BUILDING INFORMATION MODELING (BIM) IMPLEMENTATIONS IN THE TURKISH CONSTRUCTION INDUSTRY

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BUILDING INFORMATION MODELING (BIM) IMPLEMENTATIONS IN THE TURKISH CONSTRUCTION INDUSTRY

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ABSTRACT

BUILDING INFORMATION MODELING (BIM) IMPLEMENTATIONS IN THE TURKISH CONSTRUCTION INDUSTRY

The construction industry has always been highly significant for the national economy. Due to increasing pressures from clients to improve quality, reduce costs and speed up construction processes, Building Information Modeling (BIM) can be a key source of competitive advantage for construction companies. This study is investigates the critical success factors (CSFs) of successful BIM implementation. A questionnaire survey is designed and administered to both public and private sector participants. The questionnaire consists of three parts; the first two parts deal with the general information and CSFs and third part with project specific questions. Eighty-one respondents provided valid responses out of 244 questionnaire forms sent out. Based on the collected data, the relative importance of 16 potential CSFs for BIM projects in Turkey is examined. The results show that the three most important factors are: "availability of qualified staff", "effective leadership", "availability of information and technology". Factor analysis indicated that proper factor groupings for the 16 CSFs are: human related factors, industry related factors, project related factors, policy related factors and resource related factors. Another objective of this research is to examine the application process of BIM in the construction sector with the parameters set out to shed light on the success of future projects. In order to achieve this, an extensive literature survey was conducted to find the most appropriate components including the drivers, enablers, barriers, inputs, benefits, and impacts. A total of 11 cases were investigated and findings have been reported. Proposal of such a framework has considerable contributions to increasing BIM awareness of companies in Turkish construction industry and thereby assisting their on long-term strategies.

ÖZET

TÜRK İNŞAAT SEKTÖRÜNDE YAPI BİLGİ MODELLEMESİ (YBM) UYGULAMALARI

İnşaat sektörü, ulusların ekonomisinde her zaman büyük bir öneme sahip olmuştur. İnşaat projelerinde, işverenin proje kalitesinin artırılması, maliyetlerin azaltılması ve süreçlerin hiızlandırılması için yaptıgğı baskılar, yapı bilgi modellemesini inşaat firmalarının rekabetçi avantajı için en önemli kaynaklardan biri haline getirmiştir. Çalışma YBM projelerinin başarıyla tamamlanmasına katkıda bulunan kritik başarı faktörlerini (KBF) belirlemeyi amaçlamaktadır. Bu sebeple hem özel sektör hem de kamu katılımcılarına yönelik bir anket formu tasarlanmıştır. Anket üç bölümden oluşmaktadır; ilk iki bölüm genel bilgiler ve KBF'ler, üçüncü bölümü ise projeye özel sorular içermektedir. Gönderilen 244 anketten seksenbir tanesine geçerli yanıt verilmiştir. Toplanan verilere dayanarak, Türkiye'deki YBM projeleri için 16 potansiyel KBF'lerin bagil önemi incelenmiştir. Sonuçlar en önemli üç faktörün "nitelikli personel durumu", "etkili liderlik" ve "bilgi ve teknoloji kullanilabilirliği" olduğunu göstermektedir. Faktör analizi 16 KBF için uygun grup başlıklarının: insan ile ilgili, faktörler, sanayi ile ilgili faktörler, proje ile ilgili faktörler, politika ile ilgili faktörler ve kaynak ile ilgili olduğunu göstermiştir. Bu çalışmanın amacı, inşaat sektöründe YBM uygulamalarını inceleyerek belirlenen parametreler ile gelecek projelerin basarısına ışık tutmaktır. Bu kapsamda en uygun parametreler olan "itici güçler", "katalizörler", "engeller", "girdiler", "faydalar" ve "etkileri" belirlemek için, detaylı bir literatür araştırması yapılmıştır. Toplam 11 vaka incelenmiş ve bulgular rapor edilmiştir. Bu çalışmanın, Türk inşaat sektöründeki firmaların YBM farkındalığına katkı sağlaması beklenmektedir ve uzun vadeli stratejilerinde yardımcı olacaktır.

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LIST OF ACRONYMS/ABBREVIATIONS

2-D	2-Dimensional Computer Aided Design
3-D	3-Dimensional Computer Aided Design
4-D	4-Dimensional Computer Aided Design (3-D + time)
5-D	5-Dimensional Computer Aided Design (3-D + time and cost)
BIM	Building Information Modeling
BMS	Building Management System
CAD	Computerized Aided Design
CAFM	Computer-Aided Facility Management
CMMA	Computerized Maintenance Management System
COBie	Construction Operations Building Information Exchange
FM	Facility Management
FUSS	Facilities and Construction, Utilities, Safety and Security
GSA	General Services Administration
IAI	International Alliance for Interoperability
ICT	Information and Communication Technology
IFC	Industry Foundation Classes
IFD	Integrated Project Delivery
IT	Information Technology
MEP	Mechanical, Electrical, and Plumbing
NIBS	National Institute of Building Sciences
O&M	Operations and Maintenance
SCM	Supply Chain Management
TCA	Turkish Contractors Association
TCEA	Turkish Construction Employers Association
VDC	Virtual Design and Construction
XML	Extensible Markup Language

1. INTRODUCTION

1.1. Background of the Research

Construction industry has been changing rapidly since the beginning of the twentieth century. In the highly fragmented construction industry, a majority of the information and processes taking place throughout the life cycle are neither integrated nor interoperable and result in a high degree of redundancy. The development of new technologies has accelerated this pace. Because construction projects are mostly unique, one-time jobs, construction organizations struggle with the temporary status mindset. Teams are collected for a specific purpose or project and disbanded as soon as the tasks or the project are completed. People are motivated to complete their tasks within short period of time and under strict budgetary constraints.

There have been many changes in the business environment due to the advancement of technology and information systems. The construction industry is generally regarded as a conservative and slow in adopting new innovations and technology. It can be seen that utilizing information technology (IT) would allow construction industry to connect the power of collective knowledge systems. In addition, regulation of municipalities and competition between construction companies, financial demands of owners, and shortening project durations increased the contribution to the utilization of IT in the construction industry. Compared to other sectors, it took much more time to realize the importance of IT applications and implementation of them.

The development of ICT and Building Information Modeling (BIM) has provided construction companies with tools that can be used for planning and managing construction projects with less effort and greater accuracy. But still the implementation of these technological solutions have been made in a slow rate (Eastman, Teicholz, Sacks and Liston, 2008; Fisher and Kunz, 2004).

In 2004, the National Institute of Standards and Technology (NIST) published a

report stating that poor interoperability and data management costs the construction industry approximately $15.8 billion a year, or approximately 3-4% of the total industry (NIST 2004). Since this report, many have dubbed BIM, an emerging technological information management process and product, as the answer to this problem. From the 2007 publication of the National BIM Standard (NBIMS), a BIM (i.e., a single Building Information Model) is defined as "a digital representation of physical and functional characteristics of a facility" (NBIMS 2007). Furthermore, a BIM represents a shared knowledge resource, or process for sharing information about a facility, forming a reliable basis for decisions during a facility's life-cycle from inception onward.

Work preparations are an important part of the quality, environment and work conditions assurance of a construction project and are performed for activities that have significant impact on the project in these areas (Skanska, 2010). If project activities are well prepared, the chance of having a successful project increases. The implementation of BIM in this process could enhance its effectiveness and thereby cut production costs, save time and honor the client's quality and economical requirements.

Success of BIM implementation in construction depends on various factors. How construction companies can successfully select and use BIM systems is a critical issue that needs to be investigated.

1.2. Problem Determination

BIM is an IT enabled approach to managing design data in the AEC/FM (Architecture, Engineering and Construction/ Facilities Management) industry. BIM enables improved inter-disciplinary collaboration across distributed teams, intelligent documentation and information retrieval, greater consistency in building data, better conflict detection and enhanced facilities management (Ellis 2006, Popov *et al.*, 2007, Haymaker and Suter 2007, Fischer and Kunz 2004, Haymaker *et al.*, 2005). There are selected examples of successful BIM usage in the industry (Campbell 2007), and the number of commercial BIM applications is increasing rapidly (Khemlani 2007a). Despite this, the adoption of BIM in practice has been slow (Bernstein and Pittman, 2004).

In today's business world, competition between construction companies has increased more than before. Local competition has migrated to international markets and the challenges to the construction companies have risen more than ever. Therefore, construction companies have to increase their profitability and effectiveness.

The development of new technologies has helped the construction companies to become more competitive. A lot of companies in the world in various regions have committed to spending and have already spent large sums of capital for the implementation of BIM in their organizations. However, although IT has helped companies be more effective, it should be defined and guided how construction companies should use IT resources to apply their organizations.

In order to have a successful implementation phase of any IT system, critical success factors of the implementation duration should be determined and controlled carefully. If construction companies know what critical success factors are important and what kind of positive or negative experiences other construction companies have had, they can implement their systems in much more healthy and effective way.

1.3. Problem Statement

In this thesis, critical factors of the implementation of BIM system will be investigated and the current status of the construction sector in Turkey in terms of BIM implementation will be discussed. All of these studies will be based on a questionnaire survey and real experiences based on case studies.

1.4. Related Studies

There are a lot of studies that try to explain the history and effect of BIM in many sectors (Khosrowshahi and Arayici, 2009; Ilhan and Yaman, 2012; Bernstein and Pittman, 2004; Gerber and Kensek, 2010). Also, there are many studies that try to explain the importance of BIM system in construction companies; but there is limited number of studies that has explained the analysis of critical success factors

at the implementation of BIM systems in construction companies (Khosrowshahi and Arayici, 2012, Arayici and Coates, 2013, Linderoth, 2009, Succar and Williams, 2013, Edie and Browne, 2013, Howard and Bjork, 2007, Gu and Singh, 2007, Dave, 2010, Fogg, 2010, Campbell, 2007).

Also, there has not been any research that investigates and covers the real implementation experiences and critical success factors of BIM in terms of Turkish Contractors and Turkish construction-related project management companies.

1.5. Aims and Objectives of the Research

The main purpose with the thesis is to promote the use of BIM in the Turkish construction industry. In this respect, the critical success factors of BIM implementation will be determined based the perceptions of the construction professionals and real experiences collected through case studies. This research aims to help companies increase their awareness in terms of long-term benefits of using BIM.

1.6. Research Method

A detailed description of each phase of the research is as Figure 1.1:

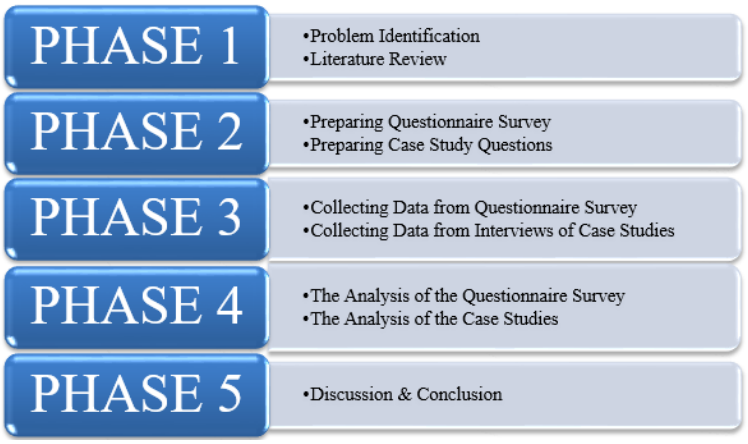


Figure 1.1. Research Methodology.

A qualitative case study methodology and questionnaire survey was performed

to gain a better understanding of BIM implementations in the Turkish construction industry.

After literature review is done, a suitable questionnaire survey and case study questions are prepared in order to determine critical success factors (CSFs) of the implementation of BIM at construction companies from questionnaire and to learn the drivers, barriers, resources, and benefits of BIM.

The questionnaire and the case study form were reviewed by a team composing of two professionals from construction sector and one academician. After some modifications, the questions were finalized.

The questionnaire survey is administered online to construction companies established in Turkey. A questionnaire consisting of questions about basic information about firms, general BIM information and CFS questions. The data collected from respondents were analyzed using Factor Analysis technique. By using this technique, validity of the hypothetical relationships and the proposed measures were tested.

Case studies were performed on different firms which have been using BIM in Turkey. The objective has been to find answers of why and how. Face to face interviews were made with different people and numerical, written and visual data were taken from the interviewees. The views of different clients, engineers, architects and also contractors were sought.

1.7. Scope and Limitations

The limitation of this research is mainly based on the data collection process. Data were collected from medium to large size construction companies established in Turkey. Although most of the respondent companies work internationally, measures were determined according to their availability in Turkish construction industry since respondents were Turkish companies. Rating levels of some the measures as well as the relations between them would be somehow different if the questionnaire was adminis-

tered in a different country.

Since the data reflects the experiences of Turkish companies and the markets they operated in, the model may not be applicable to all construction companies; other models for companies from different countries may be developed and different results may be obtained

1.8. Organization of Thesis

The contents of the remaining chapters of this dissertation are organized as follows:

- Chapter 1, the introductory information has been given related to the background of the research as well as the definition of the problem, objectives and limitations.
- Chapter 2 reviews the literature produced by previous research related to BIM in the construction industry and other relevant topics. Particular attention is given to issues on BIM, importance of BIM implementation, advantageous and disadvantageous gain through BIM, main functions and characteristics of BIM.
- In Chapter 3 and 4, research methodology and proposed model was presented as well as the determined measures and the indicators. The questionnaire that is prepared for data collection is depicted. In this chapter, there are three main research methods and these are "questionnaire survey method", "case study of real experiences". At the questionnaire survey part, administration, content and problems encountered of the questionnaire survey is explained and then the analysis of the questionnaire survey is examined. Firstly, the definition of factor analysis is made and then the convenience of factor analysis method for this questionnaire survey is checked. Then, the explanatory factor analysis of the questionnaire survey is done and the results are given. Secondly, case studies with all available information are explained in detail in this chapter. Also eleven case studies are explained and the analysis of them is presented.
- In Chapter 5, the results of eleven case studies and the questionnaire survey are explained and summarized. Findings are presented and discussed in the fifth

chapter. Besides, common properties and outcomes of examined projects were first determined and then indicated also in this chapter.

- In Chapter 6, the conclusions and further works are drawn and lessons learned from the case studies were briefly summarized.

2. BIM IMPLEMENTATION IN CONSTRUCTION

2.1. Introduction

The two reasons why the construction industry has been criticized are its disintegrated approach to project delivery and its inability to generate effective teams. This leads to inefficiency in project delivery. Continued usage of procurement practices which does not support involvement of the parties, leads to poor performance. Yet, over the past ten years, with the introduction of several improvement tools and techniques, the industry has attempted to better the performance of its delivered products (Baiden, *et al.*, 2005).

The focus of team integration in the construction industry is to better project procurement and the processes of product delivery. The objective of design and construct strategies and partnering arrangements are boosting team formation, collaborative working and confinement of workforce. The integrated forms of procurement which bring the design and construction phases of projects together, have been introduced as well. Yet, even though no harm was meant, a majority of those efforts haven't succeed expectedly, presumably because they are superimposed onto spheres that have adversarial cultures and behaviors. There are a few concrete instances of where integration has been succeeded in the industry (Baiden, *et al.*, 2005).

The traditional project delivery methods are mostly based on 2D drawings which often results conflicts and errors during the construction stage of the projects. These errors and conflicts causes' high costs, time waste and productivity loss. The Figure 2.1. shows that ability to influence on the cost of the project is at its higher at the beginning of the project life cycle. In the advancing stages ability to influence on the cost decreases so, analytic information such as energy analysis, cost estimates, structural analysis can improve the project if it's done at the design phase of the projects. However, in 2D projects generation of such information is usually late. To overcome the above mentioned problems a more sophisticated model is required.

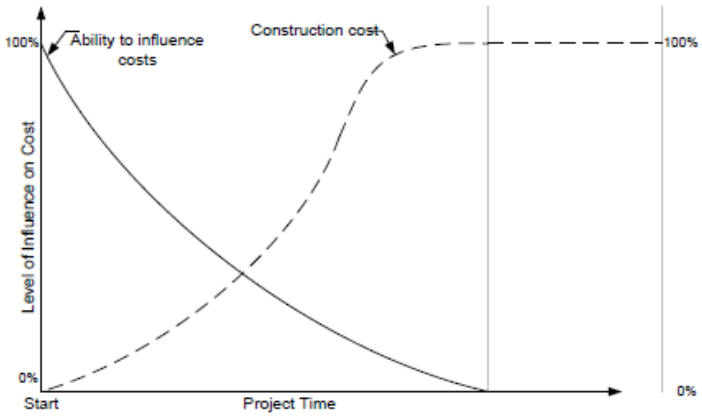


Figure 2.1. Project Time vs. Level of Influence on Cost (Eastman, *et al.*, 2008).

2.1.1. Definition and Characteristics

Construction industry has established the basis of object-oriented building product modeling in 1990s. Initially, certain market sectors such as structural steel utilized the parametric 3D modeling. Building Information Modelling (BIM), therefore, as a technology is not new to the construction industry. This technology under different names such as product model, virtual building, and intelligent object model has been in use for over twenty years. The term building information modeling came into popular use after Jerry the publication of Laiserin's article in Laiserin Letter in December 2002 (Laiserin, 2009). The definitions of Building Information Modeling (Figure 2.2) could be count as follows:

- The process that is focused on development and use of computer generated model to stimulate the planning, design, construction and operation of facility. (Azhar, *et al.*, 2008).
- Traditionally, the construction industry has relied on hard copies of 2D drawings to depict the work to be executed. They formed part of the contract documentation that were assessed by building codes and used for facilities management (Eastman, *et al.*, 2011).
- According to NBIM Committee the definition of BIM is defined as "a digital representation of physical and functional characteristics of a facility" (NBIMS,

2007). This model is a bridge between architectural, engineering and construction industries. BIM enabled project teams are learning to collaborate more effectively so they can integrate their modeled work.

- BIM used to reduce or eliminate traditionally cumbersome and wasteful steps in the project delivery process. And most are reporting higher productivity, fewer claims, less rework and better profitability as a result (McGraw Hill Construction).
- Building Information Modelling (BIM) is a collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets. BIM embeds key product and asset data and a 3 dimensional computer model that can be used for effective management of information throughout a project lifecycle - from earliest concept through to operation. It has been described as a game-changing ICT and cultural process for the construction sector. (HM Government, 2012).
- Chuck Eastman, together with his co-authors of book about BIM, describes Building Information Modelling as "one of the most promising developments in the architecture, engineering and construction (AEC) industries. With BIM technology, an accurate virtual model of a building is constructed digitally. When completed, the computer - generated model contains precise geometry and relevant data needed to support the construction, fabrication, and procurement activities needed to realize the building". (Eastman, *et al.*, 2008)

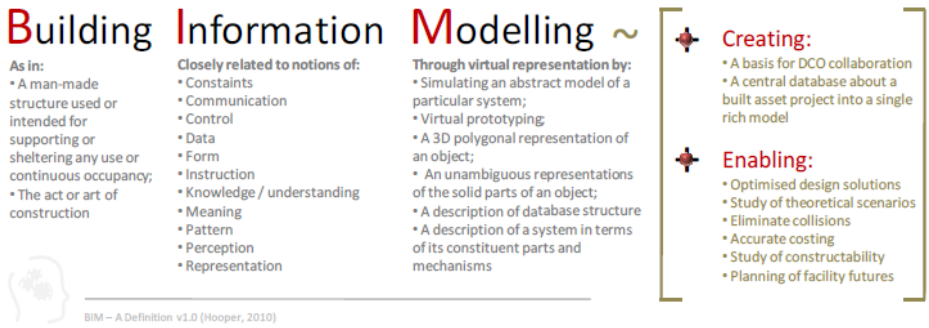


Figure 2.2. BIM as a Definition (Hooper, 2012).

The aim is to visualize a project before the construction works start, to figure out potential problems that may arise during the construction phase. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and to improve the process of delivering the facility (AGC, 2005).

BIM is not only implementing a software it is a new way of thinking, which requires a move away from traditional workflow. Architects, engineers, contractors and related all parties effectively working on a common database. This is a radical change from the traditional ways of working in which parties are often work on separate information pools and using different (usually incompatible) software packages. In essence, BIM involves building a digital prototype of the model and simulating it in a digital world.

At its simplest level, BIM provides a common environment for all information defining a building, facility or asset, together with its common parts and activities. This includes building shape, design and construction time, costs, physical performance, logistics and more. More importantly, the information relates to the intended objects (components) and processes, rather than relating to the appearance and presentation of documents and drawings. More traditional 2D or 3D drawings may well be outputs of BIM; however, instead of generating in the conventional way i.e. as individual drawings, could all be produced directly from the model as a "view" of the required information (RICS, 2012).

The principal difference between BIM and 2D CAD is that the latter describes a building by independent 2D views such as plans, sections and elevations. Editing one of these views requires that all other views must be checked and updated, an error-prone process that is one of the major causes of poor documentation. In addition, data in these 2D drawings are graphical entities only, such as lines, arcs and circles, in contrast to the intelligent contextual semantic of BIM models, where objects are

defined in terms of building elements and systems such as spaces, walls, beams and columns (CRC, 2007).

Geometric shapes and 3D are used to create models of buildings through parametric modeling by BIM. Moreover, it includes geographic data, properties of building constituents and quantities as additions to fourth and fifth dimensions, for instance sequencing, scheduling, and cost estimating. This is named as object-orientated modeling and 4D and 5D simulation. Along with these features, interoperability of BIM is also discussed below.

2.1.1.1. Parametric modeling. Parametric modeling forms the foundation for BIM processes. It is data based modeling, based on large digital databases containing building information regarding a structure's elements and their relations to other building elements (Ashcraft, 2007). These databases are enriched at the creation of building information models, as data for each model are stored in the database, and will be available for use and reuse at a later stage of the project (Autodesk, 2002).

These building product models will consist of building elements and their spatial and non-spatial relationship with one another, that contains material elements, such as windows and doors, and immaterial spaces that are surrounded by these material elements (Matipa, 2008). Parametric modeling permits the elements or objects to have fixed or flexible ties between them, to either preserve their form or change as its related element changes. Parametric elements are automatically restructured according to the rules programmed into their databases. The rules may be as simple as, requiring a window to be wholly within a wall, or complex such as defining size ranges and detailing (Eastman, *et al.*, 2008).

2.1.1.2. Object-orientated modeling. In computer science an object can be defined as an autonomous procedure that is embedded with information about all of its characteristics as well as instructions to perform certain directives, and the programming code necessary to adhere to the commands that it may receive (Ibrahim, *et al.*, 2004). The

computer is used as a pencil to depict the shapes graphically in the traditional design, which limits the stakeholders of the project to observe various building elements in isolation, as several sections and elevations are required to display a 3D object in a detailed form.

In BIM design, object-orientated modeling or "intelligent objects" are used (Ashcraft, 2007). Intelligent objects are objects, such as a door or a window, which has all its characteristics and rules embedded in them. Traditionally a designer would draw a line to depict the position of a wall or a door or a type of service. These lines can then only be interpreted by certain people, but not by computers. With BIM however, the designer uses a wall or door object that will automatically take on its characteristics, such as window integrating wholly into a wall (Eastman, 2007). These objects then transfer information between one another, and then adjust it accordingly in order to accommodate the new object, such as the new window (Ashcraft, 2007). The rules imbedded in objects allows for software packages to initiate design changes if necessary or even adjust the objects automatically as changes are made to the model. The model is therefore basically constructed by itself through preprogrammed building objects creating a spatial experience, which enables the stakeholders to make informed decisions based on proper visualization (Campbell, 2007).

