# Current State of Building Information Modeling (BIM) and Total Building Commissioning and study of their applicability in Kazakhstan

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## Abstract
This paper investigates the current practices of Building Information Modeling (BIM) and Total Building Commissioning (TBC) for raising the understanding of these emerging approaches in the engineering and construction industry of Kazakhstan. Findings from the literature review and two questionnaire surveys reveal that the use of BIM for building commissioning and TBC needs more investigation by researchers. Findings also demonstrated the participants' positive perceptions of adopting and employing BIM and TBC in their companies' practices in Kazakhstan. It was also found that the current application of BIM and TBC in Kazakhstan is not high as one can compare with other countries. However, with the involvement of a number of foreign AEC companies in high profile construction projects in Kazakhstan and with more research and BIM awareness studies performed in Kazakhstan, the applications of BIM will gradually increase in Kazakhstan to align with the developments in other countries.

**Keywords:** Total Building Commissioning; Building Information Modeling (BIM); Sustainable built environment.

## 1 Introduction
Construction industry is facing challenges in achieving greener, sustainable and better quality built environment. There is a demand for new sustainable infrastructure that consumes less energy and resources, and implements sustainable and green construction. According to recent statistics, building sector remains a major energy consumer that is responsible for approximately 10% of global energy end-use during the manufacture of building materials (UNEP 2011). In the operation stage of building life, it is responsible for production of 30-40% of greenhouse gas (GHG) emissions, and around 40% of all solid waste in developed countries is produced as a result of construction and demolition (UNEP, 2011). In recent years, numerous regulations have been made in many countries that address targets for energy and resource efficiency and encourage emission mitigation in new and existing building projects. Various rating systems such as Leadership in Energy and Environmental Design (LEED) from the US, Building Research Establishment Environmental Assessment Methodology (BREEAM) in UK, Green Star from Australia, the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) from Japan and the Building Environmental Assessment Method (BEAM) Plus in Hong Kong are being used to assess the environmental performance of buildings. Architects and planners progressively look for ways to decrease the environmental impact and energy consumption of buildings through improved design, increased energy efficiency and conservation. To address abovementioned challenges to make greener, sustainable and better quality built environment different powerful tools and processes have been introduced to industry. Two of these tools are Building Information Modeling (BIM) and Total Building Commissioning (TBC). This paper aims to investigate the development of BIM and Total Building Commissioning by a review of past research

and to study BIM as a facilitator of Total Building Commissioning Process. Also, the research presents recent survey results on the state of the art and application of BIM and Total Building Commissioning in Kazakhstan construction industry practices.

## 2 Literature Review

### 2.1 Total Building Commissioning

Building commissioning is simply a means of ensuring that a building owner gets the quality of facility that is expected and deserved. The first commissioning activity performed in North America in 1977 by Alberta Public Works Supply and Services (APWSS) in Canada when Public Works started use the Commissioning in their project delivery systems (Commissioning Milestones, retrieved in 2016). While in the United States building commissioning activities started in 1980s. The first commissioning project was undertaken by Disney in Florida in 1981. In 1984, the University of Wisconsin-Madison began offering the commissioning courses and ASHRAE Heating Ventilation and Air Conditioning (HVAC) Commissioning Guideline Committee has formed in the same year (Commissioning Milestones, 2016).

In 1989 ASHRAE introduced the first guideline (later named Guideline 1) for commissioning HVAC systems and published an updated version in 1996 and formed it as a Guideline 0-2005. The definition of commissioning given by ASHRAE in 1996 version of guideline was "a quality oriented-process for achieving, verifying and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria".

Building commissioning has generally been viewed as being applied primarily to mechanical systems (especially HVAC) and perhaps electrical systems. This mental bounding of the scope of commissioning to dynamic systems has limited its potential usefulness in providing verified quality for building systems and assemblies. The idea of total building commissioning was developed to overcome this limited view and expand the value of the commissioning process. Total building commissioning addresses all building systems through the entire life cycle of the facility (Grondzik 2009).

