as e-procurement reinforces a system to reduce complexity, improve competitiveness & transparency, and create an integrated electronic environment to support advanced electronic instruments to manage and monitor contracts. Considering such advantages, several countries are encouraging the implementation of e-procurement in the public sector. For instance, in Portugal, the Public Contracts Code (PCC) approved by Decree-Law 18/ 2008 on January 29, 2008 and is enforced since July 2008 and mandates public e-procurement (Costa et al. 2013). Currently, public procurement is paperless and the private sector is recognizing its advantages and implementing e-procurement, in the construction sector.

Against technological potential of electronic instruments, strategic perspectives on procurement and more integrated approaches to supply chains can gain momentum and the integration of e-procurement with other industry-oriented ICT, such as BIM, becomes extremely important. BIM promotes more cooperative work between all specialties during the different stages of a construction project and is also used during the lifecycle of a building allowing more efficient use of resources, a decrease of errors due to lack of information/ communication, and a more efficient management of the building operations costs (Eastman et al. 2008, Volk et al. 2014, Grilo and Jardim-Goncalves, 2010). Several authors point out that the true benefits of BIM are obtained when a technology is applied throughout a project lifecycle (Eastman and Jeng, 1999). However, this leads to challenges such as data exchange between all parties demands seamless interoperability (Grilo & Jardim-Goncalves, 2010; Martins and Monteiro, 2013).

The construction industry is gradually starting to understand the importance of interoperability to achieve integrated and automated work processes, with savings in cost and time (Ma et al. 2013). As more disciplines of the construction industry adopt building information modeling, integrated design, delivery work process, and the need for interoperable applications grows clearer (Lipman et al. 2011). Lipman et al. also observed that industry leaders and government agencies recognize the importance of addressing interoperability problem and numerous reports document the imperative to solve this problem. The National Research Council report (Gallaher et al., 2004) on competitiveness and efficiency of US construction, for example, clearly state that the lack of interoperability is a major source of construction industry waste and inefficiency.

Considering the huge number of tender being brought to the attention of potential bidders every year, a sizable share of

public resource is wasted to resolve disputes caused by such information gap among owners, designers and contractors. In reaction to most of the public paper-based approach, a form of indolence with the contracting industry to embrace the actual benefit which 3D based design can offer; beyond the ability to work on 2D drawings and concepts including quantity surveying, construction planning, system integration, etc., is still the major point of concern (Tsung-Shi Liu and Ting-Ya Hsieh, 2011). Hence, the evolution from 2D paper-based to a true 3D digital approach in the construction industry hinges upon the government's will to adopt a 3D procurement approach in the first place. This is where BIM technology that is a 3D digitalized mode of building information management system needs its capitalization on being the platform for a 3D procurement approach.

In an interoperable scenario, BIM is a powerful tool to support lifecycle integration (S. Lijun and D. K. H. Chua, 2011) and in the specific case as it is the main intent of the discussion here, to support the e-procurement process. The information contained in the BIM-based design model can be shared directly in an e-procurement process, which can reduce the heavy human workload and manual errors in traditional work. Due to the complexity of construction, e-procurement processes are still time-consuming and prone to error (S. O. Cheung et al. 2004). Having all the information centralized in a specific model may increase process efficiency and accurateness. As (Z. Ma et al. 2013) mention, highlighting the case of cost estimation, several BIM-based software applications have emerged, such as Innovaya (M. E. Johnson and S. Whang, 2002) and Vico Estimator (H. L. Lee and S. Whang, 2004), in which the BIM based design model can be imported to perform effective tendering of building projects cost estimation, confirming that the use of BIM throughout the procurement process may realize considerable gains.

Finally, this study has dealt with issues to see and investigate the routes for inducing BIM technology with its electronic procurement system or search for improvement mechanisms that can be implemented in the current system. As already mentioned above, an innovative approach to e-procurement in construction that uses BIM to support the e-procurement process is proposed as a solution having the hypothetical statement saying "BIM-based structure of the information system may reduce the negative effects of the fragmentation of the construction project life cycle through the integration and integrity of information across the procurement process in a project's lifecycle. "Step-by-step establishments that need to be sought to use BIM technology in the industry together with the accompanied electronic procurement setup are recommended.

3. Conceptual Framework

In a research, there are several approaches in attaining what one intends to find with relation to that particular research. Some scholars mentioned that in order to fulfill the purpose of a research it should entail the use of a theory where the theory may or may not be made clear in the design of that research (Saunders et al. 2007). This is apparent in researches where researchers deliberate whether to use the deductive approach or the inductive approach. Deductive approach is used when one develop a theory and hypothesis (or hypotheses) and design a research strategy to test the hypothesis; and on the other hand, inductive approach is when one collect data and develop theory as a result of your data analysis. These two approaches are vital in the design of the research.