2.1.1.3. Interoperability. Interoperability is defined by the National Institute of Standards and Technology as "the ability to manage and communicate electronic product and project data between collaborating firms and within individual companies design, construction, maintenance and business process systems" (Martinez, *et al.*, 2006). In aspects of information and data sharing in the design and execution processes, the construction industry is greatly cooperative. However, BIM wouldn't be able to succeed without appropriate interoperability between different stakeholders of a project.

This interoperability barrier can however be overcome, with the right software solutions and the implementation of BIM standards. Various software companies, such as Autodesk's Revit, Bentley Systems and Graphisoft, are developing software solutions

to facilitate interoperability (Howell, *et al.*, 2005). The National Institute of Building Science has undertaken the task to define BIM standards, and has released the first edition of these standards (Ashcraft, 2007). The purposes of these standards are to: "provide the diverse capital facilities industry with a vision of how to support and facilitate communications throughout the facility lifecycle, from project inception through design and construction, even past demolition for improved operations, maintenance, facility management, and long-term sustainability". (Ashcraft, 2007).

The purpose of BIM software is to create and operate on digital databases for collaboration (Autodesk, 2002). For the purpose of this report, the main focus will be on Autodesk's Revit. BIM applications capture multiple facts, figures and information to manage and store in a database instead of in a format (such as a drawing file or spreadsheet) predicted on a presentation format. It then transforms this information into conventional illustrations or in any other appropriate way that is suitable for that particular stakeholder for revision of editing (Autodesk, 2002), so although each professional works on his own, familiar working view, they are all still working on the same information model. One of the main benefits of this is the co-ordination of changes to the model in such a database, meaning that if a revision is made to a model, in whichever view by one of the professionals, the changes will be immediately depicted in the model and will also be reflected in the associated views (Howell, *et al.*, 2005).

BIM ensures interoperability or collaboration by all the stakeholders, whether individual members working in the same company or other members of the building team. This is accomplished through the distributing and sharing of information through computer networks or sharing files through project collaboration tools (Autodesk, 2002).

2.1.1.4. 4D and 5D simulation. One of the well-known aspects of BIM is its multi-dimensionality. The first three dimensions are found in the design of the model, the fourth dimension incorporated into the model is time and space and the fifth dimension is cost.

The time dimension consists of scheduling and sequencing. Scheduling and sequencing methods are usually used by the contractor or construction manager, to plan and monitor the progress of the execution of a construction project as well as manage the logistics and resource required for the execution of the project. 4D models are formed through linking a 3D design model with a construction schedule (Meadati, 2010).

This enables the specific stakeholders to graphically visualize the information represented by the construction schedule. To set up a construction schedule the sequence and duration of all the different activities has to be determined. The determination of the duration of these activities is supported by the 4D model, through the selecting of quantities from the model (Tulke, *et al.*, 2007). The project can then be constructed electronically before the physical start of construction, which allows for the optimization of sequencing through the evaluation of different alternatives (Ashcraft, 2007), and effective site utilization (Meadati, 2010). It can also be used to foresee what the effects of delays in construction or other scenarios will have on the project schedule or to solve space interference and constructability problems. These 4D models can also be used later in the construction process to show the current construction status or the progress of the project. Although 4D simulations shows a lot of a promise and benefits, users are still reluctant to use it in the construction, post-construction and maintenance phases of the project. As these phases are still accomplished by using 2D drawings, a lack of information exists at the end of the construction stages for the production of as-built models, which will facilitate the implementation of BIM to the post design stages of the project (Meadati, 2010).

One of the main functions in the successful management of a construction project lies in the accurate management of project costs. The BIM allows for information concerning project costs to be linked to 3D or 4D models, ultimately creating a 5D model. With the 5D model an automatic analysis of all materials and components are done, to obtain their quantities directly from the BIM model. These bills of quantities are then linked to databases where information regarding material, labor and other costs are stored, to estimate the project costs. Expenses relating to changes in design

can be generated automatically at the click of a button, without the need to measure and recalculate quantities (Meadati, 2010). This allows for quick financial analysis of different design or material options and swift estimation of the current financial status of the project.

2.1.2. Concept of BIM

As BIM is a recently introduced way of working, AEC professionals and researchers are showing effort to grasp its implementation and effects. To better that approach, one of the ways is to analyze the events on past projects which has used BIM and to synthesize the similarities and differences. Yet, the ongoing BIM practices cannot be grasped in an organized, sufficient and rational way as it is displayed with a fragmented project data. Moreover, the presently accessible BIM guidelines don't have confirmation by a large number of projects. Considering those, AEC professionals and researchers would be unable to obtain knowledge that leads them to well-defined, determinable, and controlled BIM implementations. To have a full understanding, there needs to be a framework which explains BIM implementations "from data, to knowledge".

BIM handbook introduces BIM to its readers as preceding definitions. "BIM represents a paradigm change that will have far-reaching benefits, not only for those in the building industry but for society at large, as better buildings are built that consume less energy and require less labor and capital resources". (Eastman, *et al.*, 2011).

BIM, a digital platform, is used for creating buildings virtually. Should BIM be used, a model should be able to have all the needed information to collaborate, predict, and decide about cost, operation, building, design and preservation of a facility before construction. BIM's total capacity hasn't been realized by any project yet.

To portray a set of parametric tools and processes for the creation and preservation of an integrated collaborative database of multi-dimensional information about the design, constructions or/and features of a building, with the objective of bettering

cooperation between stakeholders, decreasing the time required for documentation of the project and generating more certain project outcomes, the term BIM is widely used.

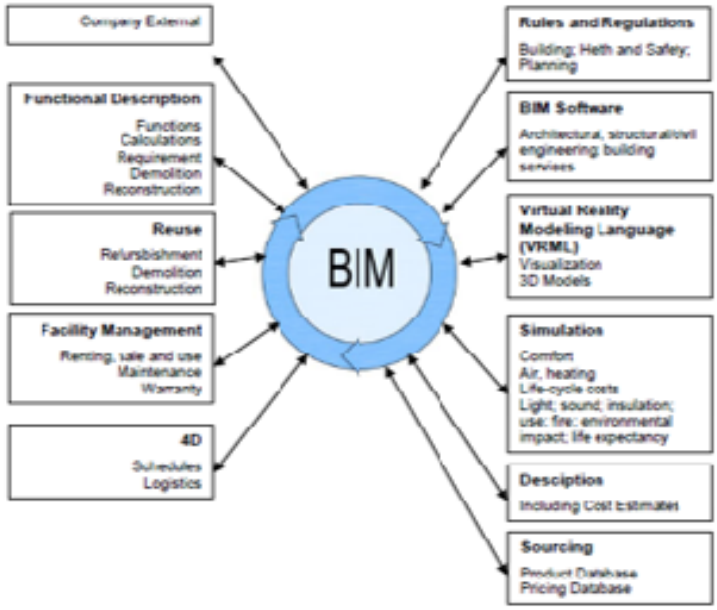


Figure 2.3. A Fully Functional BIM (Broquetas, 2010).

2.1.3. Principles of Building Information Modeling

International Alliance for Interoperability (IAI) was formed in September 1995, and since its release, has published three major releases of the Industry Foundation Classes (IFC). This was the beginning of setting standards for object based data modeling. Standards that would define the interoperability of object based data modeling for the AEC industry. Multiple vendors would be able to access a building model to supply data to the architects and engineers in a 3D space. Interoperability is the dynamic exchange of information among all applications and platforms serving the entire building community throughout the life cycle of facilities (Keller, *et al.*, 2014). Therefore, no matter what programs were being used across the broad spectrum of vendors, there would be a medium to transfer data to something that others in the industry could access, this medium being the 3D model.

Although these guidelines were set, they would need backing from major software companies in order to gain a foothold.

BIM is defined by Autodesk (2004) as: "a building design and documentation methodology characterized by the creation and use of coordinated, internally consistent computable information about a building project in design and construction". BIM incorporates the use of 3D visualization techniques with real-time, data driven, object-based imaging as a tool by all facets of the industries (Holness, *et al.*, 2006). This is a change from the current practice of; designs being manifested and put to paper with engineers then designing the structure and other supporting elements of the building. After completion of the design documents, a 3D model can be generated for the owner showing digital walkthroughs and to provide 3D renderings of spatial relationships. These tools are very useful to convey design intentions to owners and clients that who not able to visualize 3D space from 2D drawings. These can be very expensive and time consuming to produce.

BIM greatly increases the user's ability to control and manipulate data and information in an unprecedented way and in an interoperable format. Moving from paper-centric information to parametric, model-based information means that the digital design can be used for cost estimations, simulations, scheduling, energy analysis, structural design, GIS integration, fabrication, erection, and facilities management (Seaman 2006). All of which are relative to each other, and changes in one category will have impacts on the others that are automatically accounted for. Since all of the above information is dynamically linked, productivity from recalculation of simple and minor changes will be greatly increased because the computer program will be able to handle the changes and calculations internally.

Documents a BIM can generate include, but are not limited to, drawings, lists, tables, and 3D renderings related to the project. Thereby contributing more to efficiency, and provide superior accuracy than traditional 2D CAD drawings. Building models embedded with detailed information about a construction project are far beyond the capabilities of most design firms at present (which is why historical data is

difficult to find and analyze, as it relates to productivity). These models are not just the electronic drafting tools that firms now think of as digital practice, nor are they three-dimensional renderings with separate construction documentation (Kuehmeier, *et al.*, 2008). These are object based digital models which the program itself constructs the appropriate plans, details, and sections from. Any change in one aspect of the drawings, will automatically be accounted for in the other drawings. The BIM process has the potential to remove the guesswork about how the most difficult parts of a building come together, which tend in most cases to be the corners. These models also transcend 3D and can be manifest in 4th dimension (4D) and 5th dimension (5D). Projects can digitally be built in the computer environment, showing any possible conflicts with the schedule; this is an incredible tool to relate information to the owners and show models for future production. If delays arise, they can be input into the model, and BIM will be able to determine any the necessary changes in the schedule. Four D (4D) models link components in 3D CAD models with activities from the design, procurement, and construction schedules. Resulting 4D models allow project stakeholders to view the planned construction of a facility over time on a computer screen and to review the planned or actual status of a project in the context of a 3D CAD model for any day, week, or month of the project (Fischer, *et al.*, 2004).

The money facet of the program is represented by 5D. Projects will have the predicted materials for construction and work up a cost of them. Even though altering material choices for bid alternate would make it easier to observe immediate cost impacts, it would cost a life cycle to the owner. Transition to an parametric, integrated, and object-based system should bring about great changes in design and construction, besides compensation and risk allocation. Life cycle cost analysis can display a plan to the owners about cost savings and operational costs over the lifetime of a building. This data is very significant in deciding in the applicability of a project and if it meets the requirements of Green Building or LEED.

The fact that BIM can estimate the cost of materials and control the cost of the building is very attractive to owners. When material suppliers give their specific data and cost into the BIM with the appropriate factors, a hard dollar cost and a solid

calculation could be brought about, meaning the actual cost of the building. With the alterations made to specified products, new calculations and building costs could be generated. When alterations are made, they can be attributable to the architect, engineers or owners, which can distribute responsibilities for payment on alteration of orders.

2.1.4. Increasing Value through Shared Information

Results of this design methodology is not just a creation of the Architects design intentions and spatial relationships shown in 3D, a BIM is a repository for digital information and data generated by the design process and simulations; it is the design, fabrication information, erection instructions, specifications, materials palette, schedule, and project management logistics in one database (Kuehmeier, *et al.*, 2008). Data models not only would exist for the life of a building, but also for future additions, renovations and upgrades as "As-Built" documents, as well as controlling the client's asset.

Because the true benefit of a BIM is to the project owner, the push to use a BIM will most likely be a client-driven development. Many owners see the single point of responsibility in integrated practice as an attractive alternative to the "over-the-wall method" of design and construction in which an architect completes a design and hands it over to a contractor for construction (Elvin, 2007). The value is in the significant building efficiencies and initial cost savings and extends to the operations and maintenance of the facility (Kuehmeier, *et al.*, 2008). Speed, accessibility, communality, and adaptability are achieved by the use of a common database, early information user input, knowledge representation and information technology, team collocation, and information exchange in small batches (Elvin, 2007). Based on expert studies, other benefits of BIM include reduced risks, improved productivity, streamlined production, maintenance of design intent, and facilitation of quality control through clear communication and sophisticated analytical tools (Kuehmeier, *et al.*, 2008). All of which will be realized from conception based on construction to the life cycle analysis of the building.

2.2. BIM Implementation

2.2.1. Introduction

BIM is applied in the opposite order of planning. The project team is gathered first, and then the processes would be applied and adjusted accordingly, after that the outcome could be ready. This method shows great similarity to the method used by a structural engineer to estimate a structure from the highest level to the lowest, while the constructor will begin the structure by building a foundation and erecting it from the bottom up. In reality, good planning will include several back-and-forth journeys along such a path. Each trip up or down this planning sequence will generate information that will allow certain changes and adjustments to be made that help to refine the result. This also parallels the information feedback loop upon which much of BIM development is based. (Willem, 2008).

It is helpful to begin the BIM application to projects on a manageable scale. Most project teams will find it challenging to have access to enough persons with enough skills to get very deeply into the BIM approach in the beginning. It is, however extremely useful and productive for a project to have these methods implemented at any level, and care should be given to developing a comfortable level of application for the given project and project team. (Willem, 2008).

2.2.1.1. Project team dynamics. For each member's role respective to others to be clear and productive, the team structure needs to be defined. A representation in an organizational chart which displays the relationships and responsibilities of the team members could be used, which would also result in a communications protocol that generates the flow of information for the several courses.

2.2.1.2. Team roles. From this process, three main BIM-related roles; the BIM manager, the BIM operator and the BIM facilitator are come up. Each have distinctive duties and skills correlated with various tasks related to the practice of constructing

information modeling and model-aided construction management.

The duty of BIM manager is to manage most of the BIM-related processes. It is required to have a full understanding of the applications and concepts and experience with the tasks about planning and managing. Besides, the role can also involve guiding of the project team by the BIM process on a personal level, for example, choosing and training some team members to make sure that all of them are capable of performing their tasks fairly and all tasks are completed. This role shows resemblance with the traditional project managers in terms of the expectations but with an addition of BIM related schemes. In comparison to project management and BIM management, this role has the most of the duty.

BIM operator performs the BIM process-related tasks. It involves generating and analyzing models, processing data, etc. They involve more advanced tool-related skills than management skills. Even though experience with planning and construction phases would definitely be profitable to the BIM operator, it's not a prerequisite. It shows great resemblance with "project engineer" position with addition to BIM-related software skills.

BIM facilitator doesn't have a corresponding description in construction industry. In the next decade, the use of BIM and its processes will require assistance to the people who lack direct previous experience with BIM, and inexperienced people would be able to benefit from it. For instance, if an installer is working with construction drawings without any experience with 3D models, it will be significant to have a BIM facilitator for guiding through 3D modelling on a computer. BIM facilitators can comprehend, gather, and provide data to be beneficial in case BIM operator relies on feedback from field to incorporate back into the BIM process. The position would involve setting a project meeting, for instance progress or coordination meetings, which use BIM and construction management tasks as the basis of discussions. The BIM facilitator can thus be a person who will function a little as the superintendent's assistant, someone who is at the construction site most of the time to help out with the model and other BIM-related issues, someone who understands how to navigate through the BIM world

and help others explore this environment-a bit like a knowledgeable BIM tour guide. (Willem, 2008).

2.2.2. BIM Implementation Levels

The "D" elements of BIM relate to the information associated with the model. Figure 2.4 shows the concept of the BIM implementation levels.

- 4D relates to scheduling information; when will an element be built. With this information you can enable just-in-time (JIT) delivery of materials to site. This in turn has an impact on transportation, making it more efficient, and reduces storage issues as materials are delivered and immediately installed.
- 5D relates to the estimating and cost aspects of the building. Each element within the building model has a cost associated with it. This allows for detailed analysis to be done regarding budgets. It also allows the delivery team to make accurate predictions regarding how much need to be done at any given time in order to meet the construction targets.
- 6D covers the sustainability targets for a building allowing information such as energy use, sustainability from a materials and management point of view to be understood and Leadership in Energy and Environmental Design (LEED) tracking to be performed.
- 7D is the "as-built" BIM model which is important as part of the handover process to the building owner. This model is a fundamental part of the ROI for BIM as it provides accurate Facilities Management (FM) and Asset Management (AM). Each part within the building will have a lifespan and in the event of replacement, the easy identification of parts ensures that these processes may be performed efficiently.

The outcomes from having this information are impressing detail regarding all aspects of the construction project. By the very nature of the BIM model, this information is already there, you simply have to ask for the output you need whether that is a financial plan or a resource plan.

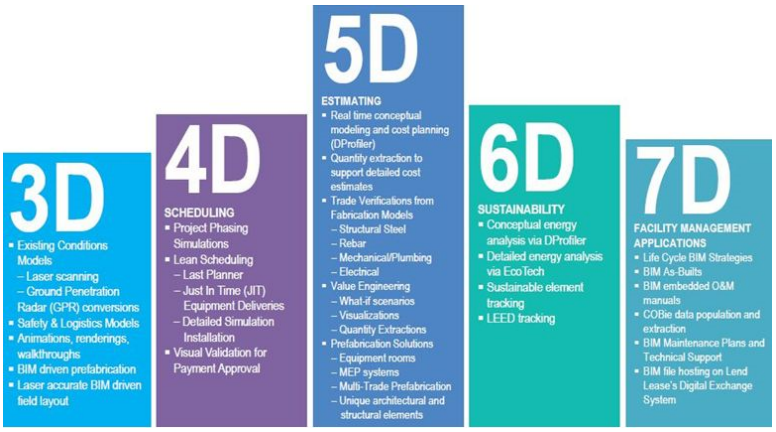


Figure 2.4. The Levels of BIM (Rancane, 2014).

2.2.3. BIM Implementation Maturity Stages

BIM can be defined differently by various people due to their perceptions, background and experiences. Some consider BIM as object-oriented modelling technology and others assert that IFC as the intermediate data model is itself BIM. Therefore, it is necessary for this research to establish a common definition, which would be based on an analytical framework which describes BIM in terms of maturity level of end use (Figure 2.5). For example, Succar carried out a systematic analysis of the BIM domain to yield a clear, use-based description of BIM, and how to implement it in an incremental and sustained fashion. To systematically analyses and understand BIM, Succar identified the BIM maturity stages by subdividing it into its components. (Arayici, *et al.*, 2012).

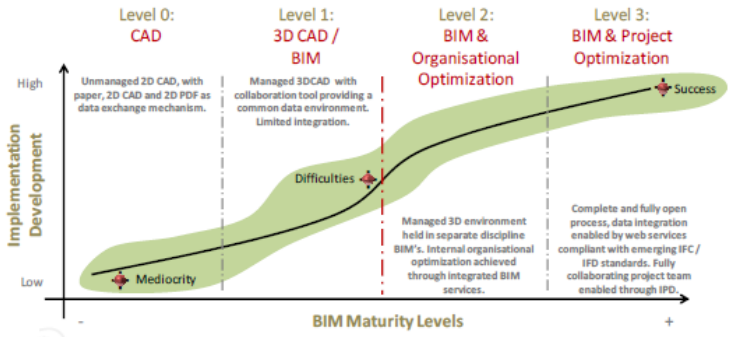


Figure 2.5. National BIM Maturity Levels (Hooper, 2012).

As depicted in Figure 2.5 and Figure 2.6 there are three stages in the BIM implementation:

(i) Stage 1 (object-based modelling).
(ii) Stage 2 (model-based collaboration).
(iii) Stage 3 (network-based integration).

The BIM maturity stages provided a systematic framework for the classification of the BIM implementation. These stages are used as a benchmarking tool for the comparison of data from the Finnish interviews and the UK questionnaire-based survey. In order to provide a clear insight, the BIM maturity stages are described briefly below.

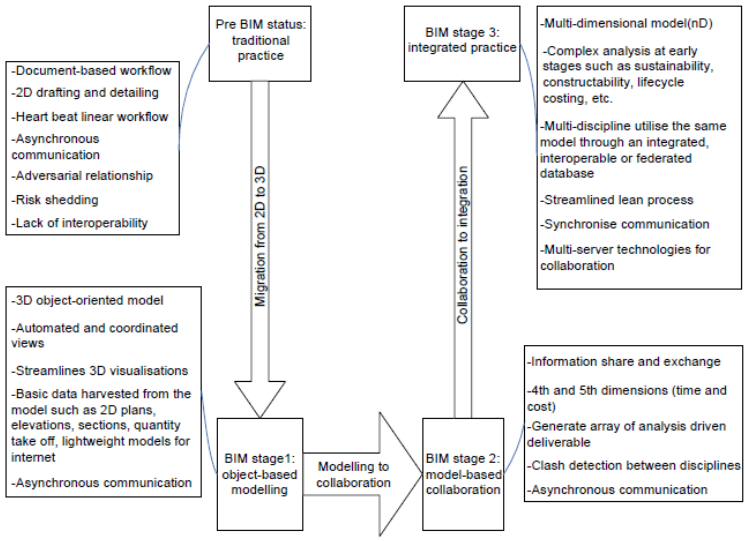


Figure 2.6. BIM Maturity Stage in BIM Implementation (Khosrowshahi, *et al.*, 2012).

2.2.3.1. The pre-BIM status. Pre-BIM status refers to traditional construction practice which embraces significant barriers and inefficiencies. For example, much project information is stored on paper as drawings and written documents. This is frequently unstructured and difficult to use. It is also easy to lose or damage. Thousands of documents are shared during a typical project, causing significant human errors in version control and use. Poor information management process leads to incomplete understanding of the planned construction, functional inefficiencies, inaccurate initial work or clashes between components. (Arayici, *et al.*, 2012).

Furthermore, lessons learned are not organized well and are buried in details. It is therefore difficult to compile and disseminate useful knowledge and best practice to other projects.

2.2.3.2. BIM Stage 1. Stage 1 refers to the migration from 2D to 3D and object-based modelling and documentation. The BIM model is made of real architectural elements that are represented correctly in all views. The BIM model is still single-disciplinary and the deliverables are mostly CAD-like documents, existing contractual relationships and liability issues persist.

2.2.3.3. BIM Stage 2. Stage 2 progresses from modelling to collaboration and interoperability. Designing and managing a building is a highly complex process that requires smooth communication and collaboration among all members of the project team. Stage 2 maturity requires integrated data communication and data sharing between the stakeholders to support this collaborative approach.

2.2.3.4. BIM Stage 3. This stage is the transition from collaboration to integration and it reflects the real underlying BIM philosophy. At this stage, project lifecycle phases dissolve substantially and players interact in real time to generate real benefits from increasingly virtual workflows. BIM Stage 3 models become interdisciplinary nD models allowing complex analyses at early stages of virtual design and construction. At this stage, model deliverables extend beyond semantic object properties to include business intelligence, lean construction principles, green policies and whole lifecycle costing. (Arayici, *et al.*, 2012).