Total Building Commissioning (TBC) officially has been defined as a "Systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction that all facility systems perform interactively in accordance with the design documentation and intent, and in accordance with the owner's operational needs, including preparation of operation personnel" (ASHRAE Guideline 0 2005). The process starts at project inception (pre-design phase) and continues through the operations and occupancy phase. It is a quality-based tool adopted by an owner in order to deliver successful construction projects. Purpose of total building commissioning is to reduce the cost of delivering construction projects and increase value to owners, occupants and end users (ASHRAE Guideline 0 2005). Implementation of Total building commissioning is gaining increased attention in the construction industry. For instance, General Services Administration (GSA) requires adopting the Total building commissioning as their quality-assurance tool for all new construction and major renovation projects, starting in 2006 (Eakin and Matta 2002). Moreover, Total building commissioning has been recognized as the best practice by It is rapidly becoming standard practice in a wide range of facilities, including data centers, laboratories, schools, hospitals, institutional and office buildings (Shakoorian and Sadri 2004) and brings manifold benefits to facilities. According to LEED-NC Reference guide, "A commissioned building provides optimized energy efficiency, indoor air quality, occupant comfort and sets the stage for minimal operation and maintenance costs". Moreover, implementing the commissioning process maintains the focus on high performance building principles from project inception through operation, which typically results in optimized mechanical, electrical and architectural systems – maximizing energy efficiency, thus minimizing environmental impacts (LEED-NC Reference Guide). In their study Mills et al (2005) investigated and studied cost effectiveness of commissioned buildings. They analyzed results from 224 buildings, representing 30.4 million square feet of commissioned space, across 21 states in the US. The results of their study show that for the commissioning of existing buildings median energy cost savings are 15 % or $0.27/ft2-year with a median payback times of 0.7 years [0.2 to 1.7 years], while for new buildings, median commissioning costs were 0.6% of total construction costs or ($1.00/ft2), with a payback time of 4.8 years [1.2 to 16.6 years]. Based on their study, Mills et al (2005) concluded that building commissioning can play a major and strategically critical role in attaining broader national energy savings goals—with a potential of $18 billion or more in savings each year.

Mills et al (2005) also concluded that "commissioning is arguably the single-most cost effective strategy for reducing energy, costs, and greenhouse gas emissions in buildings today and at the highest level, building commissioning brings a holistic perspective to design, construction, and operation that integrates and enhances traditionally separate functions". Agustsson and Jensen (2012) compared two commercial buildings. One building was commissioned while another one was non-commissioned building. During the study they looked at electricity consumption, energy used for heating and hot water production and operation and maintenance costs. As a result of the research, the authors found that commissioned building consumes 40-54% less electricity and 35-42% less energy per square meter compared to non-commissioned building. To improve building sustainability building commissioning should be performed regularly during its whole lifecycle. The authors believe that manual commissioning of buildings is labor and time intensive, thus lifecycle commissioning of modern buildings is currently not feasible. Therefore, automated building commissioning is suggested which helps in saving labor, time and cost and enhances sustainable construction.

All buildings seeking LEED- NC Certification must implement a commissioning process that meets the LEED-NC rating system guidelines. The LEED-NC guidelines also identify more advanced commissioning tasks that may be incorporated to earn an additional point. Many of the measures that will be incorporated to achieve the level of energy efficiency required for a LEED-NC rating are sophisticated and interdependent. Therefore, commissioning would be advisable even if it weren't required, to ensure that the building performs as well in reality as it did on paper.

## 2.2 Building Information Modeling

Building Information Modeling (BIM) is one of the most powerful innovations in the architecture, engineering and construction (AEC) industry. It is a promising tool to develop into the vehicle of interoperability, integration and collaboration and its primary advantage is an intelligent, 3D, virtual building model that contains all aspects of building information such as 3D geometries; costs; maintenance; materials; structural, mechanical, electrical and plumbing systems (Woo et al, 2010). According to the US National BIM Standard (NBIMS 2010), BIM is "a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition". The result of BIM activity is a "building information model", which is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, that allows to extract and analyze views and data appropriate to various user's necessities' in order to generate information for decision making and improving the process of facility delivering (Azhar et al 2012).