In this study the combination of an inductive and a deductive approach is used. The combination is known as an Abdicative approach. Some explained the concept, abdicative (abduction) approach as the deducing or re-contextualizing individual experiences within a contextual framework, and aims to comprehend something in a new way, from the standpoint of a new conceptual framework (Danermark, 2001; Dubois and Gadde, 2002). Kovács and Spens (2005) added that for researchers to take on the abdicative approach leads to new insight regarding existing phenomena by examining these from a new viewpoint. Furthermore, acquiring new insights derived from existing experiences creates the knowledge. Kovács and Spens (2005) also mentioned that the abdicative approach highlights the search for appropriate theories to a practical observation. This is what (Dubois and Gadde, 2002) termed as “theory matching”, or “systematic combining”.

This is vital in this research as re-contextualizing practical experiences within a conceptual framework is done in order to understand something in a new way. Since the purpose of this thesis is to investigate technology induction through procurement, the abdicative approach get to be the best suited for the study. This is to utilize what (Dubois and Gadde, 2002) termed as theory matching in order to emphasize the search for appropriate theories to practical observation. In this research, theories on innovation and procurement are conceived prior to the interview questions.

Before discussing about how to move on the study, it is necessary to demonstrate the relationship between the theories and construct a hypothesis. A research hypothesis is a prediction of the outcome of the study in which the prediction is based on a formal theory. The hypothesis is a statement of the relationship between facts, whereas the outcome of the theory come predicting about how certain phenomena will appear and behave. The basic components of theories are concepts, variables, and hypothesis. As a result, hypotheses bear a close relationship to the theory in that the statements of the fact are derived from the theory. Along with this process of proving the hypothesis; the objective of the study is going to be addressed in a form of research questions for each specific objective. Then, in the case of this study, as it is indicated above; there are three specific objectives to attain the overall objective of inducing technology in to the construction industry. The way these specific objectives get interrelated is going to be discussed below.

The role of procurement within an organization has traditionally been of non-strategic importance (Vollmer & Murphy, 2017). This can be explained by the famous value chain model where procurement is described as a supporting activity. The supporting activities have traditionally been addressed as areas which do not contribute to value directly and therefore holds potential for major cost reductions (Magnusson, 2018). In other words, these activities should only be as cost-efficient as possible. Magnusson argues that Porter is to blame for the role that procurement plays in most organizations. The value chain model has been adopted by many companies and academic institutions, educating millions of professionals to address procurement as suggested by Porter. The result is that procurement is only seen as something that should be cost-efficient rather than being of strategic importance.

Yet, the power of the procurement in organization lies within the category structure and their management. Category management is a procurement methodology where items are bundled

together, to consolidate purchasing agreements and maximize savings (Webb, 2015). Category management centralizes procurement and leverage economies of scale. Local purchasers, at production sites, mainly follow the set-up strategy for the category. Almost all negotiations with new suppliers and new contracts are handled centrally through the category, but sometimes new negotiations for single purchases could be handled by the local teams. Regarding transactional and daily purchases against already settled contracts, these call-offs are made by the local supply-chain teams at the factories. Then, the procurement department handles, in essence, the strategic purchasing wheel on a group, category and sometimes local level, while supply chain handles the procurement to pay-wheel for all the regular transactions.

So, the role of procurement in organization with respect to the understanding of category management is strategic enough to deal with the whole system of business transactions of the organization. Especially, from the common factors in the contractor selection process of procurement, the project packaging concept is going to be mainly addressed by this concept of category management. We can also mention a range of possible impacts of public procurement in literatures, from greater efficiencies in production, to incentives to innovation and capacity building, to demonstration effects of the utility of innovative goods or services in wider markets, to the creation of lead markets'. Then, the assessment of the current procurement system in the construction industry is going to be the very first specific objective. The assessment measures the level with which the management strategize the procurement system and how well the system is fitting to induce the intended technology; that's BIM based e-procurement.

This consequently leads us to the second specific objective of identifying the challenges to technology induction in the procurement system. The discussion on this get linked with the debate on the role of demand as a driver of innovation. Scholars embracing the demand-pull approach have always emphasized the importance of demand dynamics as a crucial factor influencing both the decision of firms to innovate and the direction of the firms' innovative efforts. However, since the 1980's, the focus of the innovation literature has shifted in favor of supply-side factors. Only more recently, in particular with the work by (Edler and Georghiou, 2007), the long debate between the supply-push versus demand-pull sources of innovation has settled for a more balanced view, which sees demand as a complementary factor driving innovation.

Despite the existing evidence points to the effectiveness of the procurement system in stimulating innovation, a number of barrier can be pointed out preventing the innovative capacity of the system. Most of the significant barriers are more related to the firms' awareness of innovation opportunities and their capabilities to seize them and, on the other hand, to the inherent risk aversion of the public sector. Most importantly for the context of this study, the expected challenges are categorized in to three elements: poor procurement management system, corrupt practices and those issues related with lack of standardized platform to establish BIM technology. Those five common factors for the contract selection process are going to be examined with professional perception trying to identify obstacles hindering the procurement system from attaining the overall goal and in respect to inducing the proposed technology.

Finally, this study is there to see and investigate the routes for inducing BIM technology with its electronic procurement

system or search for improvement mechanisms that can be implemented in the current system. This will meet the third specific objective of the study. As already mentioned above, an innovative approach to e-procurement in construction that uses BIM to support e-procurement process is proposed as a solution having the hypothetical statement saying "BIM based structure of the information system may reduce the negative effects of the fragmentation of the construction project life cycle through the integration and integrity of information across the procurement process in a projects lifecycle." Step by step establishments that need to be sought to use a BIM technology in the industry together with the accompanied electronic procurement set up is recommended.