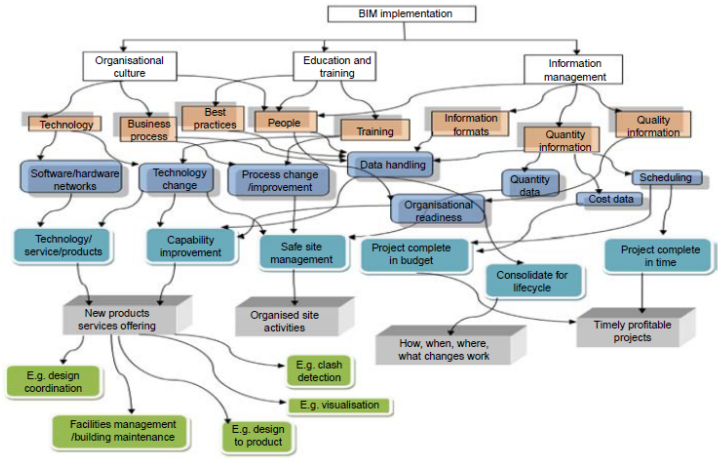


Figure 2.7. BIM Implementation Concept Map (Khosrowshahi, *et al.*, 2012).

Taking all of these into account a step by step method is essential for effective BIM adoption in the production phase. Moreover; that it is an important factor in order to ensure acceptance and reduce reluctance towards an increased BIM usage. It is important to create good reference examples that can work as drivers for others in adopting BIM. A step by step method will help implementing BIM in projects and thereby increase the chance of others following the same path.

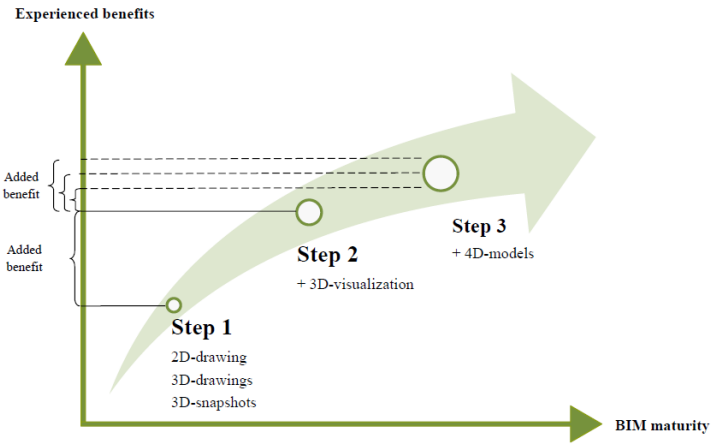


Figure 2.8. Schematic Illustration of the Relationship Between Increased BIM Maturity Level and Experienced (Löf, *et al.*, 2012).

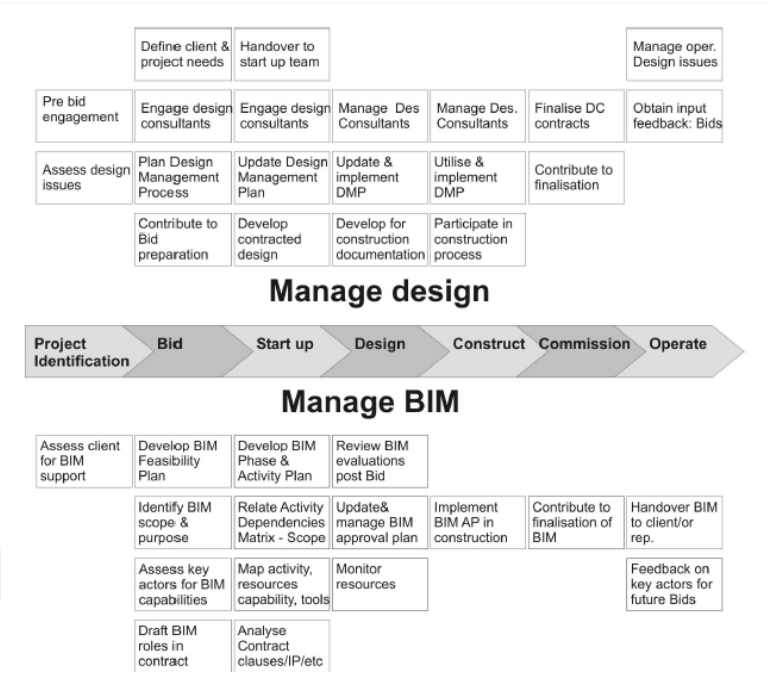


Figure 2.9. Manage Design Process Roadmap: BIM Implementation (London, *et al.*, 2008).

2.3. BIM Processes Framework

Today in many organizations multi-disciplinary teams are clashing with traditional methodologies (e.g. business models, processes, legal and compensation schemes, etc.) that impede knowledge sharing which cause reinventing the matters and processes on a daily basis. Fragmentation and calcified processes inhibit widespread change in the building industry, which is also traditionally disconnected from lifecycle evaluation methods. However, modelling techniques replaces this fragmented process with an interdisciplinary approach that consolidates the team effort, (Bernstein and Pittman, 2005). It seems the building industry is under pressure to provide value for money, sustainable infrastructure, etc. and hence adaptation of Building Information Modelling (BIM) technology has been inevitable. BIM as a lifecycle evaluation concept seeks to integrate processes throughout the entire lifecycle of a construction project. The focus is to create and reuse consistent digital information by the stakeholders throughout the lifecycle (Figure 2.10). BIM incorporate a methodology based around the notion of collaboration between stakeholders using ICT to exchange valuable information

throughout the lifecycle. Such collaboration is seen as the answer to the fragmentation that exists within the building industry and has caused various inefficiencies (Towards Implementation of Building Information Modelling in the Construction Industry, 2009).

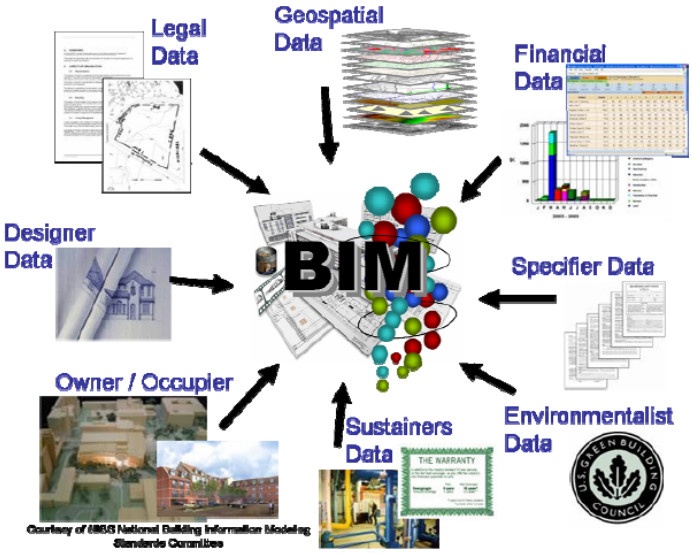


Figure 2.10. Communication, Collaboration and Visualization with BIM model (NIBS, 2008).

There exist numerous projects that have used and benefited from BIM systems in environmental planning, design and development, optimization, code checking and safety, construction. They strongly advised the utilization of BIM systems to solve problems related to low productivity.

The construction industry has been widely criticized for its fragmented approach to project delivery and its failure to form effective teams. This has resulted in reduced project delivery efficiency. Poor performance has been attributed to the continued use of procurement practices that do not encourage integration of the parties involved. However, over the past decade the industry has sought to improve the performance of its delivered products by introducing various improvement tools and techniques (Baiden, *et al.*, 2005).

Attempts at team integration in the construction industry have been largely focused on improving project procurement and product delivery processes. Design and

construct strategies and partnering arrangements aimed at encouraging team formation, collaborative working and retention of workforce have been used to attempt to integrate the construction project delivery team. Integrated forms of procurement, such as design and build, that bring together the design and construction phases of projects, have also been introduced. However, although well intentioned, many of these attempts have not fully achieved the expected success, probably because they are frequently superimposed onto environments where adversarial cultures and attitudes still exist. Tangible examples of where true integration has been achieved in the industry are limited (Baiden, *et al.*, 2005)

Building Information Modelling (BIM) is an IT enabled approach to managing design data in the AEC/FM (Architecture, Engineering and Construction/ Facilities Management) industry. BIM enables improved inter-disciplinary collaboration across consistency in building data, better conflict detection and enhanced facilities management. There are selected examples of successful BIM usage in the industry, and the number of commercial BIM applications is increasing rapidly. Despite this, the adoption of BIM in practice has been slow. Results of a study currently being conducted in Australia are presented in this paper. The aim of the study was towards action oriented research towards the development of implementation management tools which would support both increased adoption of BIM in the AEC sector in Australia by firms at the "tipping" stage of adoption and also improved decision making by those already immersed in the environment (London, *et al.*, 2008).

The building industry is experiencing a paradigm shift to (i) better; productivity, efficiency, infrastructure value, quality and sustainability, (ii) decrease; lifecycle costs, lead times and duplications. It is recommended that a majority of them could be realized by utilizing BIM. For providing a more secure and productive sphere to its occupants and asserting least possible environmental damage, and being more efficient throughout the building lifecycle, the use of ICT to concentrate building life cycle processes of a building and its surroundings is recommended.

2.4. BIM Standards

2.4.1. National Building Information Modeling Standards (NBIMS)

NBIMS promoted developing standards to be pursued by the ones who use the software, as soon as the software had been established for the new design methodology and development of construction drawings. As CAD didn't introduce a set of standards, construction drawings from different firms were virtually alike, but would only differ in how they are represented, drawn and notated. First CAD programs weren't able to interoperate with the other specific programs of AEC industry.

National Building Information Modeling Standards advocates that BIM is the future of the AEC industry and has been trying to develop a set of universal standards for the industry to follow. This is one of many components that will make using BIM a more productive asset for the AEC industry to use. Knitting together the broadest and deepest constituency ever assembled for the purpose of addressing the losses and limitations associated with errors and inefficiencies in the building supply chain is the goal (Kuehmeier, *et al.*, 2008).

These standards are an integral part of making interoperability between all phases of a construction projects life from inception onward. Using a BIM would essentially be pointless without this process. Set standards for BIM must overcome the obstructions that have begun to be identified so the implementation of BIM, for the entire industry, to be successful.

2.4.2. Collaborative Working

The most beneficial aspect of using BIM technology with software like Revit® is the way it changes the design process. A BIM's goal is to recognize the potential benefits that collaborative working through all stages of design and construction can offer. This happens to be the hardest thing to implement in the design process being that there are complications for the interoperability of the design data. In all likelihood,

multiple models will be produced in different disciplinary BIM applications and these will have to be combined into one composite model for visualization, clash detection, and other tasks (Figure 2-2). At the same time, the guide emphasizes that it is not necessary to create all the models to derive the benefits of using BIM on a project. Contractors can make many "partial uses" of BIM such as assisting with scoping during bidding and purchasing, reviewing portions of the project scope for analyses such as value engineering, coordinating construction sequencing (even if just for two trades), demonstrating project approaches during marketing presentations (Khemlani, 2006).

Despite the great potential for collaborative working in the design stage of a project, this has not yet been fully exploited, due to the lack of applicable information exchange standards that can be widely adopted by the project team. While a great deal of attention has been focused on interoperability of design applications between design disciplines, there has been less focus on the specific information needs and exchange capabilities of the cost consultant (Kuehmeier, *et al.*, 2008).

From the beginning, these are important parts of interoperability between the phases of a construction projects life. BIM would be futile if those standards weren't used. Documents which set BIM's standards, must fix the flaws that have started to be recognized therefore the application of BIM for the whole industry, would be successful. Cost consultants are essential to cooperative working in deciding the costs of construction. However, BIM is programmed to estimate it automatically form proper input, and can save the firms in the calculating phase.

It has been shown, however that BIMs sometime miss-calculate the measurements of high level information. Currently, the wider uses of BIMs incorporate the capacity to generate measurements automatically from objects created by designers. This capability is being actively promoted although its application on live projects has been limited (Kuehmeier, *et al.*, 2008). Forward thinking cost consultants might work cooperatively with design and construction firms which apply BIM into their projects, yet they will go on relying on quality and rationality of design data. As BIM is generated by software, it has the same bugs software has therefore, it should be checked con-

stantly. Buildings are becoming more complex with the new technologies and digital design. With the condition of HVAC systems, buildings are breaking the stereotypes in a unique way. All of those are connected to the computer design. New ways of working are being established by cost consultants for providing best possible cost calculations regarding the complex designs.

Although BIM software is able to keep record of how much material is used, it is not able to determine how much labor and effort are required to construct these new and complicated designs, this is a specialty of cost consultants. They will become vital to construction estimators on very complex projects. Additionally, there will be no overnight conversion to collaborative working, but for those practices which have the opportunity and capability to respond positively, the eventual gains could be substantial (Kuehmeier, *et al.*, 2008).

2.4.3. Interoperability and Data Standards

NIST (The National Institute of Standards and Technology) describes interoperability as "ability to manage and communicate electronic product and project data between collaborating firms and within individual companies, design, construction, maintenance, and business process systems". However, this definition does not provide a detail regarding specific workflows or if the data is just transmitted to others, placed in a storage, or exchange. The description is extended with tools, processes, standards and specifications for solving the problems related to interoperability.

Interoperability is a property referring to the ability of diverse systems to work together. Various stakeholders in the lifecycle of a building facility use different software's for documentation, design, construction and operations. During the various phases of the lifecycle of a project, different kinds of information are used, generated and handed over from one stakeholder to another, oftentimes using different software applications. During the design phase architects and engineers use various design and analysis software's such as AutoCAD or Bentley Micro station. During the construction phase project managers use various scheduling, estimation and project management software

such as MS Project, Timberline and Primavera Project Planner. Ability to transfer information between these various phases and applications is minimal (Shruthi, 2011).

Software interoperability is seamless data exchange at the software level among diverse applications, each of which may have its own internal data structure (NBIMS, 2007). There ways for data to be exchanged between two applications are either by direct, proprietary links between them or proprietary file exchange formats which manage geometry or XML-based exchange formats or public product data model exchange formats.

The essential links between two applications are provided by direct links by programming of level interfaces which reveal some or the whole of the building model to the other application for creation, modification, export, or deletion. A proprietary exchange format is established by a particular company to blend with a particular application. An exchange format is generally applied as a file in a text format that a person can read. DXF (Data eXchange Format) which is defined by Autodesk is a widely known AEC exchange format. The public exchange formats utilize open building standards such as the IFC (Industry Foundation Classes). Some of these public exchange formats apart from geometry also carry object, material properties and the relations between them (Eastman, *et al.*, 2011). Some software's prefer to use the direct link to exchange information between them because the exchange of information is more robust.

Construction projects involve several designers, contractors and subcontractors who utilize various applications to provide services contracted to them. Mapping the applications data to the open industry data standards allows the application to be interoperable with other applications mapped to the same open industry standard. This kind of interoperability allows several applications to exchange information among each other with a single mapping versus several mappings in a direct link (Eastman *et al.*, 2008).

Overcoming data transferability issues is key to fully interoperable integrated

project delivery system. In order for a real free flow of information to occur, three factors need to be in place (Figure 2.11):

- The format for information exchange - Digital Storage
- A specification of which information to exchange and when to exchange the information - Process
- A standardized understanding of what the information exchanged actually is - Terminology

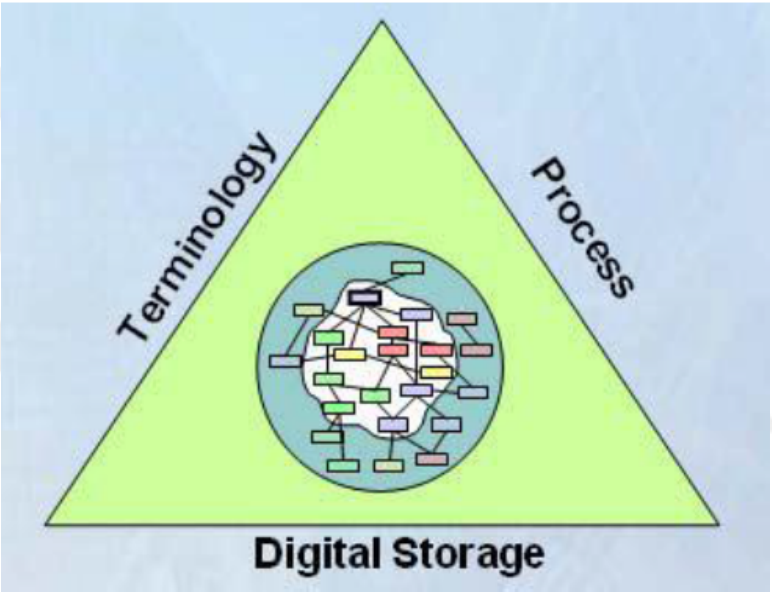


Figure 2.11. Interoperability Through Standards (NBIMS, 2007).

As individual software applications keep the information in their native formats, they pose a challenge in AEC industry. For making the data available to project stakeholders, there needs to be a facility of precise data exchange that the software uses. The methodologies, software systems, information and communication technologies which focus on efficient exchange of data between software applications vary greatly. They range from middleware software, exchange file formats developed by individual proprietary software vendors such as DXF (Data eXchange Format), standards and open-specification data models like XML (eXtensible Markup Language), IFC (Industry Foundation Classes), Web Services, deployed for distributed databases ICT (Information and Communication Technology), project model servers, and semantic Web

applications (Voytek, 2011).

Interoperability issues in the AEC industry cannot be easily resolved without a set of rules and principles for classification of information requirements into data exchange specifications. The issues are being deepened by the complexity of the building information models, wide range of specialisms and vocabularies in the AEC industry, the increasing amount of computer software applications, and the management practices employed (The National Institute of Standards and Technology, 2010a).

Several organizations such as the International Alliance for Interoperability (IAI), EPISTLE (European Process Industries STEP Technical Liaison Executive), National Institute for Building Sciences (NIBS), Facility Information Council (FIC) have been creating data standards for various industries and geographical locations. SEMI (Semiconductor Materials and Equipment International) has been developing data standards for the Semiconductor Manufacturing Industry (Figure 2.12).

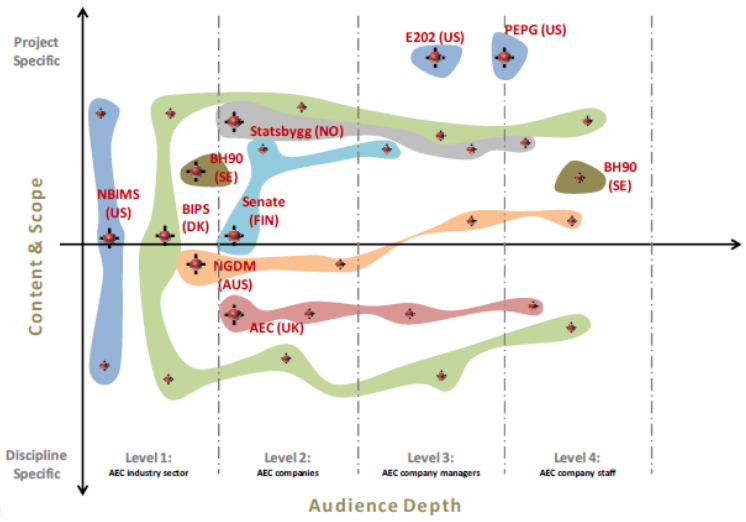


Figure 2.12. National BIM Guidelines Worldwide Audience Depth v. Content Scope (Hooper, 2012).

2.4.4. Standards / Data Models / Specifications

Standards ensure desired characteristics of products and services, such as quality, reliability, efficiency, and interchangeability within an expected cost parameters. Lack of standards is noticeable in products that are unreliable, of poor quality, and made of components that do not fit or are incompatible with other components expected to work together. When products, systems or devices work well it is most likely because they meet certain set of standards (International Organization for Standardization, 2010b). This applies to architecture, engineering and construction as well, where continuous efforts are being made to standardize data exchanged in workflows in this industry. These standardization initiatives are led in Europe by IDM (Information Delivery Manual) and in the USA by NIBS (The National Institute of Building Sciences through NBIMS Project (The National BIM Standard Project) (National Institute of Building Sciences, 2010).

With the popularity and success of World Wide Web it would be inappropriate not to examine the approach of the international community W3C (The World Wide Web Consortium) in light of development of standards used in WWW.These standards are developed under the authority of W3C called specifications or recommendations, and it is up to the users to follow them or not (Hunter, *et al.*, 2007). W3C is a group of organizations, the public, and the full time staff, lead by individuals like the inventor of the Web Tim Berners-Lee, working in unity on developing Web standards (W3C, 2009a). W3C have recognized that to assure long-term growth of the Web it is important to develop a set of protocols and guidelines which would follow a certain set of principles. These principles guide the W3C work and are about “Web for all”, “Web on everything”, “vision”, “Web on rich interaction”, “Web of data and services”, and “Web of trust”. These areas capture W3C primary goals of human communication, commerce, participation, knowledge sharing, and building trust, also availability to all people, despite what hardware, software and network infrastructure they use, and with no barriers to the language they speak, their culture, geographic location, and their abilities (W3C, 2009b).

The best known contribution to the Web by W3C is the HTML 3.2 04 4.01 Recommendations, the XML 1.0, the XSLT and XPath Recommendations. The wide implementation of recommendations is reasoned by the adopted process of creating standards by open invitation to any company or individual through the W3C membership. XML is the base recommendation upon which the whole XML family of standards is built on (Hunter, *et al.*, 2007).

2.4.4.1. ISO (International Organization for Standardization). As described by International Organization for Standardization (2010a) ISO is a non-governmental organization comprised of national standards institutes, being the world's largest developer and publisher of international standards (International Organization for Standardization, 2010a). ISO members from 163 different countries have established more than 18 000 international standards since its foundation in 1947. ISO's aim is to make services and products, according to their development, production, and supply, safer, cleaner and more efficient. Promoting innovation, sharing technology and practices, providing guidance to consumers, managing trade between different countries, and granting governments with a basis for laws, are what ISO standards are for as well. Even though they are voluntary standards, they often might become a requirement in a market.

2.4.4.2. STEP (Standard for the Exchange of Product). STEP, also known as ISO 10303, it is an international standard capable of describing product data independently from any particular system and throughout the lifecycle of a product, from design to manufacturing, using it, and the disposal. STEP contributes to a neutral file exchange used as a base for storing and sharing product database. STEP has led to improvements in CAD (Computer Aided Design) and its model development practices and overall product data quality. It has been also instrumental in fostering collaboration and communication within supply chain teams. Since its beginnings in 1984, STEP is being continuously developed, used in various industries including AEC, aerospace, automotive, and shipbuilding (International Organization for Standardization, 2010c).

2.4.4.3. CIS/2 (CIMSteel Integration Standards) . According to the National Institute of Standards and Technology (2010b) CIMSteel Integration Standards (CIS/2) is the product model and electronic data exchange format specifically intended for structural steel information (National Institute of Building Sciences, 2010). CIMSteel is the abbreviation of Computer Integrated Manufacturing of Constructional Steelwork. This standard involves the whole flow of data from design, through manufacturing, to erection. CIS/2 is developed by Steel Construction Institute in the UK, advocated by American Institute of Steel Construction in 1998, and improved further by Georgia Institute of Technology in the US for a format of data flow between software applications utilized for steel design, analyses, engineering, fabrication and construction. However, CIS/2 is not software but a format of files that are imported or exported in a steel related CAD or BIM software.

2.4.4.4. IFD (International Framework for Dictionaries). IFD is the mechanism or standard developed by ISO (ISO 12006-3:2007), allowing for creation of multilingual dictionaries or anthologies (buildingSMART, 2010e). It provides flexibility by allowing for the link between the model and the various databases used within the project (IFDWeb, 2010).