BIM tools support parametric modeling and allow new levels of visualization and simulation of the buildings' behavior. It enhances more efficient project management and construction industry performance (Miettinen and Paavola 2014). BIM is characterized as an absolute tool of collaboration that minimizes design mistakes while increasing the productivity of the construction industry. It can be seen as an evolution of CAD systems which provides more "intelligence" and interoperability of information (Miettinen and Paavola 2014). It acts as a single source of all the project information that is used by designers to analyze and modify the buildings' design before its physical implementation. Currently BIM tools are implemented in construction industry for many tasks, including materials quantity takeoff, cost estimation, documentation, code reviews, energy simulations, design validation, facilities management, construction scheduling, sequencing and collision detection (Azhar et al 2008; Azhar, 2011).

BIM is an essential contribution to sustainability; it supports the implementation of integrated design and collaboration of the different stakeholders involved in the project from the early design phases onwards, providing an overview of the project and has a great capacity for information management (McGraw Hill 2014). Studies conducted by Azhar et al (2008, 2011) and Krygiel and Nies (2008) identified and delineated the opportunities brought by BIM for better decision-making and sustainability analyses at early design and preconstruction phase to accomplish sustainability goals. An integrated BIM system can facilitate process of collaboration and communication between project participants to effectively provide a well-performing building during operations (Krygiel and Nies

2008). Incorporating sustainability principles with BIM has an impact to change the traditional design practice to high-performance design (Azhar et al 2012). An example of such effort is Columbia campus of the University of South Carolina which resulted in approximately $900,000 savings over the next ten years at current energy costs. At the initial stage BIM can be used to support the design and analysis of building system including structural analysis, environmental controls, construction method, materials selection and analysis of the whole design process. BIM and sustainable building together are able to best address the remarkable challenges in productivity and sustainability encountered by the AEC industry. At present BIM tools have the ability to provide users with an opportunity to search different energy saving alternatives at the early design stage by avoiding the time-consuming process of re-entering all the building geometry and supporting information necessary for a complete energy analysis. Krygiel and Nies (2008) suggested aspects of sustainable design BIM can aid. These aspects include building orientation (choosing best building orientation with minimum energy costs); building massing; daylighting analysis; water harvesting (reducing water needs in building); energy modeling (reducing energy needs and analyzing renewable energy options as solar energy); and sustainable materials (reducing material needs and using recycled materials). BIM comprises many important functions for building performance analysis. Therefore, investigations of sustainable building design become easier and more systematic.

## 2.3 Building Information Modeling for Total Building Commissioning

A few publications have investigated the integration of BIM into commissioning process recently. Azhar et al (2012) examined the benefits that have been brought by using BIM in the healthcare facility commissioning. The authors discussed the application of BIM in healthcare facility commissioning in various stages and illustrated the effectiveness of BIM in improving the efficiency of healthcare facility commissioning through the case study of the expansion project of Maryland General Hospital. Wu and Issa (2012) raised an issue with a labor intensive and heavily 2D documented deliverables of current commissioning practice that are ineffective for use during operation and maintenance of the facility and therefore looked at BIM as a facilitator for a more viable approach for building commissioning. They analyzed the features of BIM as a lifecycle information tool and discussed the possible applications of BIM in the commissioning process by demonstrating the case studies. Moreover, authors identified the features of BIM that justify its use in building commissioning and handover process as a lifecycle information management tool. They also determined critical tasks, leading stakeholders, expected project team interactions and standardized deliverables at each phase of the commissioning and developed the BIM-enabled commissioning workflow.