4. Operationalization of the Construct

By the term operationalization, it is to refer to the process of developing an indicator or items for measuring the practice of technology induction and identifying the challenges with in it; leading to the improvement mechanisms. So, the questionnaire survey has been designed in the order of the three specific objectives. For the first specific objective, 15 measurement parameters with which the practice of technology induction in the construction can be expressed has been provided with 5 point liker scale to be rated. For the second objective, 14 measurement parameters to identify the challenges seen in inducing technology through procurement has been provided to be rated. Finally, the last specific objective got measured by 8 parameters provided as an improvement mechanisms for the challenges seen. Content wise, the major elements measured within all the parameters are procurement management and information management systems in the construction industry with respect to technology induction.

5. Research Methodology

Research philosophy is an important term in research methodology to collect data effectively and appropriately (Williams J, 2011). Research paradigm is another important term in research that defines paradigm as a set of assumptions about how things work. Rossman and Rallis (2003) express paradigm as a “shared understanding of reality.” The two paradigms are popular among social science researchers: positivist, and post-positivist (Bhattacherjee, 2012). This study employed the positivist paradigm to examine the capacity of the procurement system to be a means for technology induction in the construction industry. In the context of this research, positivist philosophy involves hypothesis testing to obtain objective truth and predict what may happen in the future as well (Greener, 2008). As it is known, quantitative research methods are well accepted in the information system or any social or natural science research and were implemented for this study too. The survey Method is one of the most widely used methods for consistently selecting data and this study used a field survey questionnaire for collecting data by the use of the online Google Plat Forms.

In this study, a total of 500 questionnaires were distributed randomly to accessible professionals that are in the field of construction, grounding on the role or position they have in the organization they work for; and collected from 140 respondents. This is based on a scientific approach of a multi-stage random sampling technique; where two or more types of sample designs are classified depending on the stratum they belong to. Before the distribution of these final questionnaires, closer contact and face-to-face interviews some with of the professionals in the Ministry of Urban Development and Construction have been

conducted to see the overall picture of the current status of the industry in the country. So, the preliminary version of the questionnaire was pre-tested together with the interview. A pre-test (pilot study) was conducted with two senior government officers and 30 professional engineers that are working on procurement-related assignments. Finally, the contents of the questionnaire were modified, deleted, and added whenever necessary following the feedback of the experts.

The researcher took further steps to confirm from MUDC professionals if there is implementation and usage of any form of public e-procurement system and the intended technology to be induced that is BIM Technology which turned out to be as there is no use of the above-mentioned technologies apart from the emergence of some capacity building training to higher professionals in the use of BIM technology. Following the suggestions and feedback from an expert panel, the final survey instrument was developed. The questions were developed in four sections, the first being the cover page providing survey titles and descriptions of the study with some general information inquiries to be filled by the professional. The other consecutive pages provide the questions for the three specific objectives in three sections. And the study adopted the Likert scale to evaluate the perceptions of the professionals on the potential of the procurement system in inducing technology.

The reduction of fragmentation of the construction project life cycle through the integration and integrity of information is the dependent variable in the study. It can be seen in the function of the overall information management system and specifically the procurement management system as to its comfort to act as a way of advancing the integration of the construction process. The bidder-related effects are also assessed concerning their effect on this variable. On the other side, an innovative action in the information management system that supports e-procurement (BIM-based e-procurement or 3D level design information management incorporating the same 3D Procurement approach) is the independent variable that's expected to have a positive effect in realizing the dependent variable. It has been covered under the final specific objective in eight variables ranking to the improvement mechanism to be applied.

Different statistical techniques were employed to analyze quantitative data out of which this study used Relative Weight Analysis for the descriptive analysis part and Structural Equation Modeling (SEM) to do the Factor analysis. Structural Equation Modeling (SEM) was used to test the study research model and the hypothesis. MS Excel for the Relative Weight Analysis, IBM SPSS version 23, and AMOS 21.0 software for the Factor Analysis have been used. Before undertaking a detailed analysis of data, all the participant responses have been checked for consistency and completeness of the entire questionnaire. Furthermore, the entire questionnaire is checked if there is any missing value when answered. The process of data and instrument validation was the next immediate vital component in the survey research method for the identification of the reliability and validity of the data used in the research (Burton & Mazerolle, 2011). Descriptive statistics, Cronbach's alpha value, Average of Variance Extracted (AVE), Cross loading, and analysis were applied for the calculation of the validity and reliability of questionnaire data for the sample. IBM SPSS Statistics is used for initial analysis and checking the reliability and validity of data such as descriptive statistical analysis then followed by AMOS Graphics for the whole structural equation modeling.