2.4.4.5. IDM (Information Delivery Manual). IDM is another recent development that captures and integrates BIM business processes and provides for the business process detailed specifications (buildingSMART, 2010d). It describes the process undertaken within design and construction and provides information required for execution of such process. The IDM overall intent is to provide a basis for reliable information exchange among the project stakeholders (buildingSMART, 2009d).

2.4.4.6. XML (Extensible Markup Language). As described in (Evjen, *et al.*, 2007), XML is a standard for data representation which was created 1998 with the W3C initiative to form a markup language representing data for use and consumption regardless of the platform. The aim of XML is to display a document so that it could be comprehended by all working boundaries. It is implemented by the possibility of

writing a text next to the items in the document thus another application can make a sense of it. Generating and presenting displays in XML are easy when compared to others, which boosts its popularity.

2.5. BIM Tools

As BIM evolves into one of the most advanced technologies in construction industry, more software developers are applying their products into the prospective area in BIM. There are many Building Information Tools available in the software market. Some of the BIM tools are listed in the table below. In Table 2.1 Mechanical, Electrical, Plumbing, Structural, Architectural and Site Work 3D modeling software programs are listed.

Table 2.1. BIM Tools (Hergunsel, 2011).

Product Name	Manufacturer	Primary Function
Cadpipe HVAC	AEC Design Group	3D HVAC Modeling
Revit Architecture	Autodesk	3D Architectural Modeling and parametric design
Autocad Architecture	Autodesk	3D Architectural Modeling and parametric design
Revit Structure	Autodesk	3D Structural Modeling and parametric design
Revit MEP	Autodesk	3D Detailed MEP Modeling
AutoCAD MEP	Autodesk	3D MEP Modeling
AutoCAD Civil 3D	Autodesk	Site Development
Cadpipe Commercial Pipe	AEC Design Group	3D Pipe Modeling
Dprofiler	Beck Technology	3D conceptual modeling with real time cost estimating
Bentley BIM Suite (Microstation, Bentley Architecture, Structural, Mechanical, Electrical, Generetive Design)	Bentley Systems	3D Architectural Structural, Mechanical, Electrical and Generative Components Modeling
Fastrak	CSC (UK)	3D Structural Modeling
SDS/2	Design Data	3D Detailed Structural Modeling
Fabrication for AutoCAD MEP	East Coast CAD/CAM	3D Detailed MEP Modeling
Digital Project	Gehry Technologies	CATIA based BIM system for Architectural, Design, Engineering and Construction Modeling
Digital Project MEP System Routing	Gehry Technologies	MEP Design
ArchiCAD	Graphisoft	3D Architectural Modeling
MEP Modeler	Graphisoft	3D MEP Modeling
HydraCAD	Hydratec	3D Fire Sprinkler Design and Modeling
AutoSPRINK VR	M.E.P. CAD	3D Fire Sprinkler Design and Modeling
FireCad	Mc4 Software	Fire Piping Network Design and Modeling
CAD-Duct	Micro Application	3D Detailed MEP Modeling
Vectorworks Designer	Nemetschek	3D Architectural Modeling
Duct Designer 3D, Pipe Designer 3D	QuickPen Internation	3D Detailed MEP Modeling
RISA	RISA Technologies	Full suite 2D and 3D structural Design Applications
Tekla Structures Affinity	Tekla Trelligence	3D Detailed Structural Modeling 3D Model Applications for Early Concept Design
Vico Office	Vico Software	5D Modeling which can be used to generate cost and schedule data
Power Civil	Bentley Systems	Site Development
Site Design, Site Planning	Eagle Poing	Site Development

There are number of BIM software for scheduling, clash detection, coordination and planning of the construction projects. Some of the BIM software's are listed in Table 2.2 and their use are briefly explained. There are also integration programs such as Innovaya and Synchor (Hergunsel, 2011).These integration programs are a bridge between the 3D model of the project and the scheduling programs (MS Project, Primavera). In addition, Vico is powerful BIM software which has tools for 5D modeling.

Table 2.2. BIM Construction Management Tools (Hergunsel, 2011).

Product Name	Manufacturer	BIM Use
Navisworks Manage, Navisworks Scheduling	Autodesk	Clash Detection Scheduling
ProjectWise	Bentley	Clash Detection Scheduling
Digital Project Designer	Gehry Technologies	Model Coordination
Visual Simulation	Innovaya	Scheduling
Solibri Model Checker	Solibri	Spatial Coordination
Synchro	Synchro Ltd.	Planning & Scheduling
Tekla Structures	Tekla	Structure-centric Model Schedule Driven Link
Vico Office	Vico Software	Coordinate Scheduling Estimation

A survey conducted by Burcin and Samara (2010) of 424 construction firms in United States shows that various BIM tools have already been adopted in the construction industry. Figure 2.13 shows the market share of various BIM tools which are used by these 424 construction firms. Autodesk BIM tools are the most widely used BIM solutions in U.S with 54% of those construction firms using them; Graphisoft ArchiCAD^{TM} follows with 10.7% and Bentley BIM tools with 8%. Tekla and Vico BIM tools are utilized by 6.5% and 5.8% of the construction firms based on the survey. The other software tools such as Innovaya^{TM}, Dprofiler^{TM}, Vectorworks^{TM}, etc. are also being utilized by a small portion of the construction firms (Burcin, *et al.*, 2010). The software tools have been used in different phases during the project lifecycle such as Preliminary Design and Feasibility Study, Shop Drawing and Fabrication, Estimating, Scheduling, and File Sharing & Collaboration. The purchase of the software package is different from regular purchases, since the buyers need to consider the capabilities of each software tool in the package. This section provides general information about BIM software packages which are widely adopted by users.

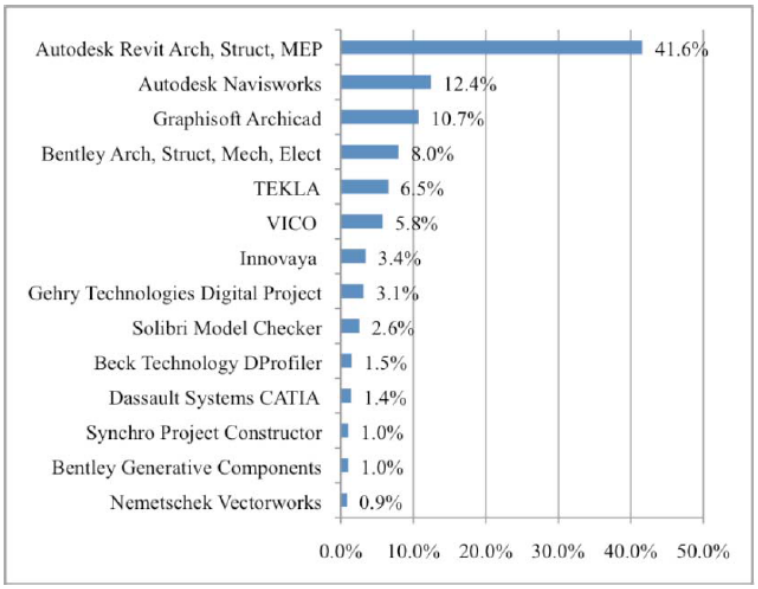


Figure 2.13. Percentages of Market Share of BIM Tools Which are used by Construction Firms (Burcin, *et al.*, 2010).

2.6. BIM Application Areas

BIM is parametric-object based which means that all the data it has could be shared and reused by different stakeholders who are involved in the building lifecycle. BIM can offer more rational data and information of the building by storing and exchanging information automatically. Design, modeling, energy analysis, clash detection, cost calculation and construction planning is some of the areas it can be utilized. Those various areas in BIM provide the users with an opportunity to communicate, reduce errors, and save money and time potentially. Application areas in several processes of the building lifecycle will be discussed in this section.

2.6.1. Design/Modeling

Architects, MEP and structural engineers, and fabricators are able to influence several functions on the same building model for their use thanks to the object-based parametric modeling feature in BIM. Precise building data and object models help the process of design and modeling greatly. The preciseness of the design and data sharing

betterment are also beneficial for precise quantity takeoffs that can be utilized in cost calculation and the process of construction can be computerized for the control.

2.6.2. Energy Analysis

The capability to link the building model to energy analysis tool allows users to conduct the energy analysis in the early design phase. Traditionally, a separate energy analysis would be conducted at the end of the design process and it is not possible for users to modify the design to improve the building's energy performance. By using BIM technology, the building model can be linked to energy analysis tools for the energy evaluation during the early design phase. The analysis allows users to make energy-conscious decisions and to test the energy-saving ideas without postponing the design process (Stumpf, *et al.*,).

2.6.3. Clash Detection

The designs from all organizations can be brought together and compared, and the geometric clashes between architectural, structural and MEP systems will be detected, checked and modified. Coordination among different organizations is enhanced and errors and omissions are significantly reduced, thus speeding up the construction process, reducing costs, minimizing the likelihood of legal disputes, and shortening the construction period.

2.6.4. Construction Scheduling

The design and the construction schedule can be synchronized by linking the building model to the project schedule. It allows users to simulate the construction process and show the virtual view of the building and the site. More details about construction scheduling will be provided in the following sections.

2.6.5. Cost Estimating

BIM users can generate accurate and reliable cost estimates through automatic quantity takeoff from the building model and get a faster cost feedback on changes in design. It is possible to make all the involved organizations aware of the cost associated with the design before it progresses to a more detailed level. The following sections will provide more detailed discussions about cost estimating in BIM.

2.6.6. Visualizations

BIM allows generation of 3D renderings in-house with very little effort. This is very important for visualization of the project. The 3D rendering of the project provides a better understanding of what the final product will look like. The designer and owner can see the envelope of the project so this will help them to make better decisions on the aesthetic and functionality of the projects. The virtual model helps team members to communicate and collaborate more effectively. In addition a virtual model is much more cost efficient in comparison to a physical mock-up (Hergunsel, 2011). However a physical model may still be necessary for the project so, the virtual mock up can be used as a good standard for the physical one.

2.6.7. Fabrication/Shop Drawings

For various building systems, the shop drawings can be very easily generated as soon as the model is complete. During the construction stage of the projects, due to site problems or clients requests the project will change and new shop drawings will be needed. By using BIM software shop drawings of all mechanical, electrical and plumbing designs will be updated and can be extracted easily.

2.6.8. Prefabrication

Prefabrication reduces the costs and time that is necessary to produce a product and also increases the quality. It is better to work in a controlled environment rather

than working in construction site. However more accurate information and specification about the project is needed for prefabrication. Building information models can provide this level accuracy by including the specifications, sequence, finishes, and the 3D visual for each component. However, the construction team must make sure that the BIM is interoperable with the software used by fabricators (Hergunsel, 2011).

2.6.9. Code Reviews

Fire departments and other official bodies to review the building projects for better results use the BIM drawings. In BIM models all projects are in the same model and with detailed specifications thus, it is easier for the officials to control the buildings if designs are complying with the regulations.

2.6.10. Facilities Management

BIM can be used for space renovations, planning and maintenance operations. The whole life cost of the buildings refers to the total cost of ownership over the life of an asset. Using BIM decreases the whole life costs of the buildings.

2.6.11. Cost Estimating

BIM software can be used for accurate detailed estimating. They have built in cost estimating features, which helps in updating the material quantity whenever any changes are made to the model.

- BIM combined with cost
- Model enables accurate quantity survey of materials and components
- Quantities linked directly to cost databases
- Cost implications of design changes can be understood in real-time

2.6.12. Construction Sequencing

An effective plan of ordering of necessary materials, manufacturing and delivery of all the components can be generated by BIM. The plan of the project might be merged into virtual building; one that uses scheduling as 4th dimension. Trucks, cranes, lifts, excavators could be examples to 4D model, however routes for them needs to be submitted into the BIM.

4D BIM can also be used to identify safety needs at different stages of the project life cycle. Based on the observations of the 4D model engineers can decide on safety precautions and temporary safety structures can be modeled in BIM. Safety committee meetings can also be arranged in the schedule of the BIM model. Overall, 4D BIM can be used a proactive approach to enhance the planning and monitoring of the jobsite safety (Hergunsel, 2011).

The planning of the project by using BIM will improve the use of site, space coordination and product information.

- 3D model plus time as 4th dimension
- Visualize the schedule
- Find flaws in logic
- Optimize sequencing on the construction site
- Trade laborers who struggle to read schedules can contribute

2.6.13. Conflict Interference and Collision Detection

BIM helps in visually inspecting for all interferences, clashes and collision and thus reduce conflicts.

Clash detection as a spatial “spell check” for building components

- Equipment

- Fixtures
- Pipes
- Ducts
- Conduits
- Structural members
- Architectural features

2.7. BIM Related Approaches

2.7.1. Project Delivery Methods and BIM

The most widely used methods in project delivery that the industry currently applies are Traditional Design-Bid-Build, Construction Management at Risk, Design/Build, and Integrated Project Delivery. Regardless of the delivery approach, the general contractor or the construction manager can utilize BIM, to prepare cost calculations. Moreover, 3D renderings can be provided. Furthermore, 4D BIM (schedule integrated) can be utilized for animations, safety analysis and developing site logistic plans. BIM can be used by construction managers for coordinating with subcontractors. Besides, the schedule and costs can be updated with BIM. Finally, an "as-built" building information model could be turned into owner's maintenance team.

Collaborative integrated working and stakeholder's interest have been among key drivers that underpin and encourage the use of BIM within the AEC industry. BIM is becoming a major means to deliver projects with better improved product, and reduced risk within the construction industry. Furthermore, using BIM in areas like buildability, quality assurance, cost and scheduling can be justified through BIM-nD modeling application (Ganah, *et al.*, 2013).

Integrated project delivery suggested as an alternative to the traditional process. Integrated project delivery will help in reducing waste streams and improve productivity of construction processes through the integration of people, systems, business structures, practices into a process that collaboratively harness the talents and insights

of all the participants. BIM plays a key role in the integrated project delivery approach by facilitating full collaboration and information sharing amongst the participants of a construction project throughout its lifecycle.

"Building Information Modeling" and "Building Information Model" are terms that are often used interchangeably, reflecting the terms growth to manage the expanding needs of the constituency. There are several definitions of BIM and no universally accepted one. However, many researchers seem to accept the definition advanced jointly by the RIBA, Construction Project Information Committee and Building Smart Alliance. That definition states that BIM is "a digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition". Thus, BIM is a digital model of a building in which information can be in 3D (visualization and coordination of project), 4D (integrating time) 5D, (including cost estimating), 6D (procurement and thermal properties analysis), 7D (operational applications lifecycle), 8D (integrated project delivery)- right up to "nDé (a term that covers any other information needed for construction and running of a facility). BIM is a new technology that brings with it a new method of working which is aiming to revolutionize and make the construction process more responsive to of the end-user's needs (Ganah, *et al.*, 2013).

The "MacLeamy curve" or "Effort curve" (Figure 2.14) illustrates the concept of making design decisions earlier in the project when ability to influence positively the outcomes is greater and the cost of changes is lower. This curve demonstrates clearly the differences between the integrated and the traditional project delivery.

The MacLeamy curve consists of four different curves. Curve 1 depicts how easy changes can be abated into a project according to where along the process the change is suggested. Curve 2 depicts the economic effect of a change according to when along the process the change is implemented. Curve 3 and 4 respectively depicts when the knowledge about constructability is consolidated in respectively a conventional project and a BIM/Lean project.

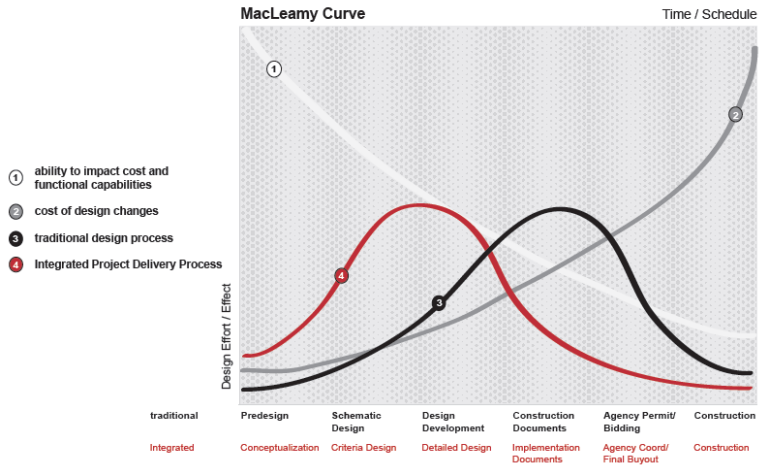


Figure 2.14. "The Effort Curve" by Patrick MacLeamy (The American Institute of Architects, 2007).

2.7.1.1. Degrees of collaboration: an evolutionary process. In construction, there are degrees of collaboration. Owners, more than any other stakeholder, drive the degree of collaboration they receive on their projects. They influence this early in projects through their procurement and contracting process. In this manner, owners may establish the baseline for the level of integration that they may expect on each project (Kenig, *et al.*, 2010).

Merged project delivery has been regarded as an alternative to the traditional practices which help in reduction of waste streams and improvement in efficiency of construction phases through the merging of people, systems, business structures, practices into a process that tracks talents and opinions of the participants. Several research papers argue that BIM has a key role in merged project delivery approach with its boosting full collaboration and information sharing between the members throughout its lifecycle. A majority of owners are deciding on a project-by-project basis if it is profitable to try to develop a higher level of integration and what the shortcomings might be.

Integrated Project Delivery for Public and Private Owners presents a gradual approach which has three levels for succeeding in collaboration. They serve as spectrums

through which owners act. Regardless of legislative restrictions, policy limitations or cultural barriers, all owners fall into one spectrum because of some reasons (Figure 2.15). The three collaboration levels are:

(i) Collaboration Level One - Typical; collaboration not contractually required
(ii) Collaboration Level Two - Enhanced; some contractual collaboration requirements
(iii) Collaboration Level Three - Required; collaboration required by a multi-party contract

It is a recognizable fact that those integrated principles mentioned here or anywhere else have long been used. Level one (Typical Collaboration) corresponds to the way many owners have been working for years. It is presumed that owners grasp the concepts of collaboration and integration at least to level one, whether they are capable of applying the concept or not.

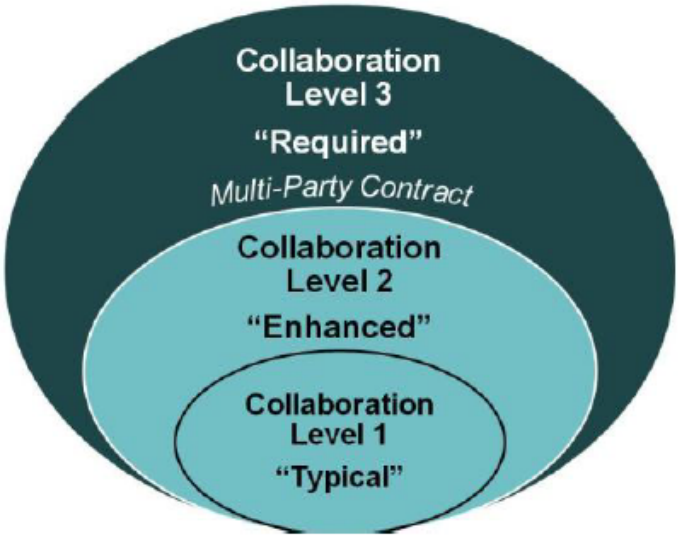


Figure 2.15. Levels of Collaboration (Kenig, *et al.*, 2010).

2.7.1.2. Challenges to practice (drivers for IPD). What are the industry issues that are fueling the integrated project delivery trend? A convergence of forces seems to be moving the AEC industry in the direction of integration-based on economics, productivity and nature of current owner design requirements (Autocad, 2007). These issues

include:

- A transition to globalized work processes: The supply chain of the construction products is becoming greatly globalized, complicating the cost predictions and demand for the construction materials. The workforce is globalized by outsourcing and shifting demographics as well, which boosts the need for new abilities about cooperative processes, while generating a new set of potential competitors around the world at the same time.
- The demand for higher productivity and lower margins: Decreasing productivity in construction is limiting the competency to carry out building projects profitably and reliably and baffling the demand for more planned results.
- The wish for sustainability: Sustainable building design is contingent on the capability to obtain insight into building outcomes through analysis, prediction and optimization of the design in reducing environmental harm through limiting energy consumption, carbon footprint and utilization of fresh water. Consequently, sustainability in building standards are becoming more common and progressing to mention performance based assessments which cover a building's whole lifecycle.
- More Complex Buildings: With more interesting building forms, complex supply chains, new standards in project delivery, restrictions in regulations, interactions between project specialists and demands of the owners, buildings have definitely become more complex.

2.7.1.3. Practice responses (opportunities for innovation). In response to these drivers, we are witnessing fundamental changes within the building industry's design and construction processes, which include:

- Collaboration: With the help of technology, an improved and more efficient kind of cooperation between everyone who are involved in the project delivery is enabling digital cooperation as well by sharing outcomes, risks, and gains with strategic partners.

- Representation: There is a transmission from 2D to digital models where display is simultaneous with the analysis. This new understanding alters the process of the design from representational to performative.
- Analysis: Design displays becoming performative enables fast design inference, with analysis as a merged part of the design process. This is against the traditional evaluations of the designs as they alter over time.
- Standards: The designers are obliged to provide higher levels of insight about building outcomes as building codes are updated to regard performance. In some cases, the owners might use technology standards to fulfill opportunities for a better and a more flexible project.
- Manufacturing: Digital manufacturing techniques make it hard to distinguish between design and production. Meanwhile, design sensibility changes, increasing extensive pre-fabrication, mass customization, and factory-produced building materials. Digitally manufactured building materials lessen the demand on field construction efficiency.

2.7.2. Lean and BIM

Lean Production was developed by Toyota led by Engineer Ohno. The term lean was coined by the research team working on international auto production to reflect both the waste reduction nature and to contrast it with craft and mass forms of production. The basic idea behind lean production is the elimination of inventories and other wastes through small lot production, reduced set up times, semiautonomous machines, cooperation with suppliers, and other techniques (Ohno, *et al.*, 1988).

Lean production presents a very different model. Production is managed so that actions are aligned to produce unique value for the customer. The total duration and cost of the project is made more important than the cost or duration of any activity. Coordination is accomplished in general by the central schedule while the details of work flow are managed throughout the organization by people who are aware of and support project goals (as opposed to activity or local) performance (Hoop, *et al.*, 1990).

The improvement focus from the activity is shifted to the delivery system by moving towards zero waste or perfection. Lean production continues to evolve but the basic outline is clear. Design a production system that will deliver a custom product instantly on order but maintain no intermediate inventories. The concepts include (Howell, *et al.*, 1994):

- Identify and deliver value to the customer value: eliminate anything that does not add value.
- Organize production as a continuous flow.
- Increase output value through systematic consideration of customer requirements
- Reduce Variability
- Simplify by minimizing the number of steps, parts and linkages
- Increase output flexibility
- Increase process transparency
- Focus control on complete process
- Build continuous improvement into the process
- Perfect the product and create reliable flow through stopping the line, pulling inventory, and distributing information and decision-making.
- Pursue perfection: Deliver on order a product meeting customer requirements with nothing in inventory.
- Benchmark

Lean construction and BIM are not dependent on one another i.e., lean construction practices can be adopted without BIM, and BIM can be adopted without lean construction. This is illustrated by the numerous cases of separate adoption of each in design and construction companies within the past decade. However, we hypothesize that the full potential for improvement of construction projects can only be achieved when their adoption is integrated, as they are in the integrated project delivery IPD approach. A similar notion is expressed in the American Institute of Architects document on IPD, "Although it is possible to achieve IPD without BIM, it is the opinion and recommendation of this study that BIM is essential to efficiently achieve the collaboration required for IPD" (Sacks, *et al.*, 2010).