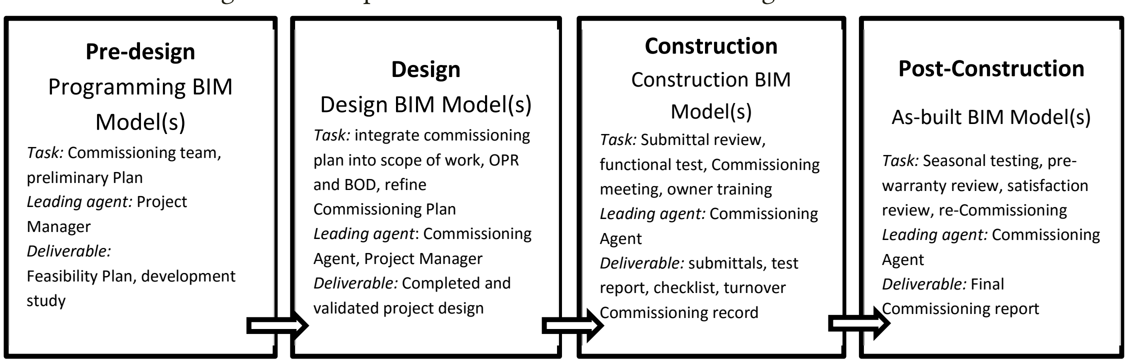


**Figure 1** BIM-enabled building commissioning workflow (Wu and Issa2012).

According to Wu and Issa (2012), this workflow compared to the non-BIM commissioning process uses the information in the BIM model, while gaining an advantage from the BIM-aided collaborative working environment and performing commissioning activities based on interoperable information exchange between BIM and other internal/external applications, such as IFCs. Moreover, during the project execution process commissioning data is transferred from phase to phase and at the same time BIM model(s) continually updated and expanded. Authors illustrated the effectiveness of this workflow through the case studies in which Vela Systems as-built model was used to conduct the commissioning. These publications studied the integration of BIM into commissioning process focusing on possible automation of BIM-enabled commissioning process during different phases of project execution process.

Nevertheless, as of today no research or studies exist for integrating BIM into total building commissioning which covers whole building and its systems from inception to operation and maintenance.

## 3 Research Methodology

The research aims to investigate the development of Building Information Modeling and Total Building Commissioning by reviewing the past research and to study the feasibility of incorporating these tools. Two separate surveys were developed and administered to investigate the state of the art and application of BIM and Total Building Commissioning in the fields of design and construction in Kazakhstan, and to understand the sustainability actions. The BIM questionnaire was sent via email to designers, architects, contractors and other professionals working in different areas of construction industry in Kazakhstan and consisted of 24 questions broken down into three main sections: 1) Demographics, 2) current use of BIM in Company practices and 3) Sustainability. The e-copy of the survey was emailed to 120 email addresses of abovementioned professionals, and only 34 people filled and returned the survey. The Total Building Commissioning questionnaire consisted of 24 and 6 questions that were distributed before and after the seminar, respectively, held at Nazarbayev University in Kazakhstan. The seminar was about introducing the concept of Total Building Commissioning Process to Industry and collecting their viewpoint on applicability of the concept in Project Implementation processes in Kazakhstan. Around 60 people attended the seminar and 52 people filled the before seminar questionnaire. After the seminar, questionnaire was filled in by 16 people that were in a panel meeting. The survey results were analyzed by using descriptive statistics.

## 4 Survey Results: Building Information Modeling and Sustainability

### 4.1 Demographics and company information

The survey results demonstrated that 26% of the respondents were general contractors, 24% were design organizations, 21% were architects or engineers, 18% owners and 11% were in “other” category including project and facility managers.

38% of respondents stated that they had 5-10 years of work experience in the Architecture, Engineering and Construction Industry, while 35% indicated that they had worked in this field for more than 10 years. Proportion of those who worked in the AEC field for 1-5 years is 21% and only 6% of respondents had less than one-year experience of working in corresponding field.

Next question in demographics category was about annual revenue of the company respondents’ work. Results were as follows: more than one third of respondents (35%) indicated that their companies’ annual revenue was between US$50 to 100 million, whereas 26% stated that they work in a company with US$10 to 50 million annual income. 21% of respondents indicated the annual revenue of less than US$10 million, and proportion of those respondents that worked in a companies with more than US$100 million is 18%.

Percentage of those respondents who worked on commercial and industrial projects was equal to 32% each, while 26% of respondents indicated that worked on residential projects construction. In addition, 6% of respondents stated that worked in institutional buildings construction, and remaining 4% indicated that performed work in “other” category that includes multifunctional complex buildings, scientific and research centers and educational buildings sector.

Thirty five percent of respondents worked for companies with 50 to100 employees, while one quarter (26%) of respondents showed that worked for medium sized companies with a range of 100 to 500 people. 21% indicated that worked in large companies where number of employees exceeds 500. The rest of the respondents (18%) stated that came from small sized company with less than 50 employees.

The last question in this category asked about the project implementation methods in company practice. Particularly, choices were Design-Bid-Build, Design-Bid, Construction Management at Risk and Integrated Project Delivery. The results show that 60% of the respondents stated that Design-Bid-Build used in their company as a primary project delivery method, while 40% indicated that their company uses Design-Build method.