6. Analysis and Discussion

6.1 Relative Weight Analysis

The analysis goes both to the descriptive statistics by the use of the Relative weight Index value and to the inferential statistics using Factor analysis. In the descriptive analysis part, the ranking based on the relative importance index has been made for all three sections independently. Relative Weight Analysis is a descriptive analysis technique ranking the professionals response for the dominant factor from the measures used to evaluate the three specific objectives. Then, according to the rank on the Relative Weight Index "Long-term mutual relationship by bidders", "Project Packaging within the Category Structure" and "Innovation and Technology Induction as one of the primary goals of the Procurement System" get to have a higher weight among the variables respectively. This is then the descriptive reflection of the dominant practice in the construction industry concerning technology induction based on the perception of the professionals. The sample professionals weighted the measures for the practice in the above order as they are the most frequently occurring parameters from among the 15 measures with which the practice has been expressed.

The same way, the ranking for the second section on the challenges and the third section on the improvement mechanisms for technology induction has been made. The challenges and the improvement mechanisms both in the procurement management and the overall information management system has been put to be measured. As per the ranking made on their frequency of occurrence "Lack of deep understanding of BIM", "Lack of Standardization in the Information Management System" and "Influence of Human Decisions in the Procurement Management System" got the highest rank from the expected challenges in inducing technology through procurement**.** When it comes to the third section, the rank in the relative importance analysis shows that "Capacity Building Training" and "Establishment of e-procurements" ranked 1st and 2nd while "Promotion of Interoperable network" and "Inclusion of Technology Induction as Primary Goals" got same third rank in relative importance to be employed as improvement mechanism for the challenges seen in inducing technology. This is all about the perception of professionals on the parameters for the dominant challenges and improvement mechanisms for technology induction.

Table 1 Relative Weight Index for the assessment of the Practice of Inducing Technology

No.	Metrics	Frequency of Occurrence					Frequency of Occurrence		
	Section 1 (Practices)	1	2	3	4	5	Mean	RII	Rank
1	Project Packaging within the Category Structure(PMS)	3	13	22	65	30	3.797	0.759398	2
2	Reduced complexity, Improved competitiveness and Integrated environment to manage contract(PMS)	7	24	14	54	34	3.759	0.75188	4
3	Stimulated Innovation by high standards and clear set of needs(PMS)	5	29	44	37	18	3.256	0.651128	6
4	Promoted convergence of single standard to match international standards(PMS)	10	45	40	27	11	2.88	0.57594	11

5	Forced innovation on the part of contractor (PMS)	31	33	34	24	11	2.632	0.526316	14
6	Give the best value for money(PMS)	24	41	22	31	15	2.789	0.557895	12
7	Innovation and TI as one of the primary goals of the PS(PMS)	8	21	15	38	51	3.774	0.754887	3
8	Bidders move concurrently with the on-going development of the PS(PMS)	5	17	51	48	12	3.338	0.667669	5
9	Improved level of availability and High quality Products by the contracting parties (PMS)	5	29	43	43	13	3.226	0.645113	8
10	Long-term mutual relationship by bidders(IMS)	2	14	18	68	31	3.842	0.768421	1
11	Bidders engagement with new alternative proposals(IMS)	5	22	52	42	12	3.256	0.651128	6
12	Standard formats representing product model data(IMS)	5	24	63	30	11	3.135	0.627068	9
13	Effective in reducing wastes and improving performance (IMS)	17	52	33	22	9	2.654	0.530827	13
14	Sufficiently organized communication practice and Integrated construction process(IMS)	19	54	29	25	6	2.586	0.488722	15
15	Integrated, coordinated and consistent decision making practice (IMS)	12	32	49	27	13	2.977	0.595489	10

Table 2 Relative Weight Index to Identify Problems of Inducing Technology

No.	**Metrics**	**Frequency of Occurrence**					**Frequency of Occurrence**		
	Section 2 (Challenges)	**1**	**2**	**3**	**4**	**5**	**Mean**	**RII**	**Rank**
1	Information Asymmetry (PMS)	7	8	17	63	38	3.88	0.77594	6
2	Influence of Human Decisions (PMS)	2	16	20	50	45	4.008	0.801504	3
3	Corrupt Practices (PMS)	2	16	16	50	49	3.962	0.792481	4
4	Lack of fruitful interactions (PMS)	4	26	39	41	23	3.398	0.679699	13
5	Use of over specified tenders(PMS)	1	14	36	60	22	3.662	0.732331	11
6	Low competency of Procurers (PMS)	9	20	29	53	22	3.444	0.688722	12
7	Lack of consistent Monitoring(PMS)	7	18	20	48	40	3.722	0.744361	10
8	Lack of Interoperability(IMS)	2	3	34	56	38	3.94	0.7879705	5
9	Lack of Standardization(IMS)	2	5	21	61	44	4.053	0.8126	2
10	Unfriendly to adoption of Technology (IMS)	8	30	25	45	25	3.368	0.673684	14
11	Limited confidence on Security (IMS)	2	9	38	52	32	3.774	0.754887	9
12	Organizational Problems (IMS)	2	11	22	69	29	3.842	0.768421	8
13	Lack of Policies (IMS)	5	8	15	79	26	3.85	0.769925	7
14	Lack of deep understanding on BIM (IMS)	0	5	16	53	59	4.248	0.849624	1