2.7.3. Green BIM

Energy (2015), buildings are responsible for the 70 percent of the electricity consumption and according to US Information Administration (2015) 39% of the greenhouse-gas emissions. Therefore, it is obvious that alleviating the carbon footprint of the built environment is vital for the environment.

There are two preliminary approaches that diverts the perspective to design and construction in the last ten years. The green building movement has turned into a force within the industry while it consisted of a small group of enthusiasts before. This movement has gained force and importance because of the burden of the climate change and energy dependence, besides building in a cost-effective manner for increasing efficiency. What is more, this movement was subsided by the local, state and federal levels. Using BIM also has a vital effect on design and construction of environmentally friendly buildings. Many companies are diverting their approach to BIM, which allows all parties ability for input in the early design process while making greater use of prefabrication possible (McGraw-Hill Construction, 2013). The "green themes" can be count as below;

- Regulations and performance
- Design versus actual - Carbon Buzz project
- "Embodied" and "Operational" carbon
- New buildings and existing building stock - the Green Deal
- Zero carbon - houses and offices
- Minimising site waste
- Maximising recycling and recycled content
- Operational activity, recording and feedback

2.7.3.1. Green BIM benefits.

- It allows for a faster and more effective process as data is more effortlessly shared

and reutilized. Therefore it allows for early estimation of technical and green solutions in a short time.

- Due to cooperation of the supply chain and customer with it's better design, it assists the progress of green designs, comprehensive solutions and better integration of supplier products while diminishing the risk and errors.
- The arrangement of as-built data for handover, betters the management of the facility and enables the development of the building's green performance.
- It diminishes the life cycle cost, therefore reduces the environmental impact of the building with its construction and operation, which brings out a better asset value.
- As it offers improved indoor circumstances, for instance climate and lighting, it leads to the occupant's wellness and efficiency.
- It diminishes the waste of materials therefore betters moving the waste of construction due to it's lowering the cost and carbon footage of the construction.
- BIM's allowing performance monitoring causes a better comprehension of building performance and thus, upcoming betterments for design (Skanska, 2014)

2.7.3.2. Green BIM and life cycle costing. With growing demand from customers for Green BIM, the practice of implementing models into project planning is moving the industry away from a linear outlook to a life cycle approach. The use of BIM and Green BIM makes Life Cycle Cost (LCC) analysis easier and more reliable, allowing a long term holistic approach to project decision-making that considers both the cost and environmental impacts of materials, equipment and technology not only now, but also in in the future. (Krygiel, *et al.*, 2008)

2.7.3.3. BIM, Lean and Green. As BIM has introduced more efficient methods of conducting tasks for designers and contractors, it has taken an outstanding role in encouraging lean practices and bringing about positive results. When focused on diminishing waste, many lean construction methods are naturally sustainable. Derek Cunz states that the more efficient and the less waste producing the project, the greener the project is.

Mortenson started to use lean principles in the middle of 1990's, as a better focus on early planning, bettered cooperation and approaches to prefabricate components. With the developments of BIM, it became a crucial element for fulfilling those today.

2.8. Advantages and Disadvantages of BIM

2.8.1. Advantages

According to a study made by Journal of Building Information Modeling, the benefits of BIM can be listed as; Quality control (90% favorable), On-time completion (90% favorable), Cost (84% favorable), Units/Man-hour (76% favorable), Dollars/Unit (70% favorable) and Safety (46% favorable) (Suermann, *et al.*, 2009).

By using BIM software the information is easily shared and new information is easily added. A better design is achieved by analyzing the building proposals, benchmarking, quick simulations and it enables improved innovative solutions. During the design phase most of the problems are solved and in this way the number of problems occurred during construction phase are diminished (Figure 2.16).Design changes are easily entered and model is updated automatically. In this way, there will be less rework which will save time and extra costs (Eastman, *et al.*, 2008).

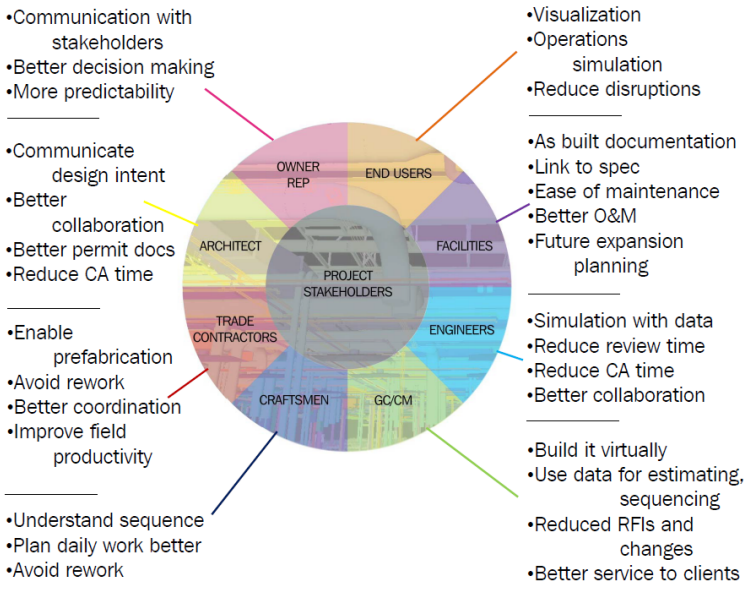


Figure 2.16. Benefits for Stakeholders (DPR, 2010).

One of the main objectives of BIM technology is to support all the processes starting with feasibility study stage and continuing through whole building lifecycle. Major benefits presented by Chuck Eastman for each building project lifecycle phase are described below (Eastman, *et al.*, 2011).

2.8.1.1. Pre-construction phase. In feasibility phase, the client attempts to decide which project he would be able to afford. The calculation of the cost at this point is very hard. However, spending time on calculating the cost of the budget is also affecting the budget, therefore it is not desirable. With BIM the building model might be connected to the cost database and the cost would be estimated.

Even though in the early stage only schema is available, it is possible to discuss building functionality and sustainability with utilizing analysis/simulation tools. This increases the total quality of the building as it makes it possible to have a right definition of project development directions.

2.8.1.2. Design phase. 3D is available from the beginning, without any need to 2D drawings. They are just ready for updates. Assembling the object using parametrical constraints minimizes the probability of errors during the design.

It is possible to obtain precise and consistent drawings for any perspective or object of the project. Moreover, after each alteration of 3D model all the 2D displays are changed accordingly. To fulfill a set of requirements such as "Area of certain type room has to be of particular size", it is feasible to use automatic evaluations of 3D models.

Extracted quantities and spaces can be utilized for cost calculation with BIM. Initially, calculations rely on available quantities such as areas. However, while the design is getting more detailed, more accurate calculations can be obtained. It facilitates better design decisions on the way of project development process, as the cost would be observed continuously.

2.8.1.3. Construction and Fabrication. To observe how the construction of the building will be and reveal possible problems on the construction site and seize opportunities for improvements, 4D BIM might be used.

BIM enables identification of clashes between different parts before the construction. Therefore, boosts construction process, diminishes risk for project cost's increase due to clashes, minimizes the likelihood of legal disputes.

If the design alters during the construction, BIM will update the cost calculation and plans instantly. BIM also helps manufacturing. 3D elements of the model are delivered to factories where the manufacturing process happens. It is much simpler to use Lean Construction Technique thanks to 4D BIM.

2.8.1.4. Post-construction phase. BIM models contain lots of information which might be beneficial for building operation processes. Early participation of the team members is very important for integrated teamwork. BIM facilitates early participation of all the players which helps to reduce costs and shortens the design time and also reduces errors (Ningappa, 2011).

Regardless of the phase of the project, 2D drawings can be obtained from 3D. If there are any alterations in the project, 2D drawings are instantly updated and drawings could be obtained without redrawing. Bill of quantities could be obtained at the beginning of the project therefore the cost of estimation would be more accurate.

Building Information Modeling (BIM) helps to predict environmental performance and whole life costs of the projects better (Azhar, *et al.*, 2008). Using energy modeling tools the model's energy use can be calculated and this tool provides an opportunity to design buildings with better energy efficiency.

The 3D model could be connected to planning programs such as Primavera and MS Project and during the building phase the engineers would be able to see how the

site would look whenever they want. Therefore, the problems which may emerge in the project site can be observed before and necessary precautions could be taken, or the model might be modified as well.

In 2D drawings such as machinery, electric or plumbing, changing one of the 2D drawings will not update other related drawings. In the proceeding phases of the project this will cause lots of inconsistencies, reworks and time waste. These problems at the start of the project will cause lots of conflicts which will lead legal disputes and change orders. Using BIM will reduce these issues because problems are identified during the design phase of the project and fixed. Detection of the errors speeds the construction process, reduces the costs, minimizes legal disputes and provides a better process (Eastman, *et al.*, 2008).

Digital product data can be exploited in the downstream process and be used for manufacturing/assembling of structural systems. In BIM, the components are already defined in 3D and hence their automated fabrications using numerical control machinery is facilitated. This facilitates accurate off site fabrication and hence reduces cost and construction time. Likelihood of on-site changes is reduced, and then larger components can be fabricated without the worry of later possible dimension change due to other items being constructed. The site is also safer since more items are fabricated off site and trucked to the site keeping onsite trades minimum (Ningappa, 2011).

The following are some of the benefits of BIM as explained by Alliance for Construction Excellence, (Alliance for Construction Excellence, 2008).

- Enables collaborative design and construction techniques.
- Increased communication between owner, design professionals, constructors and vendors/suppliers.
- Clarifies project risk/reduce risk.
- Shared information between owner, design professionals, constructors and vendors/suppliers.
- Reduces design and construction change orders and RFI's

- Centralized warehouse of information.
- Allow for "What If" scenarios.
- Pricing of modification in "Real-Time"
- Facilities and asset management for owners.
- Instantaneous system analysis (sustainable building, air flow, energy modeling etc.)
- Improved visualization for the owner as well as designers and constructors.
- Improved productivity due to easy determination of information.
- Build virtually before real world.
- Move "plan/permit review" from paper to electronic media.
- Improved maintenance, operations and facilities management potential by owners (once assuming occupancy).
- Quicker building and system startup times and personal training due to the virtual building BIM model.

2.8.2. Disadvantages

Even though BIM is very profitable for the construction sector, it also has some setbacks and it is still developing. There are a number of challenges and obstacles that needs to be overcome. One of the main issues in BIM is the ownership of the model. As there are many designs, manufacturing and building datasets in BIM, who the owner is, who is responsible, and who is paying is vague. AIA and AGC groups are working to establish guidelines which might answer those questions.

Another issue in BIM is clarification of responsibilities. In BIM it is not clear who has control of the data entry and who will be responsible for data accuracy in BIM. Taking the responsibility of data entry can cause a great risk so, before BIM technology full utilized the risks should be identified clearly and the cost of consequences should be paid (Ningappa, 2011).

In building projects, BIM is generally not used by the architectural company which is problematic, and the prime contractor needs to look for another firm to out-

source the model. Moreover, members' using different types of modeling ends up with cooperation problems, increased cost and waste of time. Before the initiation of the project, BIM implementation needs to be fully comprehended and the plan should be done accordingly. The disadvantages of BIM are briefly listed below as explained by ACE (Alliance for Construction Excellence, 2008).

- Concerns that model will change without all stakeholders input.
- Licensing and security of intellectual property used within model and model.
- Untested/untried liability issues.
- Concern that design and construction fees do not support the BIM process (or training for BIM)
- The BIM process will be a complete paradigm shift for the design and construction industry.
- Legal/Insurance language and procedures will need future clarification.
- Level of detail from the design team.
- Project specific standards for collaborative file sharing/exchange.
- Ownership of the model at various stages of the project.
- Project specific standards for file sharing.
- 2D documents are generated from the design model for permits and distributed to general contractor and subcontractors along with 3D design model.
- Shop drawings and submittals may only be eliminated for subcontractors, vendor/suppliers participating in the development of the model. There will be others who have no need to access the model (i.e. -toilet accessories, component, etc.).

2.9. BIM Implementation

2.9.1. The Role of the Public and Private Sector in Developing BIM

2.9.1.1. The role of the public sector. Wong, *et al.*, (2009) argue that the public sector support in every country can work as a driving force for higher BIM implementation in the construction industry of each country by requiring BIM implementation in public projects and setting requirements and developing regulations and standards. This

regulatory context can create a uniform environment and lead to a wide acceptance in the industry and help to create a common base for construction actors to stand on. In addition, this support of the central government towards BIM can also provide an official approval of their BIM utilization and provide incentives for research and development in BIM (Wonk, *et al.*, 2009).

The importance of public sector involvement can be observed in Finland, Denmark, and Norway where this involvement has led to a wider and stronger adaption of BIM (Wonk, *et al.*, 2009). It is furthermore concluded by Wong, *et al.*, (2009) that inside a country the level of support provided from both the public and private sector for BIM implementation can present significant advantages.

In addition, Wong, *et al.*, (2009) emphasized that in general a strong public sector support in BIM implementation can provide a more uniform, homogenous and better coordinated mechanism of BIM development established across the country. It is also contended that a strong public sector support should be still required even in the case of the great interest of the private sector to implement BIM across the country (Wonk, *et al.*, 2009).

2.9.1.2. The role of the private sector. The strong interest of the private sector of a country in BIM development and implementation can create new business activities and collaborations and trigger commercial incentives for BIM development, even though these efforts may not spread across the country. Central government support towards BIM is needed to increase the effects nationwide and drive smoothly the changes (Wonk, *et al.*, 2009).

On the other hand, a weak private sector support towards BIM would not give incentives to the companies for inter-organizational collaboration. In this case, companies show more interest in developing their internal business processes, causing problems of incompatibility with other companies and increasing the fragmentation of construction industry, hindering the public sector to get the necessary feedback to push nationally

the BIM development. This can also have effects in the hardware and software BIM development. This situation is often prevalent in countries where the BIM implementation is at the initial stage or is non-existent for both public and private sector (Wonk, *et al.*, 2009).

The adoption of BIM has different extend in each country. The public sector in Turkey is not involved in great extent in the development of BIM. It is the private sector and industry that has taken more initiatives, and the Turkish consulting firms have an active role influencing the use of BIM and leading the development.

2.9.2. BIM Implementation in the Public Sector

This chapter describes the improvement of BIM in the Turkish Construction Industry and the current implementation of BIM in the Public Sector of several countries. There are different degrees of development and in some countries it is mandatory and BIM guidelines are available (Figure 2.17), whereas in others BIM is not promoted. Over the past six to seven years many pilots and live projects have been completed and documented in Finland, USA, Denmark, Singapore, and UK, which demonstrated the capability of using BIM within the construction process facilitating construction lifecycle. Many ongoing projects have been proven to develop more environmentally sustainable products, compared to non-BIM based projects. The present situation of Turkey, Australia, Canada, China, Denmark, Estonia, Finland, Germany, Hong Kong, Iceland, India, Ireland, Italy, Netherlands, New Zealand, Nigeria, Norway, Singapore, South Korea, Spain, Sweden, Taiwan, United Arab Emirates, United Kingdom and USA is described below. Moreover, the limitations and possibilities of BIM development in public contexts are discussed.



Figure 2.17. Worldwide BIM Adoption Levels (Hooper, 2012).

2.9.3. Current Acceptance of BIM in the Industry

In some states such as Finland, Denmark, Norway and USA, the use of BIM has been endorsed, while some other states have progressed toward it (Table 2.3). Rapid advancement of some of these activities is discussed detailed in the following section.

Table 2.3. BIM Promotes and Supports in Some Countries.

Incentives and Supports	USA	Australia	China	Denmark	Finland	Netherlands	United Kingdom	Norway	Singapore
BIM / IFC requirement in public projects	+ 2003-GSA	-	-	+ 2008	+ 2007	-	* 2016	+ 2010	+ 2012
Required BIM knowledge	-	-	-	PLC[1]	PLC[1]		PLC[1]	A[3]	E[2] A[3]
Financial support by the Government	+	-	-	-	+	-	-	-	+
IFC / BIM standards and / or the development of guidelines	+ 2003	+	-	+	+	-	+ 2009	+	+ 2011
Implementation of pilot projects	+	+	-	+	+	+	+	+	+
BIM courses in universities	+	-	+	+	+	+	+	+	+
BIM certification programs	+	-	+	+	-	-	+	-	+
Events related BIM	+	-	+	-	-	+	+	-	-

The U.S. General Services Administration notified the requirement of utilizing IFC model server standards by October 2006. Through conducting 10 pilot projects many BIM authoring tools have been certified as to their fitness for use. Many author-

[1](PLC: Project Life Cycle).
[2](E: Engineering).
[3](A: Architecture).

ing tools like Autodesk and Bentley's products that passed this certification and the continual development of modeling requirements proceed further. National Building Information Model Standard (NBIMS) has initiated another US project at 2007, which aimed to raise awareness of using BIM systems and consequently NBIMS has released National BIM Standard Version 1. Nevertheless National CAD Standard (NCS) Version 4.0 was released in January 2008 to further streamline design, construction, and facility operations communication among construction stakeholders over the lifecycle. These standards aim to reduce errors and lower costs for all disciplines. It coordinates the efforts of the entire industry by classifying electronic building design data consistently. Also these systems allow streamlined communication among owners, and design and construction project teams.

BuildingSMART was initiated as a Norwegian activity, which followed the IFC compatibility that has been introduced by IAI. Many international chapters of BuildingSMART are actively promoting and sharing the latest findings related to BIM implementation within the building product development lifecycle. Today BuildingSMART is an alliance of international organizations within the construction and facilities management industries dedicated to improving processes through active collaboration.

HITOS project of University of Tromso has been one of the well-known international activities that used IFC model server technology in a comprehensive manner. The researchers recommend that current business processes required changing to gain advantage from BIM.

Statsbygg (The Norwegian Directorate of Public Construction and Property) has also produced brief documentation of the project. Statsbygg aims to utilize BIM in all phases, to a complete extent for projects. Further works on BIM and associated IFC files were carried out in the technology program launched by TEKES focusing on developing eco-efficient solutions for multi-story and low-rise buildings and provides tools to facilitate the adoption of BIM in construction. During the program, BIM tools and processes have been developed in order to considerably improve productivity in the industry and make it possible to manage the information generated and maintained

throughout the lifecycle of buildings more efficiently. Finland as the world leader in BIM implementation has 108 projects (TEKES, 2008).

On the other hand, slow progressive changes are taking place within the Turkish industry whilst many Turkish companies are happy to continue using traditional CAD. However, it is noticeable that some of the Turkish organizations working in the Turkish markets are effectively converting their processes to utilize BIM technologies. This conversion requires; training, resources, content creation, team working and new workflows which all need to be managed simultaneously. It is clear within the Turkish industry that change will not happen overnight; however having a clear strategy along with the correct guidance will enable this process. Lack of cohesive directions from the Turkish authorities comparable to the discussed international initiatives have created this drag and further research is needed to direct them through meaningful engagement with the industrial bodies to bring the intelligence forward for making the valuable decision to aggressively engage with BIM within the construction projects in a timely manner.

2.9.4. BIM Diffusion in Turkey

With having 42 construction firms listed in the ENR's 2014 Top 250 International Contractors List, Turkey is one of the main contributors to the global construction industry (ENR, 2014); it is vital that the Turkish Construction Industry embraces such technologies as BIM in order to remain competitive. Moreover, in order to facilitate this adoption it is advocated that an industry wide strategy is needed. Hence, the first step is to identify the Turkish construction industry's current position in the global market is to determine existing and new trajectories for further adoption and implementation (Ezcan, *et al.*, 2013).

There is no doubt that the policy of mandating BIM use for government work will create economic growth (Saxon, 2013). Therefore, Building Information Modelling is a valuable tool which is been advocated that can promptly act as a "game changer" in global construction market. The scale and speed of the effect is not quantifiable as

yet but should become so if monitoring is well done'.

Given that Turkey is one of the main contributors to the global construction industry; it is vital that the Turkish Construction Industry embraces such technologies as BIM in order to remain competitive. Moreover, in order to facilitate this adoption it is advocated that an industry wide strategy is needed. Hence, the first step is to identify the Turkish construction industry's current position in the global market is to determine existing and new trajectories for further adoption and implementation (Ezcan, *et al.*, 2013).

The level of BIM adoption has been rapidly rising within the last four years and the application of BIM in infrastructure projects was three years behind of the BIM implementation on vertical building projects (McGraw-Hill, 2012b).

The level of benefit that can be obtained by using IT is directly proportionate to its level of adaption. As an overview, some of the recent efforts on the improvement of BIM in Turkish construction industry are presented as follows. Many companies in the private sector are aware about BIM in Turkish Construction industry, also these firms producing projects with BIM consciously provided by this awareness. Turkish construction firms produce BIM based projects in abroad mostly in Middle East countries and also in Turkish cities such as Adnan Menderes Airport, Third Airport of Istanbul and many building projects. Recently, there was a huge development in Turkey. This step that will make a major contribution of BIM development in the Turkish construction sector is that BIM is mandatory for the railway systems projects in subway construction tender.

The current tender coverage just includes rough construction works, so a Building Information Modeling (BIM) related clause was added to the Terms of Reference for the adaptation of companies to the BIM process. The static model, route and tunnel systems were demanded in LOD 300 detail level. Nevertheless, contract coverage was planned as CAD priority to prevent possible failure of works and delay in submissions. Therefore, the contractor planned all the project, team and calculations in accordance

with the CAD based system. In addition, BIM model was produced in the project delivery period.

The second phase of the tender involves the electromechanical design of architectural, static, mechanical and all other systems of three stations between Kabatas and Mecidiyeköy. In this context, a technical appendix was added to the tender documents. This appendix includes information about BIM-CAD work schedule, project sharing and documentation. Here, the aim is to follow a new procedure to increase the awareness of BIM specifications and to reach LOD 500 detail level in future Terms of Reference documents.

BIM the scope of serving the global market will be related to the uptake of the BIM approach among all the stakeholders such as clients, consultants, constructors, product makers and facility managers across the world. To facilitate this aim, other countries should recognize UK classification, standards and contract processes (Saxon, 2013).

2.9.5. BIM Diffusion in Other Countries

2.9.5.1. Australia. Cooperative Research Centre for Construction Innovation published two guidelines related to National BIM Guidelines in 2009 (Figure 2.18).

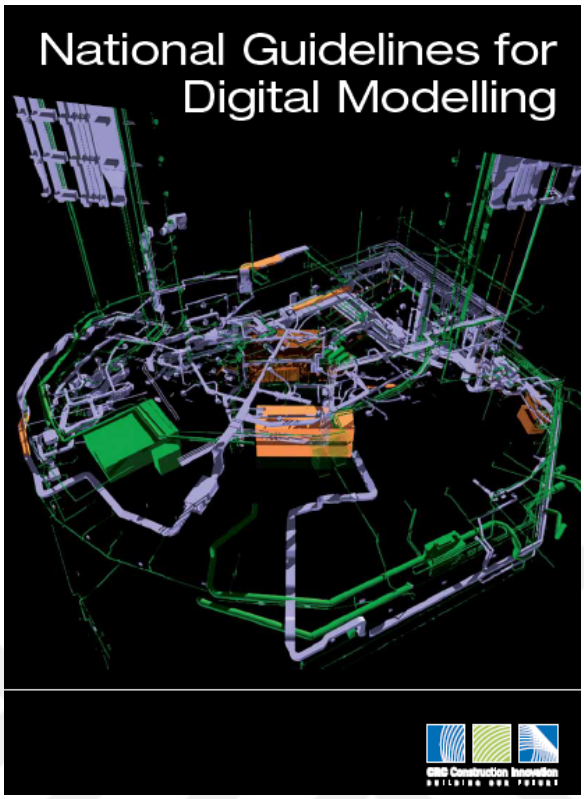


Figure 2.18. National Guidelines for Digital Modelling, Australia (BuildingSMART, 2009).