## 4.2 Use of Building Information Modeling in current company practices

Since the BIM technology is not widespread and generally used in AEC industry in Kazakhstan the survey questioned whether respondents are familiar with BIM or not. The results showed that more than a half of respondents (55%) were not familiar or never heard of BIM, while 45% stated that they had some familiarity with BIM. The majority of respondents (85%) stated that their company did not use BIM in their practice; only 15% mentioned that BIM was used in their company's practice.

Two questions in the survey intended to examine the reasons why companies do not and do use BIM in their practices.

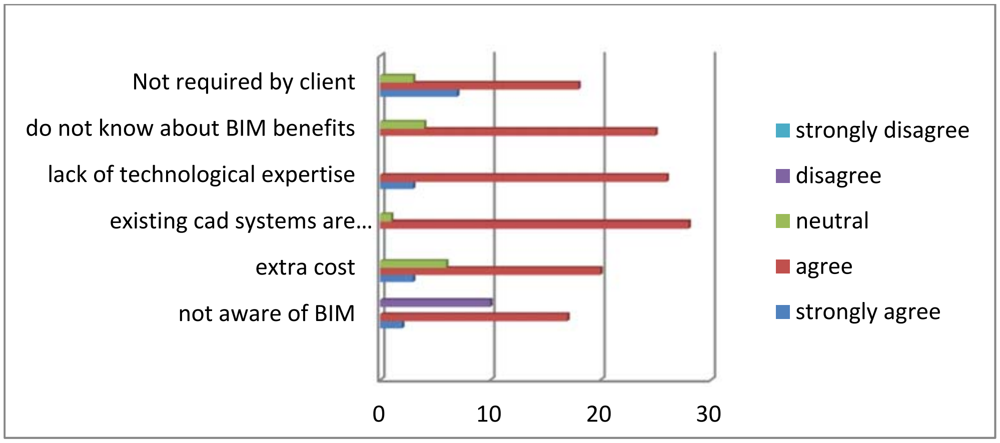


**Figure 2** Reason why BIM is not used in company's practice

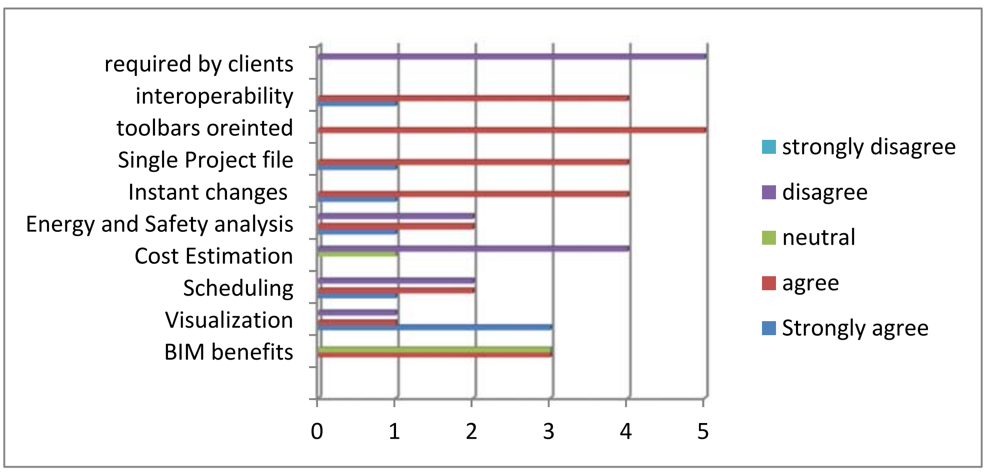


**Figure 3** Reasons of using BIM in company's practice

The great majority of respondents (85%) agreed that BIM is not used in their company's practice because existing CAD systems can fulfil the design and drafting needs. Other reasons indicated by respondents included lack of technological expertise and unawareness of its benefits. About one third of the respondents were concerned about extra cost that might be brought up by implementing new technology, while half of the respondents indicated unfamiliarity with BIM and client requirement factors as another reasons for BIM not being used in their companies' practice.

All five respondents which indicated that their companies' were using BIM have disagreed about the client requirement being the reason for using BIM in company's practice. Interoperability of BIM, its toolbars oriented interface, ability to allow instant changes in all drawings and to store all the data in a single project file were the reasons of using BIM indicated by the majority of the respondents. About half of the respondents have disagreed about scheduling and energy/safety analysis reasons for using BIM, while slightly more than half of the respondents felt that visualization was an important reason for using BIM. Four respondents have disagreed with cost estimation using BIM.