Table 3 Relative Weight Index for the Improvement Mechanisms

No.	Metrics	Frequency of Occurrence					Frequency of Occurrence		
	Section 3 (Improvement Mechanisms)	1	2	3	4	5	Mean	RII	Rank
1	The motivation by government side	2	7	15	64	45	4.075	0.815038	8
2	Promotion of Interoperable network	0	5	17	53	58	4.271	0.854135	3
3	Establishment of e-procurements	0	5	13	48	67	4.331	0.866165	2
4	Reinforcement of High Standards	0	2	25	54	52	4.173	0.834586	5
5	Capacity Building Trainings	0	1	9	43	80	4.519	0.903759	1
6	Inclusion of TI as one of the Primary Goals	0	2	19	54	58	4.263	0.852632	4
7	Enabling clients engagement prior to construction	0	4	27	55	47	4.09	0.818045	7
8	An obligatory approach to establish the use of BIM	0	3	26	53	51	4.143	0.828571	6

6.2 Factor Analysis

Factor analysis is a collection of methods used to examine how underlying constructs influence the responses on several measured variables. There are basic types of factor analysis that are exploratory and confirmatory. Exploratory factor analysis (EFA) attempts to discover the nature of the constructs influencing a set of responses. Confirmatory factor analysis (CFA) tests whether a specified set of constructs is influencing responses in a predicted way. Both types of factor analyses are based on the Common Factor Model. The model proposes that each observed response (variable) is influenced partially by underlying common factors (latent variables) and partially by underlying unique factors. The strength of the link between each factor and each measure varies in such a way that a given factor influences some measures more than others. And the very specific tool employed to do the Factor analysis is Structural Equation Modeling (SEM).

The main type of factor analysis on which the findings based, is Confirmatory Factor Analysis. It is a statistical procedure for testing a hypothesis about the commonality among variables (Hoyle R.H, 2004). It is used to simultaneously test multiple hypothesis that collectively constitute a measurement model. All such model comprise four components. At least two variables or indicators, are necessary for the most rudimentary measurement model. Variability in scores on the indicators is allocated to two sources – LATENT VARIABLES and measurement ERROR. Latent variables are not observed; they are inferred from the commonality in the indicators. Measurement error is variability in the indicators not attributable to the latent variables. Finally, the degree to which variability in scores on the indicators can be attributed to the latent variables is indexed by loadings, coefficients that are estimated in measurement equations in which the indicators are regressed on the latent variables hypothesized to influence them.

The IBM SPSS Statistics 23 with AMOS Graphics was used to run the

measurement model for the sample data. Testing of validity and reliability of the model data was the other significant process. In this regard, Average Variance Extracted (AVE), composite reliability (CR), and Cronbach's alpha were used to test the reliability and validity of the measurement model. Various scholars have already pointed out that threshold values of AVE, CR, and Cronbach's alpha >.50, >0.70, and >0.7 respectively. The reliability of the overall constructs for exploratory factor analysis has been checked for its Cronbach's alpha value and met the requirement of having "0.888" greater than 0.7. In the same way, the reliability of the data for the confirmatory factor analysis has been made using composite reliability (CR) test in each section, for each factor; showing an almost satisfactory green light to move on with the result. As to the suggestion of some authors, the AVE value of above 0.50 indicates a sufficient level of convergent validity (Henseler et al. 2009). The convergent validity has been met for all most all the factors in each section; except for some, indicating a minor disability of the variables to express the convergence of values to be grouped in one factor. Discriminant validity was also examined using the square root of average variance extracted (AVE) and cross-loadings. All the square root values of AVE have been compared with the highest estimate of the correlations of constructs and found to be greater than the correlation estimates in almost all factors of each section confirming there is a discriminant validity.

A structural model assessment of a structural equation model generated through AMOS was used to test the relationships. A good-fitting model was accepted if the value of the CMIN/df, the goodness of fit (GFI) indices (Hair et al, 2010), the Tucker and Lewis index (TLI) (Bollen, 1989b); the confirmatory fit index (CFI) (Bentler, 1990) is > 0.9 (Hair et al, 2010). In addition, an adequate fitting model was accepted if the AMOS computed value of the standardized root mean square residual (RMR) < 0.05, and the root mean square error approximation (RMSEA) is between 0.05 and 0.08 (Hair et al, 2010). The squared multiple correlations (R-Square) for the observed variable were used to test how valid and significant the measures are in their ability to express the intended specific objective in each section.

6.3 Practice of Technology Induction

Then, the results of the Measurement Model for the Practice of Technology Induction after having been analyzed by Factor analysis and grouped into four latent factors with 14 observed variables are shown in Figure 4.1. As you can see the number of the observed variables after the analysis for the relationship between the latent factors and the observed variables using AMOS; get reduced to 14 eliminating one variable from the structural model. F1 is seen to be expressed by PPMS1, PPMS2, PPMS7 and PPMS8; which are procurement management focused observed variables assessing the innovativeness of the current procurement system by process. And the other four observed variables categorized under F2, that are PPMS3, PPMS4, PPMS5 and PPMS6 resembles in expressing the assessment of the innovativeness of the procurement management system with regard to qualifying the minimum standards expected. The same way, being focused on assessment of information management system F4 get expressed by observed variables PIMS1, PIMS5 and PIMS6; at the same time F3 by PIMS2, PIMS3 and PIMS4.