BuildingSMART Australasia published a National BIM Initiative in 2012 (Figure 2.19) BuildingSMART Australasia aims to drive the construction industry into a new efficient, low carbon era of BIM. It recommends that industry and the Australian Government work together to promote initiatives that will accelerate the adoption of BIM in Australia and ensure the growth of the construction sector. The National BIM Initiative Report contains two volumes: the Strategy and the Implementation Plan.

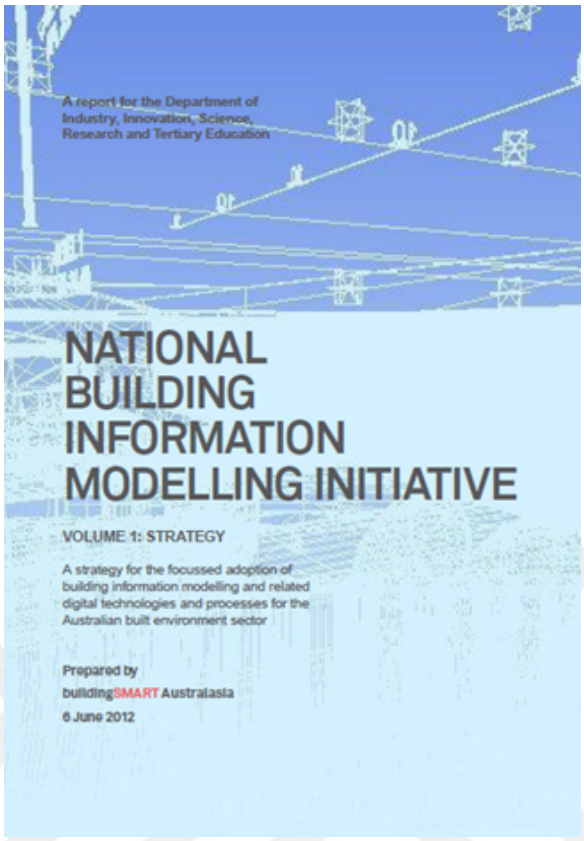


Figure 2.19. National Building Information Modelling Initiative Volume 1: Strategy, (Mitchell, *et al.*, 2012).

The Key Initiatives recommended include:

- All Australian Government building procurements require full 3D collaborative BIM based on open standards for information exchange by 1 July 2016;
- Encourage the Australian States and Territories through the Council of Australian Governments to require full 3D collaborative BIM based on open standards for information exchange for their building procurements by 1 July 2016;
- Development of the National BIM Initiative Implementation Plan, which requires
  - Execution project work programs related to Procurement
  - BIM Guidelines, Education, Product Data and BIM Libraries
  - Process and Data Exchange
  - Regulatory Framework and Pilot Projects;
- Establish a taskforce with key stakeholder representation to manage a 5-year

program for the delivery of the National BIM Initiative Implementation Plan. (buildingSMART Australasia, 2012)

The Department of Defense of the Australian Government recognizes BIM benefits and it is going to integrate BIM an IPD it its projects. Indeed, it will adopt 3D, 4D and 5D together with new forms of contracts.

2.9.5.2. Canada. The status of BIM adoption in Canada is still unknown for governments and public because there is no academic research or survey related to the use of BIM in Canada. However, the real status of BIM adoption in Ontario can still be portrayed by interviewing with Ontario-based engineers. Alberta BIM Centre of Excellence (ACE) published first research of BIM with the best BIM practices in Canada at November 2011 (Figure 2.20).

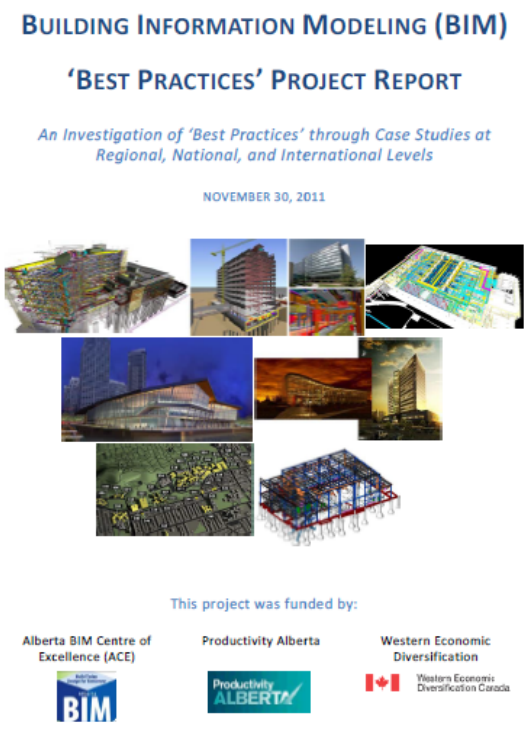


Figure 2.20. Building Information Modeling (BIM) "BEST PRACTICES" Project Report, (Staub-French, *et al.*, 2011).

The Government of Ontario has not issued any mandatory policies which aids at

BIM implementation. The reality is zero policy has come into operation to implement BIM in Canada. CanBIM is the business voice of Canada's BIM community. CanBIM, published national BIM protocol in October 2012, (Figure 2.21) represents, supports and advocates on behalf of the entire AECOO and educational community to build a positive business environment for the effective deployment of BIM.



Figure 2.21. AEC (CAN) BIM Protocol v 1.0, (CAN BIM, 2012).

The sense of competition is weak in Canadian construction industry comparing with US. The building industry in Canada is smaller and relatively stable, so most of firms are non-proactive for applying BIM into projects. Firms generally prefer to follow a more traditional and conservative method more than to pursuit a high-level technology. Currently the BIM in the Canadian market are far away from maturity. Despite the high rate of LEED certified buildings, most of projects are entrenched in current 2D drafting practices. However, BIM adoption projects are limited within visualization of building models rather than information models or whole lifecycle.

The awareness of BIM is low in Canadian Construction Market. Most practitioners of building industry have heard the concept of BIM but a few of them really understand what it is or have BIM experience. There is a request for use of BIM from clients in private sector. For this reason, the industry just considers it as an interesting attempt more than an effective approach to undertake projects.

2.9.5.3. China. Chinese BIM Series: Standard Guide for Design Enterprises BIM Implementation (Chinese Edition) published in March 2013. However, BIM is not obligatory and it is not mentioned in the five-year plan manifesto. China is highly interested in the energy efficiency of buildings, which is not possible without a model-based representation of the facility. For this reason Khemlani (2006) says that China is indirectly encouraging the adoption of advanced technologies such as BIM. Implementation of pilot projects, BIM courses in universities and BIM certification programs are the milestone of the development of BIM which have begun to implement in China.

2.9.5.4. Denmark. Danish Enterprise and Construction Authority have carried on a Digital Construction Initiative to develop common standards and guidelines for digital construction projects in 2007 (Steffensen, 2012). In 2007, it was decided to adopt BIM requirements for governmental projects (Wong, *et al.*, 2009) and the main requirements are:

- the Danish Building Classification System;
- project web-system for exchange of digital information on building projects;
- 3D-models (BIM) in competitions, design and construction;
- digital bidding and tendering (based on 3D-model);
- hand-over of relevant, digital information at the end of the building process;
- IFC-format for data exchange.

Danish Building Classification System is a combined classification and identification system, which includes traditional classification based on "kind-of" relations and identification of systems and subsystems in a construction entity based on the "part-of"

relation. DBK is partly based on the ISO 12006-2 classification framework standard.

In June 2011 the Danish Parliament decided to extend the mandatory adoption of BIM to all local and regional projects worth over 2.7 million euro (BuildingSMART, 2011b).

- The Danish Building Classification System (8 guides and 29 classification table);
- 3D Working Method guideline (BIPS, 2007);
- Logistics & Process guideline;
- ICT-specifications guideline that help the definition of agreements between the actors concerning digital deliveries (Steffensen, 2012).

Moreover, the no-profit organization BIPs published several standards to support the development of digital constructions (Figure 2.22).

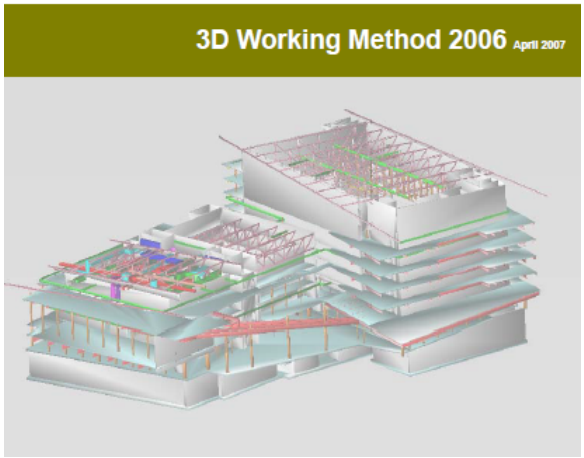


Figure 2.22. 3D Working Method, (bips, 2007).

2.9.5.5. Estonia. BIM is not enforced in Estonia but the Estonian real estate company Riigi Kinnisvara in 2009 promoted an initiative to implement BIM on design procurements, based on Senate Properties activities (Alt, 2011). Estonian BIM Manual (Figure 2.23), published in 2013, is available only in Estonian.

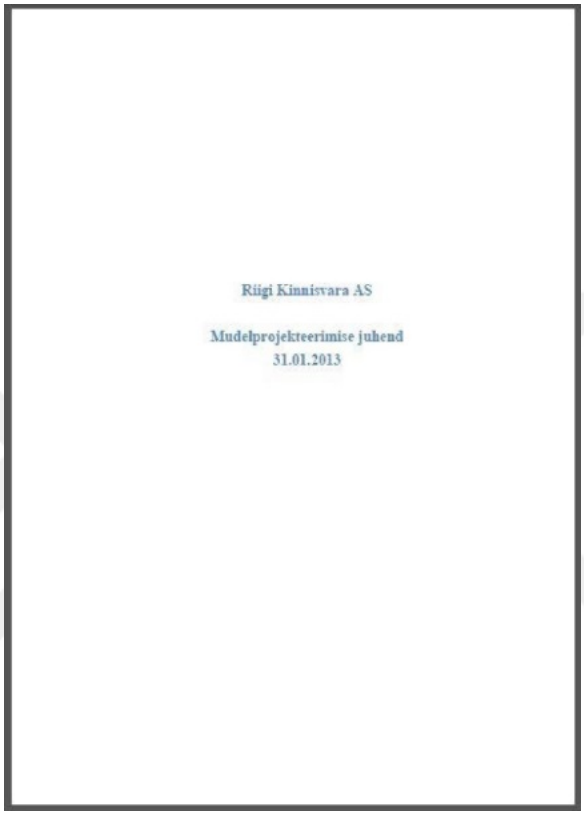


Figure 2.23. Estonian BIM Manual, (Tallinn, 2009).

2.9.5.6. Finland. Finland is one of the first and leading countries among the countries engaged in research on BIM. Therefore Finland has a long run in BIM-based processes since 2001. Senate Properties has carried on a number of pilot projects to develop and study the use of BIM and since the 1st October 2007 it has decided to adopt BIM and IFC standard in both the construction and the renovation of ordinary projects. Senate Properties can be count as the Finnish unincorporated state-owned enterprise, published its Requirements and guidelines, which have been updated and replaced by the National Common BIM Requirement's (COBIM) in 2012. Their aim is to define more precisely what is being modeled and how the modeling is done during all the phases of a construction project to support the parties involved (COBIM, 2012).

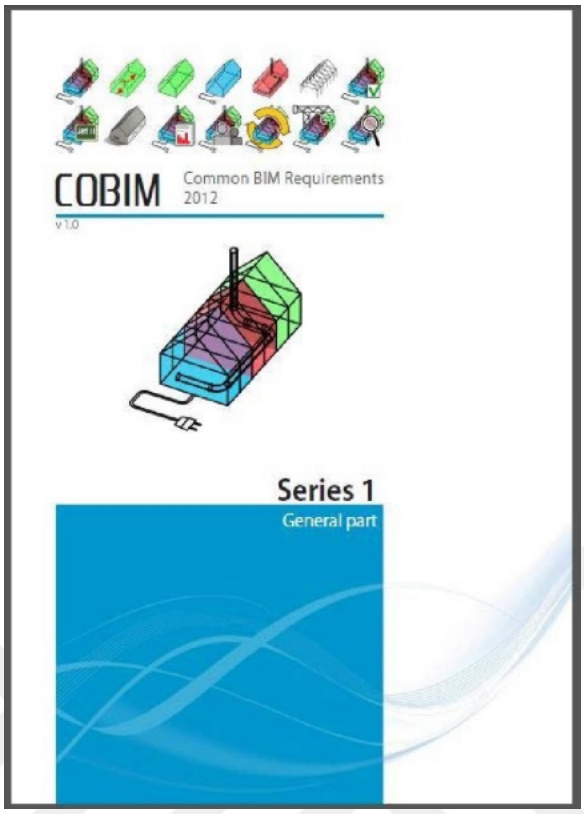


Figure 2.24. COBIM, Series 1 General Part, (Henttinen, 2012).

COBIM are available in internet both in English and in Finnish. COBIM series are divided in 13 Series. Also, another Series related to the "Use of Models in Building Supervision" will be published. COBIM series are as follows:

(i) General BIM Requirements
(ii) Modeling of the Starting Situation
(iii) Architectural Design
(iv) MEP Design
(v) Structural Design
(vi) Quality Assurance
(vii) Quantity Take-off
(viii) Use of Models for Visualization
(ix) Use of Models in MEP Analyses
(x) Energy Analysis
(xi) Management of a BIM Project

(xii) Use of Models in Facility Management

(xiii) Use of Models in Construction

The starting situation and the architectural design are mandatory as well as the monitoring of costs. Moreover, the architectural design is useful to study alternatives based on space models and to prepare the tender documents for the contracting stage. During the project planning stage, BIM supports the investment decision, the quantities extracted from the model are adopted to assist the production phase and BIM is also useful for energy simulations.

Recently the City of Helsinki (The Real Estate Department), HUS (The Hospital District of Helsinki and Uusimaa), Senate Properties and City of Vantaa (The Real Estate Department) have made a sort of BIM project guideline for Clients in co-operation (Figure 2.25). This document is based on COBIM guidelines but it is more detailed and practical and it is one of the few examples of an official definition of BIM implementation within Public Procurement. It defines in advance the aim of BIM and how to manage both new and renovation BIM-based projects (Tietomallihankkeen tilaajaohje 1.0).

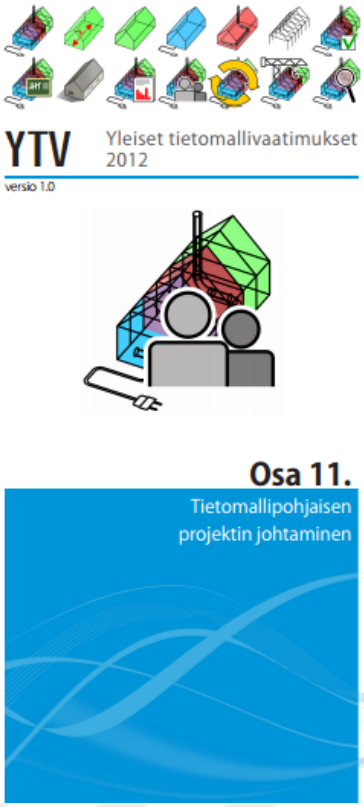
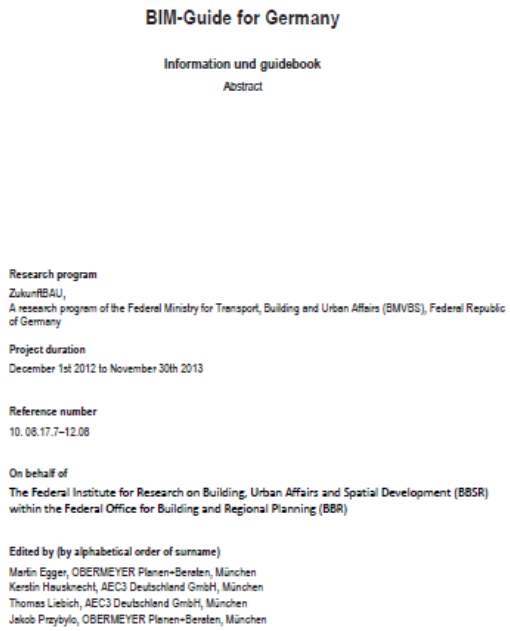


Figure 2.25. Tietomallihankkeen Tilaajaohje 1.0 (BIM Project Guideline for Clients), (Osa 11, 2012).

2.9.5.7. Germany. The implementation of BIM in Germany is still at early stages. Software vendors are already offering BIM solutions, some general contractors are adopting it and some pilot projects of public authorities are going on (Both, 2012). In 2010 the German Government organized a Research project called "BIM - Potentials and Barriers". The aim of this project was to investigate the BIM situation in Germany together with the benefits and barriers related to its development. Representatives from public authorities, practice, AEC associations and buildingSMART took part and prepared a questionnaire to analyze the current situation (Both, 2012).

A research program of the Federal Ministry for Transport, Building and Urban Affairs (BMVBS) published a brief information and guidebook of BIM implementation for German construction industry in 2013.



BIM-Guide for Germany

Information und guidebook

Abstract

Research program

ZukunftBAU,
A research program of the Federal Ministry for Transport, Building and Urban Affairs (BMVBS), Federal Republic of Germany

Project duration

December 1st 2012 to November 30th 2013

Reference number

10. 08.17.7–12.08

On behalf of

The Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) within the Federal Office for Building and Regional Planning (BBR)

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Figure 2.26. Information and Guidebook of BIM, (Egger, *et al.*, 2013).

2.9.5.8. Hong Kong. The Hong Kong's Housing Authority has also developed a set of BIM standards manual (Figure 2.27), library component design guide (Figure 2.28) and references for effective model creation, management and communication among BIM users (Build Smart, 2011).

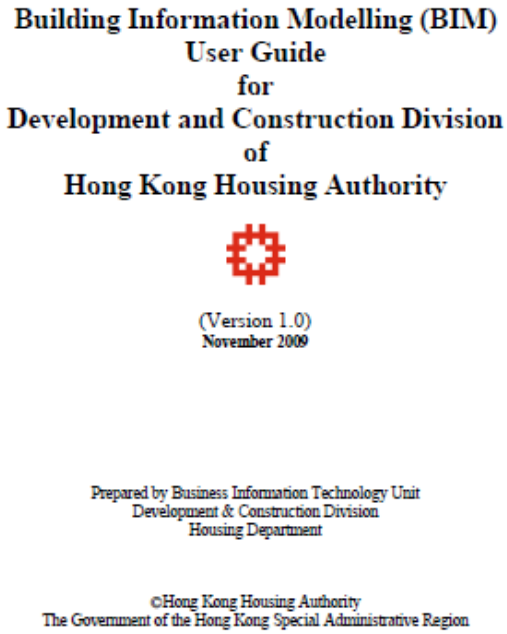


Figure 2.27. BIM Standards Manuel, (Hong Kong Housing Authority, 2009).

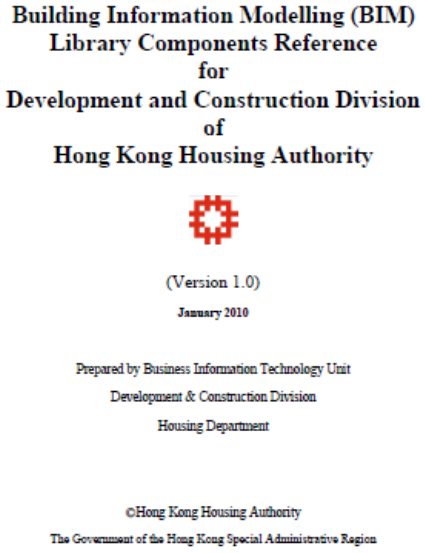


Figure 2.28. BIM Library Components Design Guide, (Hong Kong Housing Authority, 2010).

The Hong Kong's Housing Authority has started piloting BIM since 2006 and it

will require BIM for all new projects from 2016.

2.9.5.9. Iceland. BIM is not enforced in Iceland, however the Icelandic Construction Technology Platform established the project BIM-Iceland and in 2008 a four people group was created to work on the implementation of BIM into the Icelandic construction and design method (Guttormsson, 2011). Iceland construction industries adoption rate of BIM was 40%. The results of Kjartansdóttir's surveys indicated that BIM was not being used by contractors, which indicated a low level of BIM maturity (Kjartansdóttir, 2011). Iceland regulations were lacking, to fully support implementation of BIM in Iceland. Public organizations were striving for BIM, though they could require it.

2.9.5.10. India. BIM is not enforced in India, however BIM is also known as VDC: virtual design and construction. It has many qualified, trained and experienced BIM professionals who are implementing this technology in Indian construction projects and also assisting teams in the USA, Australia, UK, Middle East, Singapore and North Africa to design and deliver construction projects using BIM (Sawhney, 2014).

2.9.5.11. Ireland. Irish Government will not agree to a BIM mandate while the country is being funded by Europe for the BIM implementation cases. The engineers and academic experts explain the importance of a Government move towards the mandatory implementation of BIM to improve the value and the cost of public works (McAuley, *et al.*, 2012).

2.9.5.12. Italy. BIM is not mandatory in Italy and there is not a BIM policy. The current situation is more outdated in comparison to other European countries, although Italy is a member of buildingSMART. Italian Government funded a research project called InnovANCE (Daniotti, *et al.*, 2012), to create the first national database of technical, scientific and economic information useful to the AEC industry. Moreover Italian BIM development requires pushing the Government like InnovANCE project into adopting BIM tools, interoperability standards and simplifying the normative to

improve the current situation of the public works process.

2.9.5.13. Lithuania. Public body “Skaitmenine statyba” (“Digital Construction”) is an organization that joins associations of Lithuanian construction sector and coordinates the digitalization process of Lithuanian construction. Lithuania is moving towards adoption of BIM infrastructure by founding a public body “Skaitmenine statyba” (Digital Construction), which is managed by 13 associations.



Figure 2.29. Digital Construction in Lithuania, (Skaitmenine, 2013).

An annual international conference “Skaitmenine statyba Lietuvoje” (Digital Construction in Lithuania) has been held since 2012. The idea of rationalizing the construction sector by introducing digital construction came recently. Even though enthusiasts started talking about it a while ago inspired by experiences from abroad, it was officially included in the strategic development agenda only in the year 2014 (Berg, 2015).

As a main motor to drive the digitalization process in Lithuania, the public body “Digital Construction” was established (Figure 2.29).

2.9.5.14. Netherlands. The Dutch Ministry of the Interior and Kingdom Relations mandates the BIM adoption and in 2012 it published the English version 1.0 of the BIM Standard (Rijksgebouwendienst, 2012) (Figure 2.30). The first manual describes the specifications of BIM extracts and accompanying deliverable files but it does not show neither the instructions step-by-step for achieving a result in compliance with these specifications nor a BIM or CAD manual (Rijksgebouwendienst, 2012).