The majority of respondents (74%) stated that their company plans to implement BIM in the future, whereas 15% of respondents indicated that their company have no plan to implement BIM and remaining 10% answered that they do not know whether they will be implementing BIM in their company or not.

Two respondents indicated that their company had been lightly utilizing BIM in their projects (in a range of 1-33%); the same number of respondents (2) stated that their company uses BIM considerably in a range of 33-66%. The majority of respondents stated that BIM was implemented during the predesign (4 respondents) and design (2 respondents) stages of the project implementation. 5 respondents stated that some type of BIM software was used within their company practices. Autodesk Revit was the predominant software used by majority of the respondents (4 respondents). The remaining 1 respondent indicated that his/her company used Nemetschek allplan as part of the company's practice.

## 5 Survey Results: Total Building Commissioning

Total Building Commissioning survey was administered during the seminar and workshop on introducing the concept of Total Building Commissioning to AEC Industry experts in Kazakhstan. Before the beginning of the seminar questionnaire survey was distributed to participants in order to understand and investigate the state of the art of quality control/assurance processes, communication issues in companies and in Kazakhstan, rate of adherence to Building codes requirements and amount of money spent on quality control in organizations.

The results illustrated that forty-five percent of the respondents in this survey were general contractors, 27% were architects, 18% were facility managers and 10% were in "other" category including government, design organization and other management positions. One third of the respondents (31%) indicated that their company's annual revenue was between US$ 50 million and US $100 million, while approximately a quarter of the respondents (29%) worked in a company with annual revenue of more than US$ 100 million, another quarter of the respondents (25%) came from companies with annual revenue in a range of US $10 million and US$50 million, and the remaining 10% of the respondents worked in companies with annual revenue less than US $10 million. The next questions in the survey questionnaire were intended to understand and evaluate the state of quality control and quality assurance in Architecture, Engineering & Construction (AEC) industry in Kazakhstan. 97 percent of the respondents stated that state of quality control in Kazakhstan AEC industry was unsatisfactory and needed improvement. Approximately 70 percent of the respondents indicated that the quality control and quality assurance in AEC was poor because of the poor quality of education in universities and colleges, while 20 percent of the respondents linked it to the lack of experts, bureaucracy and corruption level in the corresponding field. The remaining respondents felt that it was hard to control the level of quality due to the huge discrepancy of Standards in Kazakhstan with World experience.

Approximately a half of the respondents stated that their organization spent 10-15% of total project cost on QA/QC, whereas a quarter of the respondents believed it was 20-22%. The remaining respondents indicated that their company spent 1-5% on quality control. More than a half of the respondents (65%) indicated that cost of the rework, warranty, failure and other quality related issue in their organization was 15% of total revenue, while 20% of the respondents felt it was 10%, whereas 10% of the respondents believed that their company spent 20% of total income on these issues.

Fifty percent of the respondents stated that the rate of the System of Documented Quality Assurance in their company was average; thirty six percent indicated it was good, seven percent of the respondents felt it was fair and remaining five percent of the respondents gave no answer to this question.

Since the total building commissioning process improves the coordination among project participants and stakeholders, next question intended to study the rate of communication issues among designers, contractors and engineers involved in a particular project in their company and in Kazakhstan as a whole. The results showed that 48% of the respondents felt it was average, 15% of the respondents felt it was fair, 12% felt it was good, and the rest (25%) believed it was excellent within their company. The rate of communication issues in Kazakhstan was average according to 46% of respondents, 2% thought it was poor, 5% indicated as fair, 8% indicated it was good, and 39% of the respondents believed to be excellent.

Rate of adherence to the Building Codes requirements in Kazakhstan was also evaluated as follows: thirty eight percent of the respondents felt that this rate was average; thirty seven percent stated it was fair, twenty two percent of the respondents thought it was poor, and remaining three percent rated it as excellent. Whereas the rate of standard practices (what is perceived to be acceptable) in construction industry in Kazakhstan compared to European and or American standard practices was average according to 54 % of the responses, 33% fair and 13% good. Importance of the cost of silent failure in building for owners was rated as very important (60% of responses), extremely important (23% of responses) and neutral (18% of responses). More than forty percent of the respondents (43%) stated that the cost of silent failure during life time of a facility was in a rage of 10-20 percent of total construction cost, whilst 38% of the respondents indicated this range was 5-10%, 11% of the responses stated less than 5%, 3% felt this range was 20-30% and remaining 5% stated that the cost of failure was more than 30% of total construction cost.