From the results of the analysis based on the value of squared multiple correlations (R-Square), three outstanding measures valid and significant to express the practice of technology induction were sorted out to

be: “Forced innovation on the part of contractor (PPMS5, 84%), Reduced complexity, improved competitiveness and integrated environment to manage contract (PPMS2, 82%) and Sufficiently organized communication practice and Integrated construction process (PIMS3, 79%). These outstanding measures can be taken as parameters of indications for the presence of the intent and practice of adopting innovative approach to the existing procurement system of the construction industry.

Comparing it with what the Relative weight analysis gave us would make the result more understandable. The outstanding measures from the structural model give as the most statistically acceptable look as to what the assessment of innovative practice would manifest; whereas the highest ranking measures from the relative weight analysis can be taken as a first hand reliable, yet a shallow perceptive status viewed by professionals as a dominating practices in the assessment of the procurement and information management system. Then, based on the results from the regression weights the latent variables’ expression by the corresponding observed fact be positive and significant (All the estimates being Positive and the p-value less than 0.001) as in Table 4. So, the overall structural model is supported to be expressive of the assessment we have in the practice of technology induction.

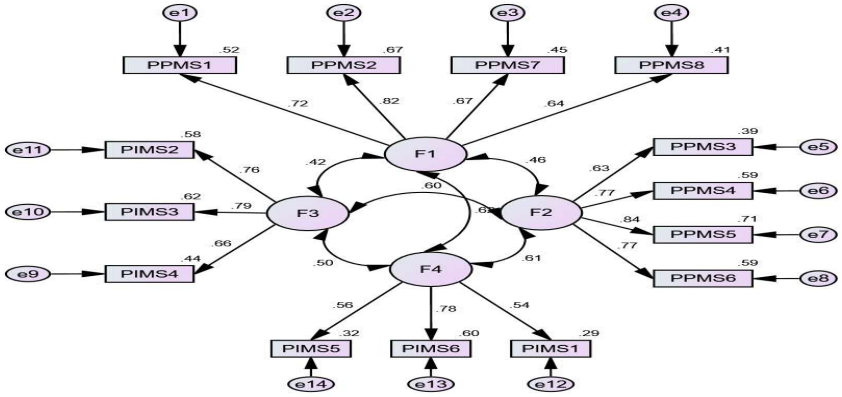


Figure 1 The Results of Structural Model for the Practice of Technology Induction.

Table 4 The Hypothesized Relationship of Factors with Decision Made in the Practice of Technology Induction

Hypothesized Relationship			Standardized Estimate	Standard Error	z-value	p-value	Decision
PPMS1	<---	F1	0.721				Supported
PPMS2	<---	F1	0.817	0.166	8.275	<0.001	Supported
PPMS7	<---	F1	0.674	0.173	7.034	<0.001	Supported
PPMS8	<---	F1	0.638	0.127	6.619	<0.001	Supported
PPMS3	<---	F2	0.625				Supported
PPMS4	<---	F2	0.766	0.18	6.939	<0.001	Supported
PPMS5	<---	F2	0.842	0.224	7.109	<0.001	Supported
PPMS6	<---	F2	0.765	0.213	7.008	<0.001	Supported

Hypothesized Relationship			Standardized Estimate	Standard Error	z-value	p-value	Decision
PIMS4	<---	F3	0.665				Supported
PIMS3	<---	F3	0.788	0.166	6.91	<0.001	Supported
PIMS2	<---	F3	0.764	0.168	6.781	<0.001	Supported
PIMS1	<---	F4	0.543				Supported
PIMS6	<---	F4	0.777	0.314	4.703	<0.001	Supported
PIMS5	<---	F4	0.564	0.255	4.215	<0.001	Supported

The first outstanding measure (PPMS5) is about the profile of public procurers forcing innovation on the part of the contractor or even engaging in co-invention, pushing suppliers to innovate and keep up with user requirements. From the identified elements (common factors) in the contractor selection process; this parameter calls for the invitation practice in the procurement process. We can ascertain from this finding that forceful inclusion of innovation on the part of the contractor by procurers together with the engagement in co-invention is the most vital element in the induction or adoption of technology through procurement which will push the invitation practice of the procurement process to the tightest level experienced before.

The second outstanding measure, that's (PPMS2) calls for the practice in the procurement management process referring to the "project packaging" element from the common factors in the contractor selection process. It is about the ability of procurement process management in the industry to reduce complexity, improve competitiveness and transparency, and create an integrated environment to manage and monitor contracts. It can be summarized as the highest efficiency level of project packaging experience in the procurement process to manage and monitor contracts. And the third outstanding measure (PIMS3) is about information management practice in the overall project lifecycle. It addresses the sufficiency of the organization as to how the communication practices within the entities are integrated. This specific measure is the one that is projected to the necessity of adopting BIM technology whereas the first two measures necessitate the need for innovation in the procurement process.