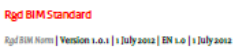


Figure 2.30. RGD BIM Standard, (Van Rillaer, *et al.*, 2012).

Also the new version 1.1 was published in February 2013 however the English translation of manual is not yet available.

2.9.5.15. New Zealand. New Zealand Government established an initiative called "Building and Construction Productivity Partnership" in 2012 to improve productivity in the building and construction industries by 20% by the year 2020 (Page, *et al.*, 2012) (Figure 2.3). There is one of the most fit tool to help achieve this goal is the BIM adoption.



Figure 2.31. Building Industry Performance Measures, (Page, *et al.*, 2012).

Masterspec is the leading specification system in New Zealand's construction industry, published the "New Zealand National BIM Survey 2012" (Figure 2.32) to describe the current BIM New Zealand's development.



Figure 2.32. New Zealand National BIM Survey, (Masterspec, 2012).

2.9.5.16. Nigeria. BIM has the potential to play a vital role in the Nigerian AEC sector. In addition to its potential clarity and transparency it may help promote standardization across the industry. BIM-based knowledge transfer framework from industrialized economies to urban construction projects in developing nations, generic BIM objects can benefit from rich building information within specification parameters in product libraries, and used for efficient, streamlined design and construction (Utiome, *et al.*, 2014). Medium and large firms were leading the adoption of BIM in the industry. Smaller firms were less advanced with respect to process and policy adherence (Kori, 2013).

2.9.5.17. Norway. Norwegian government agency, Statsbygg, adopts BIM for all its new building projects. In Statsbygg published a new version of BIM guidelines, the Statsbygg Building Information Modelling Manual Version 1.2 in 2011 (Figure 2.33).



Figure 2.33. Statsbygg BIM Manual 1.2.1, (Statsbygg).

The aim of SBM1.2 is to describe Statsbygg's requirements dealing with the adoption of BIM and IFC format. It contains both generic and discipline specific requirements which can be normative or only informative. It can be used by design teams, clients, facility managers and domain practitioners involved in the process. Moreover, SBM1.2 may also guide software application providers (Bolpagni, 2013).

2.9.5.18. Singapore. Singapore BIM guide has been published in May 2012 (Figure 2.34). Singapore BIM guide outlines the members' roles and the responsibilities in BIM projects at different stages. Singapore BIM guide helps the development of a BIM Execution Plan and explains the BIM Specifications and the BIM Modelling and Collaboration Procedures (BCA, 2012). Singapore BIM guide's new Version 2.0 was

published together with “BIM Particular Conditions Version 2.0”, which is available in the website in August 2013 (BCA, 2013).

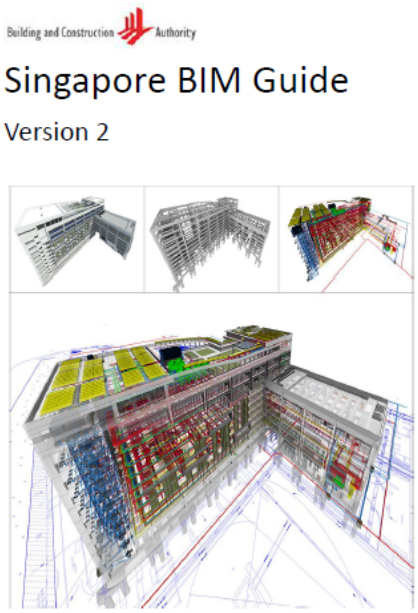


Figure 2.34. Singapore BIM Guide, (Building and Construction Authority, 2013).

The Building Construction Authority (BCA) of Singapore was one of the first government organizations developing model-based design. Singapore Building Construction Authority was working on a project for the automated code checking, called CORENET in the 1990s. Even if that project has not been further developed, the BCA has a roadmap to push the construction industry in the BIM adoption by 2015 (Khemlani, 2012a).

BCA has started to accept Architectural, Structural and MEP BIM e-Submission since 2011. BCA’s website it is possible to download templates and guidelines compatible with the main BIM software such as Revit, ArchiCAD, Tekla Structure and Bentley. BCA is developing a library of buildings and design objects. BCA also encourages BIM courses at universities and BCA organizes BIM workshops and seminars (Khemlani, 2012a).

2.9.5.19. South Korea. South Korea's Public Procurement Service made the adoption of BIM mandatory for all projects over S$50 million and for all public sector projects by 2016. (Build Smart, 2011). Public Procurement Service of South Korea published an "Architectural BIM Guide" in 2010 (Figure 2.35) is available only in Korean. Public Procurement Service aims to reduce the burdens in the industrial market resulting from the new technology adaptation. BIM is adopted on each design stage and for building energy efficiency, energy simulation and basic quantity take-off.

National Architectural BIM Guide published in 2010 by Ministry of Land, Transport and Maritime Affairs. National Architectural BIM Guide's main aim is to invigorate the systematic implementation of BIM in the inner public industrial market.



Figure 2.35. South Korea's Architectural BIM Guide, (Public Procurement Service, 2010).

2.9.5.20. Spain. Spanish government published uBIM - BIM User Guide in Spanish in 2014. After the creation of the BIM User Guide, Spanish Government predicted a road map for to maintain BIM development and implementation consistent state and

placed in the associated targets. The government believes that this roadmap will give the industry and the stakeholders involved in the construction and building cycle the time they need to adopt BIM. The roadmap explained at the 2015 BIM European Submit Barcelona with below highlights:

(i) Target 2015-2016: agree a BIM mandate in Catalonia
(ii) Target 2017: adoption of IFC standards, guidelines, classifications and delivery processes for the digital model designed for every stage of the construction project, its implementation and subsequent maintenance and integration into the city. Map out common protocols for creating and specifying information shared between stakeholders to deliver full interoperability between the parties.
(iii) Targets 2018
  - Public facilities and infrastructure with a budget over £2 million should be produced using BIM in the design to construction stages
  - Restrict this target to new build projects
(iv) Targets 2020
  - All public facilities and infrastructure should be produced using BIM in all stages: design, construction and operation (maintenance and facility management)
  - Restrict this target to all new build and refurbishment projects.

The Government of Catalonia and Barcelona City Council have decided to set up a BIM Working Group to help implement the culture, values, work methods and digital and electronic technologies needed to train industry, government, research centers, professional groups and academia.

2.9.5.21. Sweden. BIM is not mandatory in Sweden. However, Swedish public companies are collaborating to establish demands and standards regarding BIM adoption in their projects (Lindblad, 2013). Swedish non-profit organization OpenBIM published a BIM guideline which is available only in Swedish, called "BIM - Standardiseringsbehov" (Figure 2.36) to promote the BIM adoption in June 2013.



Figure 2.36. BIM - Standardiseringsbehov, (Ekholm, *et al.*, 2013).

Royal Institute of Technology (KTH) and the Stockholm Country Council have demanded the adoption of BIM in their projects (Lindblad, 2013). Swedish Transport Administration, Trafikverket, is developing the "Stockholm bypass" implementing BIM.

2.9.5.22. Taiwan. BIM is not obligatory in Taiwan Government procurements in Taiwan are still paper-based. e-Tendering that can be count as a good development of BIM has been established but the electronic procurement is not completely automatic. For these reasons the status of BIM adoption in Taiwan is still unknown for governments and public. (Liu, *et al.*, 2011). National Science Council constituted an integrated team to study a development strategy for adopting BIM in the AEC industry in 2010. Taipei Mass Rapid Transit Construction Agency publicized the "Requirements of Modeling the BIM" and chose two projects to test its effectiveness in 2011 (Liu, *et al.*, 2011). Liu and Hsieh (2011) propose a prototype of BIM-based government procurement system,

linking BIM to the already existing e-Tendering systems to deliver bidding information and other documentation.

2.9.5.23. United Arab Emirates (U.A.E.). Dubai Municipality became the first public authority in the Middle East to mandate the use of building information modelling (BIM) for most large-scale projects in the Emirates. Dubai's decision follows the mandating of BIM on public sector projects in the UK, where level 2 BIM will be required by 2016. The School of Architecture, Art, and Design at AUD hosted the Emirates Building Information Modeling (BIM) User Group first conference for 2014 on January 27th. The main focus was the Dubai Municipality (DM) BIM mandate which went into effect January 1st 2014. Over 70 members comprised mostly of practicing architects, engineers, and construction professionals along with BIM solution vendors participated and drove the discussion around the BIM mandate announcement, requirements, clarifications needed, and the way forward.

2.9.5.24. United Kingdom. The UK Government will aim to take a "leading role" in the development of international BIM standards, enabling UK firms to work on BIM projects globally with minimum compatibility issues. UK Government making a lot of work within these ideals has created protocols by identifying strategies for the sector. Also, financial issues in UK and European countries have pushed the UK Government to explore new ways of controlling costs. Cabinet Office published its Government Construction Strategy in May 2011 (Figure 2.37). These strategy document point that "Government will require fully collaborative 3D BIM with all project and asset information, documentation and data being electronic as a minimum by 2016" (Cabinet Office, 2012).



Figure 2.37. Government Construction Strategy- (Cabinet Office, 2011).

UK Government wants to strengthen the public sector's client capability in BIM implementation so that all central government departments' projects will be adopting at least Level 2 BIM by 2016 (Cabinet Office, 2012). Moreover, the Cabinet Office will develop standards enabling all members to work collaboratively because in its opinion the "lack of compatible systems, standards and protocols, and the differing requirements of the clients and lead designers, have inhibited widespread adoption of a technology which has the capacity to ensure that all team members are working from the same data" (Cabinet Office, 2011).

The government will also work with the European Union on incorporating BIM standards into the EU's forthcoming sustainable construction strategy and procurement directive. AEC (UK) BIM Standard Committee released several BIM standards (Figure 2.38) for BIM software, to help the AEC UK firms in the transition from CAD to BIM (Khemlani, 2012a).



Figure 2.38. AEC (UK) BIM Protocol, (AEC, 2012).

The aim of the UK strategy is to promote the public sector as a better client, "more in-formed and better coordinated" and to modernize the current business models and the industry practice (Cabinet Office, 2011). A BIM Task Group was created to support the work of the Government Construction Strategy and it has progressed rapidly in developing practice and in implementing the policy, so that the UK is in a leadership position amongst national governments. The Government Soft Landings (GSL) is part of the BIM Task Group and its aim is to ensure that new buildings will be well handed-over and easy to operate (Saxon, 2013).

Industrial strategy: government and industry in partnership published in 2012 (Figure 2.39). The report builds on the Cabinet Office's construction strategy, which set out a timetable for rolling-out BIM across all public sector construction projects by 2016.

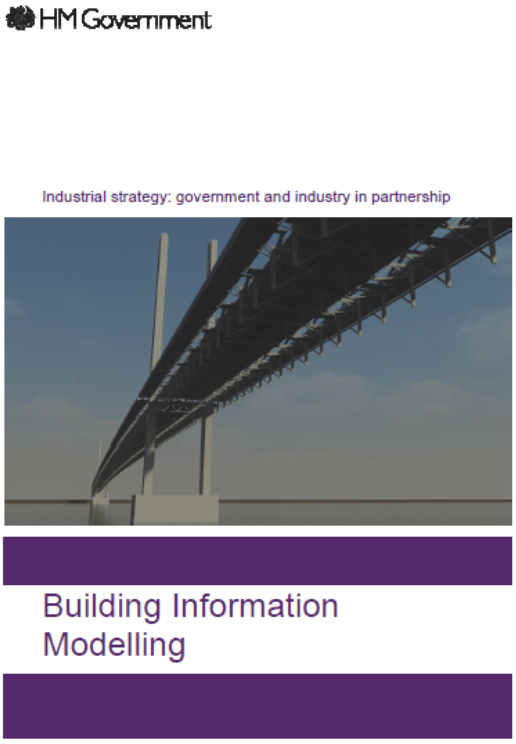


Figure 2.39. Industrial Strategy: Government and Industry in Partnership, (HM Government, 2012).

The 12-point BIM action plan, published by the Department for Business, Innovation and Skills (BIS), includes proposals to drive growth in the export of UK BIM expertise, the accelerated roll-out of BIM-compatible government tenders and a pilot program to analyses BIM data from across the public sector. Under the plan, BIS will work with UK Trade and Investment to capitalize on the "limited window of opportunity" available to export BIM expertise to countries that are less advanced in terms of BIM adoption.

BIS will also co-ordinate with other government departments to ensure BIM data feeds into the development of "smart cities", which will collate data across all city functions. Countries including the US and Sweden are widely considered to be ahead of the UK in terms of BIM expertise, but BIS insisted the UK has come a "considerable distance" in developing its BIM capabilities. The report proposes setting up a

government-backed technology hub to incubate and stimulate BIM-related technology start-up firms. BIS will soon launch its "Digital Built Britain" initiative to further encourage BIM adoption across the industry.

Nowadays the USA dominates the global market, the UK is growing faster and it would like to export its service abroad and to lead the EU construction policy development (Saxon, 2013).

2.9.5.25. USA. General Service Administration (GSA), through its Public Buildings Service Office of Chief Architect, established a National 3D-4D-BIM Program in 2003 (Khemlani, 2012a). The National 3D-4D-BIM Program promotes value-added digital visualization, simulation and optimization technologies to develop quality and efficiency during the lifecycles of projects. Indeed, 3D, 4D and BIM computer technologies give the possibility to meet customer, design, construction and also program requirements in a more effective way. Since 2007 GSA has required spatial program BIMs for all major projects as a minimum requirement for the submission for final concept approvals. Moreover, all GSA projects are encouraged to utilize 3D, 4D and BIM technologies. GSA published Series of Guidelines related to 3D-4D-BIM Overview (Figure 2.4), Spatial Program Validation, 3D Laser Scanning, 4D Phasing, Energy Performance and Operations, Circulation and Security Validation, Building Elements and Facility Management.



Figure 2.40. GSA BIM Guide, Series 1 Overview, (GSA, 2006).

In addition to the GSA guidelines, there are other USA BIM Guides published by States and Institutions such as Universities. Indeed, the US Army Corps of Engineers in 2011 has published a "Building Information Modeling (BIM) Roadmap. Supplement

2 - BIM Implementation Plan for Military Construction Projects, Bentley Platform" (Figure 2.41) to replace the previous ERDC TR-06-10, "Building Information Modeling (BIM): A Roadmap for Implementation To Support MILCON Transformation and Civil Works Projects within the U.S. Army Corps of Engineers" published in 2006. This guideline is focused on the software Bentley workflow and BIM project management practices (US Army Corps of Engineers, 2011).

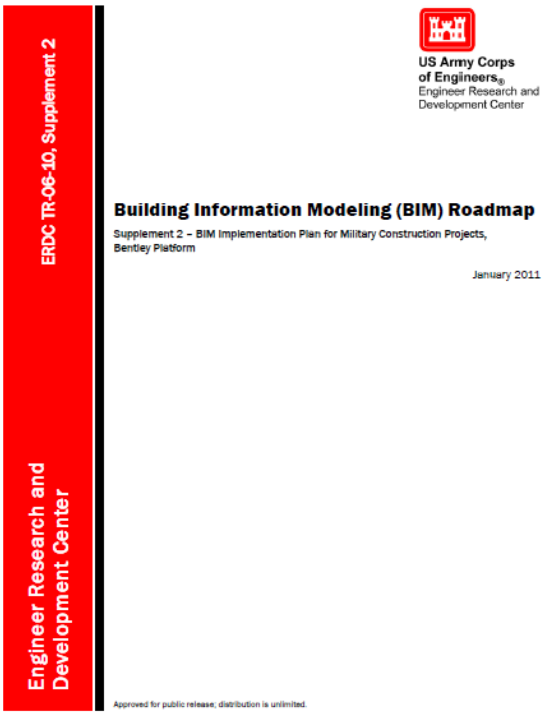


Figure 2.41. Building Information Modeling (BIM) Roadmap, (US Army Corps of Engineers, 2011).

In 2009 the Associated General Contractors of America published the second edition of "the Contractor's Guide to BIM", which analyses the implication of BIM for contractors, based on experience provided by contractors that have already adopted BIM (Eastman, *et al.*, 2011). Also the US Coast Guard has embraced the utilization of BIM (Succar, 2009) and in 2007 the National Institute of Building Science has published the "National Building Information Modelling Standards. Version 1" to help all participants in reaching more reliable out-comes from commercial agreements (Figure 2.42). Later Version 2 was published in 2008 and it is a consensus-based

standard which includes reference standards, information exchange standards and best practice guidelines to support users in their implementation of open BIM standards-based deliverables. Finally the ballot submission period for Version 3 ended in August 2013.

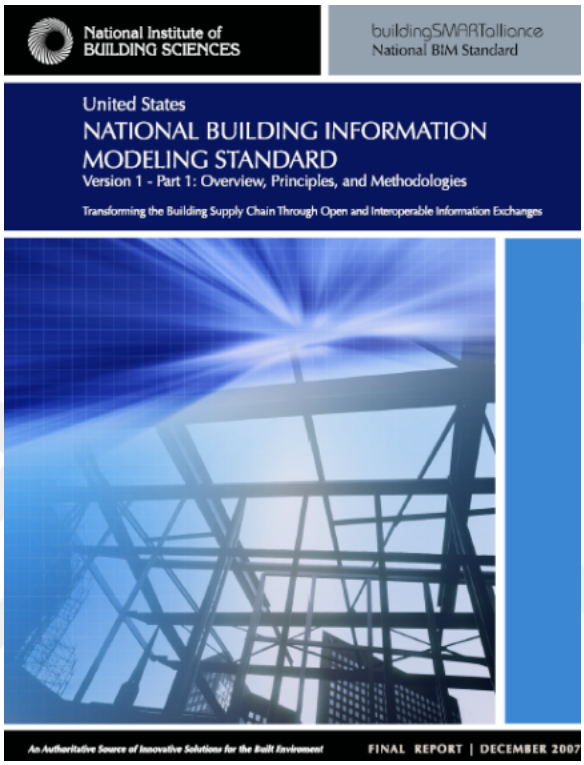


Figure 2.42. United States National Building Information Modeling Standard, (NBIMS, 2007).

Another looming national crisis is the inability to provide enough qualified engineers. Some estimate the United States will be short a million engineers by the year 2020. In 2007, the United States was no longer the world's largest consumer, a condition that will force United States industry to be more competitive in attracting talented professionals. The United States construction industry must take immediate action to become more competitive

3. RESEARCH METHODOLOGY

This thesis is part of a comprehensive study of BIM that is seeking to show that BIM helps to visualize a project before the construction works start, to figure out potential problems that may arise during the construction phase. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and to improve the process of delivering the facility (Associated General Contractors of America, 2005). The main aim of this thesis is to help Turkish Construction Industry increase the usage of BIM in the each phase of construction by providing a solution for how this technology can be applied in the production environment and into the process of work preparations.

In a research, it is important to review other researchers' experience, methods, design, findings and opinions related to similar problems. Their views based on the results of these relevant studies are organized and presented in a systematic way in the related section of this study.

The nature of research questions dictates the type of data that needs to be collected. Data types are separated into two groups; as quantitative and as qualitative. Qualitative & Quantitative methods are two standard ways to carry out scientific researches. Generally, qualitative research has been utilized in the human and social science disciplines (Denzin, *et al.*, 1998). Denzin and Lincoln (1998), indicates that qualitative research is a multi-method in focus, containing an interpretive, naturalistic approach to its subject matter. It attempts to study things in their natural settings and interpret the meanings humans bring to them. Qualitative studies also ensure researchers with a rich description and help them gain a complete understanding of the socially structured nature of reality by building a near connection between researchers and what they studied, getting the individual's point of view, and examining the constraints of everyday life (Denzin, *et al.*, 1998).

Geddes (1968) promoted survey, analysis and plan as a method for a research project. The questionnaire consist of questions about basic information about firms, general BIM information's and CFS's questions. The Statistical Package for Social Science (SPSS) software was applied in the analysis of the data collected. The results are expressed in mean value and frequency ranking. Significance of differences between the public and private sector is carried out by analysis of variance (ANOVA) technique. A multivariate statistical technique known as factor analysis was chosen as the method of grouping the components into a few, conceptually meaningful, relatively independent principal factors.

Since the other research method in this work is case study, it is explained in detail in this section of the thesis. First, the literature was reviewed in order to find examples of definition of case studies. Then comparison between qualitative and quantitative research methods were made, advantages and disadvantages of case studies are presented. Certain requirements when conducting a case study are also listed and explained. Finally, steps of designing and implementing of a case study are mentioned. Interviews within the case studies were another important research tool that was used to gain a better understanding of Building Information Modeling implementation in Turkey. An efficient interview easily leads to targeted information and more. List of interviews made for this research is also presented in the following sections.

3.1. Research Methods

The basic and applied research can be quantitative or qualitative or even both. Comparison of research methods is shown in the Table 3.1. Quantitative research is based on the measurement of quantity or amount. Here a process is expressed or described in terms of one or more quantities. The result of this research is essentially a number or a set of numbers. Some of the characteristics of qualitative research/method are:

- It is numerical, non-descriptive, applies statistics or mathematics and uses numbers.

- It is an iterative process whereby evidence is evaluated.
- The results are often presented in tables and graphs.
- It is conclusive.
- It investigates the what, where and when of decision making.

Statistics is the most widely used branch of mathematics in quantitative research. It finds applications not only in physical sciences but also in economics, social sciences and biology. Quantitative research using statistical methods often begins with the collection of data based on a theory or hypothesis or experiment followed by the application of descriptive or inferential statistical methods.

Qualitative research is concerned with qualitative phenomenon involving quality. Some of the characteristics of qualitative research/method are:

- It is non-numerical, descriptive, applies reasoning and uses words.
- Its aim is to get the meaning, feeling and describe the situation.
- Qualitative data cannot be graphed.
- It is exploratory.
- It investigates the why and how of decision making.

The detection of a particular compound is a qualitative analysis. This can be done by carrying out physical or chemical tests. Determination of exact amount of a particular compound present in a volume is essentially quantitative analysis. This can be done by volumetric, gravimetric and colorimetric methods or instrumental methods. Experimental and simulation studies are generally quantitative research. In fact, qualitative methods can be used to understand the meaning of the numbers obtained by quantitative methods.

Table 3.1. Comparison of Research Methods (Fellows, *et al.*, 1997).

	Qualitative Research	Quantitative Research
Objective / purpose	To gain an understanding of underlying reasons and motivations	To quantify data and generalize results from a sample to the population of interest
	To provide insights into the setting of a problem, Generating Ideas and/or	To measure the incidence of various views and opinions in a chosen sample
	hypotheses for later Quantitative Research To uncover prevalent trends in thought and opinion	Sometimes followed by Qualitative Research which is used to explore some findings further
Sample	Usually a small number of non-representative cases. Respondents selected to fulfill a given quota.	Usually a large number of cases representing the population of interest. Randomly selected respondents.
Data collection	Unstructured or semi-structured techniques e.g. individual depth interviews or group discussions.	Structured techniques such as Online Questionnaires, on-street or telephone interviews.
Data analysis	Non-statistical.	Statistical Data is usually in the form of tabulations (tabs). Findings are conclusive and usually descriptive in nature.
Outcome	Exploratory and/or investigative. Findings are not conclusive and cannot be used to make generalizations about the population of interest. Develop an initial understanding and sound base for further decision making.	Used to recommend a final Course of Action.