The second survey was distributed after the seminar. The survey intended to examine the familiarity of participants with the concept of total building commissioning and its applicability in Kazakhstan Construction Industry. The results illustrated that 45% of the respondents had heard about total building commissioning before and the same percent of the respondents (45%) indicated that never heard of this concept before, the remaining 10% had no answer to the question.
Eighty percent of the respondents indicated that in their company's experience there was similar construction practice as commissioning but it did not cover the whole building. 70% of the respondents totally agreed that total building commissioning would improve the performance of building, while 30% remained neutral. 45 percent of the respondents believed that they totally agree that the cost of the total building commissioning was justifiable with its benefits and so did another 10% of the respondents by agreeing, 33% of the respondents were neutral and 12% of the respondents stated that they disagree with this justification of cost to benefits.

A great majority of respondents (70%) agreed on applicability of total building commissioning in Kazakhstan Construction industry. The remaining respondents were neutral with no opinion about its applicability. The last question intended to survey about major issues with implementation of total building commissioning in Kazakhstan. It is found that the most common issues were lack of experts and cost, while lack of knowledge about its benefits is the next common issue. Industry resistance was pointed out as another issue to implement total building commissioning in AEC industry in Kazakhstan.

## 6 Concluding Remarks

The survey investigation performed in this research elucidates the current state of BIM and Total Building Commissioning use in Kazakhstan construction industry. The questionnaire results illustrate that BIM use in Kazakhstan construction industry is not widely adopted and in its early stage of implementation, whereas Total Building Commissioning is new to construction industry of Kazakhstan and its concept have been introduced during the year 2013-2014 within the frame of the Total Building Commissioning project.

The results demonstrate that BIM use is more common in large companies than in small ones and this can be explained by the fact of unfamiliarity of construction industry members with BIM. Respondents believe that existing CAD systems in Kazakhstan construction industry can fulfil the design and drafting needs.

The technological expertise, cost and time required for training were other aspects. Since the technology is new there will be high demand for training and educating people to use it skillfully.

Another issue that was raised regarding the implementation of BIM in Kazakhstan was regulatory concern or client requirement. Respondents pointed out the significance of client requirement for using BIM in their projects. That means regulatory requirements play an important role in application of BIM in Kazakhstan construction industry.

The results of the total building commissioning survey give some insight on the positive perceptions of participants to employ the total building commissioning in Kazakhstan Construction Industry. A great majority of respondents believe that employing Total Building Commissioning would improve the building performance and its cost is justifiable with its benefits.

Furthermore, participants believe in its applicability in Kazakhstan Construction Industry despite the issues associated with cost, shortage of adequate knowledge and experts with sufficient skills to carry out the process.

Industry resistance was also realized as important factor for application of Total Building Commissioning. Kazakhstan Construction Industry is used to their old way of doing things, and this may impede moving away from conventional methods.

To conclude, both BIM and Total Building Commissioning are new in Kazakhstan Construction Industry. The results of the survey shows the positive perceptions of respondents to adopt and employ these tools and processes in Kazakhstan Construction Industry to improve the performance and quality of buildings, coordination among different participants of project delivery and efficient use of human and material resources. Even though BIM and Total Building Commissioning tools are efficient in the process of executing and delivering the project, survey participants mention some complications, namely shortage of information about benefits and popularity of these technologies and processes. In addition, culture change and educating of people to provide adequate training to use these tools were also revealed to be important factors in adopting new technologies since the culture change and education is a long process.

From the literature review of past investigations on integrating BIM and Building commissioning it has been proved to have positive impact on building effectiveness and performance. The case studies demonstrated the powerful integration of these two applications in the construction industry. However, these investigations only focus on using BIM in building commissioning process. Future studies will focus on investigating BIM use in Total Building Commissioning in order to achieve sustainable built environment in whole building and its systems in all project phases.

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