Apart from these, the Oslo Manual (OECD/Eurostat 2018, p. 22) defines innovation as a process as follows: "Innovation activities include all developmental, financial and commercial activities undertaken by a firm that is intended to result in an innovation for the firm". Previous construction innovation scholars have also emphasized the importance of considering the nature of the innovation process and organizational setup involved (Ozorhon 2013, Bygballe and Ingemansson 2014, Brockmann et al. 2016). Sub-dimensions of innovation as a process that warrant attention include how (is the innovation achieved) and who (is involved) (Bygballe and Ingemansson 2014, Brockmann et al. 2016). The same concept of understanding the induction of technology as a process has been addressed in this research; focusing the dimensions on advancing the procurement and information management process as stimulated by the client side and adding bidders-related effects on top of it.

6.4 Challenges in Technology Induction

As it is done for the Practice of TI, the structural equation model was generated through AMOS to test the relationships, and the good-fitting model tests were conducted. The challenges seen in technology induction as a sequencing phenomenon of the practice have been tested with fourteen independent measures and after having been put to test by the rotated component matrix they were grouped into four factors (F1 to F4) with thirteen independent measures. Results of the analysis show three outstanding measures based on the value of squared multiple correlations (R-Square) that are valid and significant to express the challenges in technology induction well. These are Corrupt Practices (CPMS3), Lack of consistent Monitoring (CPMS7), and Lack of Standardization (CIMS2). We can say that the challenges in the practice of technology induction were best expressed by these measures.

The first two measures Corrupt Practices (CPMS3) and Lack of Consistent Monitoring (CPMS7) are there to address mainly the challenges in the procurement system where Lack of Standardization (CIMS2) addresses the information management aspect of having a standardized industrial platform to have an efficient information communication practice. As a whole, this shows that these three outstanding measures express dominantly the challenges of technology induction from all those 13 variables validly and significantly; that the focus we give to them can act as the diligence we invest to solve the problem in the current practice of procurement & information management. Based on the results from the regression weights as in Table 5, the latent variables' expression by the corresponding observed factors is positive and significant (All the estimates being Positive and the p-value less than 0.001). So, the overall structural model is supported to be expressive of the assessment we have in identifying the challenges in technology induction

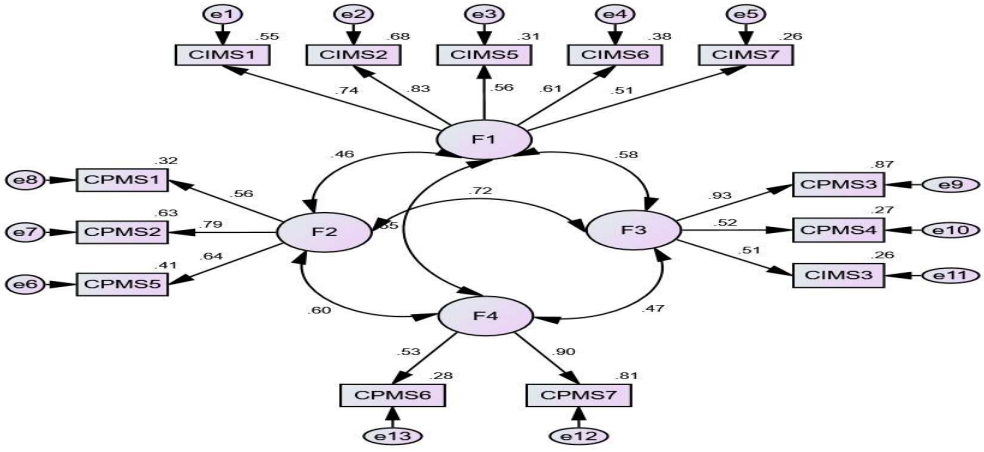


Figure 2 The results of the Structural Model for the Challenges in Technology Induction.

On the Technology and Innovation Report (UNCTAD, 2021), particular challenges in developing countries regarding access to the benefits of frontier technology have been listed. Three main issues which are the higher level of income disparities, digital divides, and shortage of skills have been pointed out. The term income disparities, it is to mean that access to goods and services is inherently more difficult for a larger share of the population in developing countries. The effect of the

affordability of technology on its broader access is a well-established fact in the deployment of digital technologies which is a common challenge unresolved. Digital divides, that's the inadequate digital infrastructure together with the shortage of skills capsulated the access of being benefited from technology in developing countries. The result from this study based on the relative weight analysis summery, also put the reflection of the report; as it is in the construction industry. Lack of deep understanding of the technology to be induced (BIM), the problem of standardizing the information management process, and the influence of human decisions have been seen pulling down the pace of innovative practice in the industry.

Table 5 Hypothesized Relationship of Factors with Decisions Made for Challenges in Technology Induction

Hypothesized Relationship			Standardized Estimate	Standard Error	z-value	p-value	Decision
CIMS1	<---	F1	0.741				Supported
CIMS2	<---	F1	0.827	0.127	8.972	<0.001	Supported
CIMS5	<---	F1	0.556	0.135	5.86	<0.001	Supported
CIMS6	<---	F1	0.613	0.143	6.384	<0.001	Supported
CIMS7	<---	F1	0.508	0.118	5.398	<0.001	Supported
CPMS5	<---	F2	0.642				Supported
CPMS2	<---	F2	0.795	0.218	6.525	<0.001	Supported
CPMS1	<---	F2	0.563	0.19	5.42	<0.001	Supported
CPMS3	<---	F3	0.934				Supported
CPMS4	<---	F3	0.523	0.097	5.818	<0.001	Supported
CIMS3	<---	F3	0.505	0.119	5.091	<0.001	Supported
CPMS7	<---	F4	0.9				Supported
CPMS6	<---	F4	0.53	0.13	4.346	<0.001	Supported

6.5 Improvement Mechanisms for Technology Induction

After a test by the rotated component matrix, the constructs for the Improvement Mechanisms were grouped into two factors F1 with five observed factors (IM3, IM4, IM6, IM7, and IM8) and F2 with two observed factors (IM1 and IM2). The analytic findings show three outstanding measures of improvement mechanisms in the technology induction process based on the value of squared multiple correlations(R-Square). These are the motivation by the government (IM 1), the Inclusion of TI as one of the Primary Goals (6), and Enabling client engagement before construction (IM7). The results demonstrated a positive and correlated relationship between the factors and the intent to improve the technology induction process in the industry as seen in Table 6. All these three outstanding variables are more intentional and motivational rather than technical and mechanical which is an

indication that most of the challenges in the industry have not yet passed the level of intentional readiness; let alone the lack of knowledge and practical skills to adopt innovations to the industry.

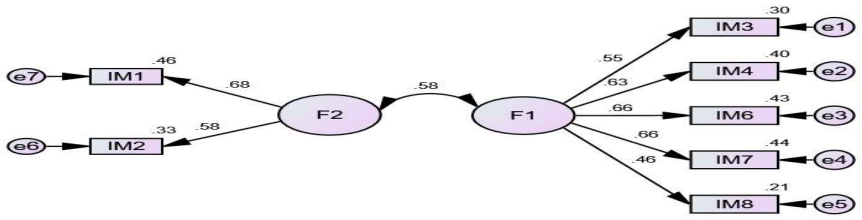


Figure 3 The results of the Measurement Model for the Improvement Mechanisms.

The theme of the main objective is the reduction of fragmentation in the construction project life cycle; it reviewed how BIM-based e-procurement can solve managerial problems through the integration and integrity of information. In research conducted in Taiwan by (Liu T. and Hsieh T, 2011), an examination of the feasibility as well as the relevant means to launch a BIM-based procurement system for public works was done. And, it mentioned that the procurement system needs significant adjustments (which is mainly expressed in their transformative nature from 2D to 3D procurement system), and many other spin-off functions surrounding government procurement; if a BIM platform is to be adopted. This study can also be seen as one of the complementary views that we can adopt in adjusting the procurement system.

Table 6 Hypothesized Relationship of Factors with Decisions Made for Improvement Mechanisms

Hypothesized Relationship			Standardized Estimate	Standard Error	z-value	p-value	Decision
IM3	<---	F1	0.546				Supported
IM4	<---	F1	0.63	0.222	4.949	***	Supported
IM6	<---	F1	0.656	0.22	5.002	***	Supported
IM7	<---	F1	0.66	0.246	4.92	***	Supported
IM8	<---	F1	0.463	0.21	3.977	***	Supported
IM2	<---	F2	0.578				Supported
IM1	<---	F2	0.677	0.392	3.28	0.001	Supported

Furthermore, a research article by (António Aguiar Costa and Antonio Grilo, 2015) from Portugal presents an innovative approach to e-procurement in construction, which uses building information models (BIM) to support the construction procurement process. The result is an integrated and electronic instrument connected to a rich knowledge base capable of advanced operations and able to strengthen transaction relationships and collaboration throughout the supply chain. The BIM-based e-procurement prototype has been developed using distinct existing electronic solutions and an IFC (Industry Foundation Class) server and was tested in a pilot case study, which supported further discussions of the results of the research. This study tried to combine and integrate the two technologies that are BIM and e-procurement in one platform which is by far related to this study in content.

7. Conclusions

Though BIM-based e-procurement is a recent development, for such a country like Ethiopia that has not yet established any form of ICT-based management in the construction industry; it will help to create a fresh start of an advanced version of the technology. Both the information management and procurement management systems go in one line of management having the same platform. For such a country like Ethiopia and developing nations, such large-scale technological transformations are a bit engaging and time taking; as has been seen in the finding of this research. The improvement for developing countries shall then begin with building motivational and intentional readiness for the major stakeholders in the industry (Government bodies and Private Consulting and Construction Companies).

So, based on the finding on the results of improvement mechanisms (specially the outstanding measures) to work on; motivating the government as to refine its engagement in the construction industry of the country by the use of such technology (BIM-based e-procurement) shall be on track. And these motivations shall be incorporated with defined objectives including such an innovative approach a primary goal of the plan, strategy and policies of the construction industry of the country. Investors and Clients showing diligence on the construction industry shall be enabled to know and understand the use and efficiency created by such technological innovative approach before their engagement in construction projects. These can be orchestrated by the disciplines and standards inserted with in the construction laws and proclamations.

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