There are five important research methods adopted in construction management research, namely action research, ethnographic, survey, case study and experimental (Fellows, *et al.*, 1997). Action research is derived to suggest and test solutions for particular problems. In the ethnographic method the researcher is the part of the study group that explores and observes subjective behavior, circumstances etc. to form a judgment in what, how, and why, models of behavior occur. Case study allows thorough examination, whilst using experimental method is appropriate in case of the variables involved are known or at least hypothesized with some confidence (Fellows, *et al.*, 1997). Surveys run based on statistical sampling by using questionnaires or interviews as a tool.

3.2. Questionnaire Survey

The questionnaire is one of the most frequently used methods of data collection in exploration and evaluation research (Fellows, *et al.*, 1997; Clarke, 1999). The questionnaire method has been used by numerous journal papers as a research tool to investigate their research subjects or to conduct a comparative study (Li, 2003).

As advocated by Fellow and Liu (1997), what determine the research method are consideration of the scope and how much deep study is needed. The questionnaire is the broadest study, while case study is the deepest study, and interview is between them in the context of breadth and depth.

This study exactly aims to investigate how various success factors affect observed success in the procurement of capital projects. CSFs in the procurement of capital projects are recent incidents and performing assessment of real-world situation is the best way of making judgment into the organization's success (Amponsah, 2010). It has several advantages over other methods (Li, 2003):

- It is capable of producing large quantities of highly structural, standardized data.
- It can quickly provide access to a lot of people.
- It can be made anonymous which results in a more honest response, especially in sensitive subjects.
- It allows respondents to take time to answer the questions, where respondents can check records before finally answering.
- It addresses a standard set of questions to a larger sample of people than interviews can, while the results obtained may be fairly reliable.
- It can be used to provide the main research data, and can be a useful source of supplementary data.
- A questionnaire survey has other advantages of validity (avoidance of self-presentation and interviewer bias) and efficiency (low labor, cost and geographical dispersion).
- It reduces errors caused by the personal characteristics of interviewers and from the variability in their skills.

The quantitative study, which allows the respondents to describe their opinions in numerical data form, analyzes the views of experts from the private sector, semi-government or government sectors depending on their extensive experiences in the delivery of capital projects through BIM approach. In this research, this method helps to categorize the success factors according to their relative importance and mean values.

The participants were interviewed to find out their opinion at first hand on the critical success factors that directly affect the successful delivery of the BIM projects. Posted interviews were conducted to provide overall consideration on the CSFs for capital project in order to give a thorough description of individual experiences (Amponsah, 2010).

Fundamentally, due to two main reasons instead of random sampling convenient sampling method was thought to be more appropriate to use in this research as the sampling technique. The first reason for choosing this way is that there is no comprehensive, or any standard, database of organizations in Turkey that are using BIM. Diekhoff (1992), Fellows and Liu (1997) have stated that in order to use random sampling method there must be large amount of organizations involved and the population is known.

In this research questionnaire survey was mailed to construction companies in top 500 of Turkey based on their annual revenues (only construction related companies) and Turkish Contractors Association members. Among the respondents, questionnaire aims to assess the level of BIM awareness of Turkish construction industry.

The factors identified through the literature review which shown in Appendix C were distilled initially into eighty-seven factors and later into sixteen success factors. Factor analysis was used to group success factors into five principal factors.

3.2.1. Survey Objectives

A questionnaire survey is adopted as the primary data collection instrument. Survey research seeks factual information, including what the respondents know about the subject under investigation, based on his/her knowledge, what the respondents did in the past and what they are doing now, and also their viewpoint on factors involved in the subject involved. Using the survey method, the respondents were asked knowledge of BIM and provide information on it. And gathering more information about BIM usage capacity we select firms to investigate case study from respondents which use

BIM. There is one main objective of the survey:

To investigate the critical success factors for BIM in Turkey from the perspectives of both the public and private sectors.

3.2.2. Population and Sample

In order to obtain satisfying results and be able to make generalizations based on the results, researchers carefully need to select sample populations (Ekmekci, 1997). The construction industry have identified as our target audience for our survey. From the identified groups namely Chairman, Board Members, General Managers, Managers, Project Coordinators, Project Managers, Chiefs, Architect/Engineers, Facility Managers and Technicians participated in the survey process for the study nation-wide. A brief description of the participants who participated in the research is as follows (Amponsah, 2010):

The owner, public or private is the promoting party for whose wills the project is designed and built. Public owners range from agencies of the government down through state, county, and municipality entities to a multiplicity of local boards, commissions, and authorities.

A manager is the person or group of persons bearing the responsibility of carrying out the defined project objectives. Key project management responsibilities embrace creating clear and reasonable project objectives, implementing the project requirements, and managing the triple constraint for projects, which is cost, time, and scope. Mostly, the manager is the owner's representative and expected to determine and implement the exact requirements of the owner, based on knowledge of the firm they are representing. The key factors for a manager are the ability to adapt to the different internal procedures of the contracting party, and to form close links with the nominated representatives. These are vital in making certain that the key issues of cost, time, quality and above all, client satisfaction, can be realized.

An Engineer/Architect approves project drawings and reports, oversees orders and delivery of equipment, takes care of any changes a client wants to make, resolves problems and ensures that work is completed on time and within budget.

Especially online questionnaire was sent to members of TCA organizations. Respondents answered online questionnaire was selected from specific people who are knowledgeable about BIM. Nevertheless, each company sent questionnaire to be informed of the "What is BIM?" fumbled with the phone.

3.2.3. Questionnaire Design

3.2.3.1. Questionnaire Structure. The questionnaire survey covers critical factors for the success of BIM: The questionnaire as shown in Appendix A is divided into two parts:

- Part One: Deals with general information about the respondents, including personal designation, industrial experience, their organization scale in terms of annual turnover and employee numbers, and participants were asked to provide their perceptions of critical success factors of BIM, based on their general experiences.
- Part Two: This deals with BIM project specific questions. In this part, questions include BIM software's, level of implementation stage, implementation information and numerical data of BIM projects.

3.2.3.2. Ranking Scales. The rating systems for the criticality of each variable in the questionnaire the Likert scale, which has an interval between 1 and 5, is adopted (Table 3.2). Recently, this kind of scale has been used for several construction management studies.

Table 3.2. Rating Systems for Criticality of Variables.

Rating Score	Criticality of Variables
1	Not Significant
2	Fairly Significant
3	Significant
4	Very Significant
5	Extremely Significant

3.2.4. Statistical Methods

Various types of structural analysis were undertaken on the questionnaire data collected, including mean ranking, Analysis of various (ANOVA), factor analysis, etc., using the Statistic Package for Social Science (SPSS) window version 15.0. This statistical analysis is described as followed:

3.2.4.1. Mean Ranking. Mean ranking is used to determine the significance of each factor rated by the respondents. Similar practice had been used by Wang, Qiao, Tiong, & Chan, (2001) before when realizing assessment from survey results. The mean can be calculated as Equation 3.1:

$$\text{Mean} = \frac{\sum_{i=1}^{5} iN_i}{\sum_{i=1}^{5} N_i} \tag{3.1}$$

Where N_5 is the number of respondents who answered “extremely significant”, N_4 is the number of respondents who answered “very significant”, N_3 is the number of respondents who answered ”significant”, N_2 is the number of respondents who answered “fairly significant”, and N_1 is the number of respondents who answered “not significant”.

3.2.4.2. One-way ANOVA. One way analysis of variance is needed when only one variable is used to classify cases into the different groups. In the following chapter, each variable is discussed by three different groups, the public/private client and the contractor. Among the groups mean square is based on how much the group means vary among themselves. If the null hypothesis is true, the two numbers (group means) should be close to each other.

F statistic is a ratio used to test the null hypothesis, where the between-groups mean square is divided by the within-groups mean square. Observed significance level is retrieved by comparing the calculated F value to the F distribution. The significance level is based on both the actual F value and on the degree of freedom for the two mean squares. If the observed significance level is small, i.e. less than 0.01 or 0.05, the null hypothesis should be rejected. The 0.01 and 0.05 are equivalent to 1% and 5% significance level respectively.

3.2.4.3. The reliability coefficient. One of the most commonly used reliability coefficients is Cronbach's alpha Alpha (a) is based on the "internal consistency" of a test (Cronbach, 1951). That is, it is based on the average correlation of items within a test. If a test were perfectly reliable, this correlation would be 1.00. If the test were totally unreliable, the correlation would be zero (Graham, *et al.*, 1984). What is regarded as a satisfactory level of reliability is dependent on how a measure is being used. According to Nunnally (1978), in the early stages of research on predictor tests, or hypothesized measures of a construct, one saves time and energy by working with instruments that have only modest reliability, for which purpose reliabilities of 0.70 or higher will suffice.

In SPSS, the Cronbach's a can be computed using the following formula:

$$\alpha = \frac{k\overline{\text{cov}}/\overline{\text{var}}}{1 + (k-1)\overline{\text{cov}}/\overline{\text{var}}} \tag{3.2}$$

where k is the number of items in the scale, coif is the average covariance between items, and var is the average variance of the items. If the items are standardized to

have the same variance, the formula can be simplified to:

$$\alpha = \frac{k\overline{r}}{1 + (k-1)\overline{r}} \tag{3.3}$$

where r is the average correlation between items (Norusis, 1992). Cronbach's α depends on both the length of the test (k in the formula) and the correlation of the items on the test.

3.2.4.4. Factor analysis. Factor analysis is a statistical technique used to identify a relatively small number of factors that can be used to represent relationships among sets of many inter-related variables (Norusis, 1992). Pictorially, this purpose of factor analysis is represented by Figure 3.1, in which the mass of several overlapping circles of various shades is reconstituted into two relatively non-overlapping circles with different shading patterns.

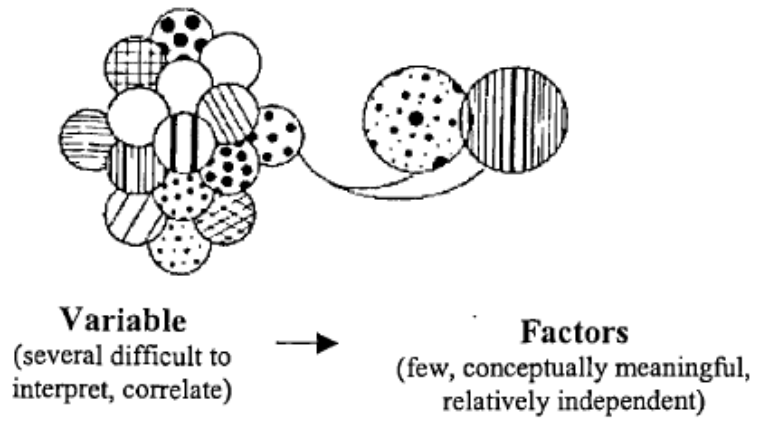


Figure 3.1. General Purpose of Factor Analysis (Kleinbaum, *et al.*, 2008).

The mathematical model for factor analysis appears somewhat similar to a multiple regression equation. Each variable is expressed as a linear combination of factors which are not actually observed. In general, the model for the th standardized variable is written as:

$$Xi = A,1F + A12F2 + AikFk + Ui \tag{3.4}$$

where the $F's$ are the common factors, the U unique factor, and the $A's$ are the coefficients used to combine the k factors. The unique factors are assumed to be uncorrelated with each other and with the common factors. The general expression for the estimate of the factor, F is

$$F_j = \sum_{i=1}^{p} W_{ji}X_i = W_{j1}X_1 + W_{j2}X_2 + ... + W_{jp}X_p \tag{3.5}$$

where $W's$ are known as factor score coefficients, and p is the number of variables. Factor analysis usually proceeds in four steps.

(i) In the first step, the correlation matrix for all variables is computed. Variables that do not appear to be related to other variables can be identified from the matrix and associated statistics.

(ii) In the second step, factor extraction - the number of factors necessary to represent the data and the method for calculating them - must be determined.

(iii) The third step, rotation, focuses on transforming the factors to make them more interpretable.

(iv) At the fourth step, scores for each factor can be computed for each case. These scores can then be used in a variety of other analysis.

Several important measures, such as Bartlett's test of sphericity, KMO, MSA and procedures (factor extraction, loading) in the factor analysis are introduced in the following sections.

3.2.4.5. Bartlett's test of sphericity. Bartlett's test of sphericity can be used to test the hypothesis that the correlation matrix is an identity matrix; that is, all diagonal terms are 1 and all off-diagonal terms are 0. If the value of the test statistic for sphericity is large and the associated significant level is small, it appears unlikely that the population correlation matrix is an identity.

3.2.4.6. Kaiser-meyer-olkin measure. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is an index for comparing the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficients. It is computed as;

$$KMO| = \frac{\sum \sum_{i \neq j} r_{ij}^2}{\sum \sum_{i \neq j} r_{ij}^2 + \sum \sum_{i \neq j} \alpha_{ij}^2} \tag{3.6}$$

where r_{ij} is the simple correlation coefficient between variables i and j, and a_{ij} is the partial correlation coefficient between variables i and j. If the sum of the squared partial correlation coefficients between all pairs of variables is small when compared to the sum of the squared correlation coefficients, the KMO measure is close to 1. Small values for the KMO measure indicate that a factor analysis of the variables may not be a good idea, since correlations between pairs of variables cannot be explained by the other variables. Kaiser characterized measures in the 0.90's as marvelous, in the 0.80's as meritorious, in the 0.70's as middling, in the 0.60's as mediocre, in the 0.50's as miserable, and below 0.50 as unacceptable.

3.2.4.7. Measures of sampling adequacy (MSA). A measure of sampling adequacy can be computed for each individual variable in a similar manner. Instead of including all pairs of variables in the summations, only coefficients involving that variable are included. For the ith variable, the measure of sampling adequacy is

$$MSA_i = \frac{\sum_{j \neq i} r_{ij}^2}{\sum_{j \neq i} r_{ij}^2 + \sum_{j \neq i} \alpha_{ij}^2} \tag{3.7}$$

Only reasonably large values are needed for a good factor analysis. Thus, variables with small values should be eliminated for the measure of sampling adequacy.

3.2.4.8. Factor extraction. The goal of factor extraction is to determine the factors. In principal component analysis, linear combinations of the observed variables are formed. The first principal component is the combination that accounts for the largest amount

of variance in the sample. The second principal component accounts for the next largest amount of variance and is uncorrelated with the first. Successive components explain progressively smaller portions of the total sample variance, and all are uncorrelated with each other.

3.2.4.9. Rotation phase. Although the factor matrix obtained in the extraction phase indicates the relationship between the factors and the individual variables, it is usually difficult to identify meaningful factors based on this matrix. Most factors are correlated with many variables. The purpose of rotation is to achieve a simple structure. The most commonly used method for orthogonal rotation is the varimax method, which attempts to minimize the number of variables that have high loadings on a factor. Rotation does not affect the goodness of fit of a factor solution. This is, although the factor matrix changes, the communalities and the percentage of total variance explained do not change.

3.2.4.10. Interpreting the factors. A convenient strategy is to sort the factor pattern matrix so that variables with high loadings on the same factor appear together. Having deducted the loadings less than 0.5, the factor represented the significant associating variables.

3.2.5. Administration and Content of the Questionnaires

In beginning of the survey, all respondents have replied general questions about them and their company as below;

- Age
- Company Age
- Business Area of Their Company
- Their Experience in The Construction Sector as Age
- Turnover of Their Company (Total)
- The Number of Total Employee of Their Company

- Company Position
- CFS's of BIM Implementation
- BIM Usage (Yes or No)

CFS's of BIM Afterwards, critical success factors questions in the survey come at the third page. There are 16 critical success factors mentioned in the survey and all respondents are answered according to the importance of the factors from 1 to 5 scales.

- 1: very low
- 2: low
- 3: moderate
- 4: high
- 5: very high

The above question is about general information on the respondents and their company. If the respondents reply the question on BIM Usage as "Yes", then the respondents reply the question on following questions;

- Which BIM Software Do They Use
- BIM Implementation Level

If the firms implement any BIM project they shall answer the following questions;

- Stage of The Project Life-Cycle
- Type of The Project
- Type of Client
- Size of The Project
- Duration of The Project
- Area of The Building
- Cost of Using BIM
- Cost Saving Based on Using BIM

- Time Saving Based on Using BIM

3.3. Cases

There are different views about the definition of case study in the literature. A case study provides detail, completeness, richness and depth for the unit of study. Business Dictionary (2014) defines a case study as follows:

"Case study is a documented study of a specific real-life situation or imagined scenario, used as a training tool in business schools and firms. Students or Trainees are required to analyze the prescribed cases and present their interpretations or solutions, supported by the line of reasoning employed and assumptions made".

Another definition made by Schramm (1971):

"The essence of a case study, the central tendency among all types of case, is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented and with what result".

According to this definition, decisions are the major focus of case studies. Alternatively, some academicians do not consider the case study a formal research method but consider it as the exploratory phase of a different type of research strategy. There are many examples of common misunderstandings about case study methodology in the literature. One example is the meaning of case study in Dictionary of Sociology (Abercrombie, *et al.*, 1984):

"The detailed examination of a single example of a class of phenomena, a case study cannot provide reliable information about the broader class, but it may be useful in the preliminary stages of an investigation since it provides hypotheses which may be tested systematically with a larger number of cases".

Flyvbjerg (2006) finds above mentioned definition indicative of much conventional

wisdom about case study research and so oversimplified as to be grossly misleading. According to him, this definition promotes the mistaken view that the case study is hardly a strategy but is best seen as subordinate to investigations of larger samples. The definition also blocks the complementarity that exists between the two types of methodology, case studies and statistical methods. This complementarity will be presented in the next sections of this chapter.

According to Yin (2009), the first form of the cases is a study case and the second is the case for research. There are two different views that are implemented for the two types:

"A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real life context, especially when the boundaries between phenomenon and context are not clearly evident".

"The case study inquiry copes with the technical distinctive situation in which there will be many more variables of interest than data points as one result rely on multiple sources of evidence with data needing to converge in a triangulating fashion and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis".

The case study is a research strategy covering the logic of design, data collection techniques and specific approaches to data analysis (Yin, 2003). In this context, the case study is neither a data collection method nor a design feature alone (Stoecker, 1991) but a comprehensive research strategy.

3.3.1. The Case Study as a Research Method

The case study is a very popular qualitative research strategy in different sciences. It is usually used to investigate real life phenomena and to support decision making. Due to their characteristics, case studies are more of exploratory nature and rather focusing on developing a hypothesis than on testing the theory (Thies, *et al.*, 2010).

Yin (2003) states that there are three types of case studies that can be used:

(i) Explanatory case studies are used for causal researches. They investigate an event and its interrelationships in depth.
(ii) Exploratory case studies aim to explore a new research area when the question is not clear. They serve as motivation and define hypotheses.
(iii) Descriptive case studies obtain information on particular properties of an issue. A phenomenon is described in detail and investigated then.

Yin (2003) proposed a table in order to present relevant situations for different research methods explicitly. According to the table, there are three conditions consisting of type of research question asked, extent of control the researcher has over actual events and degree of focus on contemporary as opposed to past events. Table 3.3 shows these three conditions and how they are related to five different research strategies: experiments, surveys, archival analyses, histories and case studies.

Table 3.3. Relevant Situations for Different Research Methods (Yin, 2003).

METHOD	(1) Research Question	(2) Control of Events	(3) Focus on Contemporary Events
Experiment	how, why?	yes	yes
Survey	who, what, where, how many, how much?	no	yes
Archival Analysis	who, what, where, how many, how much?	no	yes
History	how, why?	no	no
Case Study	how, why?	no	yes

The most important condition for differentiating among various research methods is to determine the question being asked. It is seen from the table that if research that asks who and where research questions are usually to support survey methods or analysis of archival records as in economic research. These two methods are advantageous when the research aim is to describe the effect of predominance of a phenomenon or when it is to be estimated about certain events. A typical example would be surveys conducted in order to find political attitudes. In contrast to who and where questions, how and why questions are more explanatory and usually used in histories, experiments and also case studies. These questions deal with operational links that have to be monitored over time rather than frequencies.

A further differentiation among research strategies is the extent of the investigator's control over and access to behavioral events. For example, histories are used as research strategy when there is no access or control of behavioral events. History deals with the past however case studies are preferred in investigating contemporary events. History and case study have very similar research techniques however there are two additional sources of evidence that are usually not included in historians' methods: interviews with people involved in events and opportunity for direct observation of the events being investigated. Although techniques of case study and history may overlap, the case study's strength comes from its wide variety of evidence including documents, interviews and observations (Yin, 2003).

The last major distinction among research strategies is between the case study and the experiment methods: the investigator in an experiment can manipulate the events directly and systematically. This can happen in laboratory environment by controlling all variables or in the field by treating subjects in different ways whereas relevant behaviors cannot be manipulated in case studies.

To sum up, Yin (2003) states that since case study method has distinct advantages as a research strategy, it is used to identify some situations when:

"A how or why question is being asked about a contemporary set of events over which the investigator has little or no control".

Since the answers of questions how and why are sought in this research, case studies are the proper research strategy to be implemented in this thesis. It is aimed to explain decisions by finding reasons of them. There is no control of events in this research and this leads the researcher to case studies. The main focus was on contemporary events during the whole investigation process.

3.3.2. Strengths and Weaknesses of Case Study

According to Siggelkow (2007) there are three major applications for case studies that can be counted as strengths of this type of research methodology:

(i) An illustrative instrument: concrete examples of theoretical knowledge lead to that the readers easily understand the conceptual arguments. Case data provides a more convincing argument about causal relationships than pure theory or empirical research can.
(ii) Motivating the research question: argumentation in a real life context makes a case a more convincing argument than a pure theoretical motivation.
(iii) Inspiration for new ideas: real life cases provide rich data. They may be used as tools to strength existing theory, especially in cases where limited theoretical knowledge exists.

In spite of these, there are also certain risks that case studies have:

(i) If the number of cases is small then it is generally not a representative for a specific population, hence case studies cannot make use of statistical tests for significance.
(ii) In some situations, results from case studies may seem obvious to readers. This is called the problem of ex-post obviousness.
(iii) Case studies may quickly become too rich in detail and hence may not generate

a useful theory. So it is important not to cause an over determination in the case study.

Flyvbjerg (2011) establishes a table presenting different characteristics of case studies and statistical methods and compare them in order to prove that there is a strict complementarity between these two research strategies. By looking at Table 3.4, some other strengths and weaknesses of case study method can be seen. The table also shows that if a phenomenon in any degree of thoroughness is sought, case study method should be pursued. On the other hand, if how widespread the phenomenon is and how it correlates with other phenomena is sought then statistical studies should be done.

Table 3.4. Comparison of Case Studies and Statistical Methods (Flyvbjerg, 2011).

	Case Studies	Statistical Methods
Strengths	Depth	Breadth
	High conceptual validity	Understanding how widespread a phenomenon is across a population
	Understanding of context and process	Measures of correlation for populations of cases
	Understanding of what causes a phenomenon linking	Establishment of probabilistic level of confidence
	causes and outcomes Fostering new hypotheses and new research questions	
Weaknesses	Selection bias may overstate	Conceptual stretching by grouping together
	or understate relationships Weak understanding of occurrence in population of phenomena under study	dissimilar cases to get larger samples Weak understanding of context, process and causal mechanisms
	Statistical significance often unknown or unclear	Correlation does not imply causation
		Weak mechanisms for fostering new hypotheses

3.3.3. Requirements of Case Studies

A research must represent a logical set of statements and any given design according to certain logical tests must be proved. It is also important to meet certain requirements when performing a case study. Yin (2003) addresses that following four criteria ensure that the case study is credible and persuasive from a methodological point of view: construct validity, internal validity, external validity and reliability.

(i) Construct validity is related to the quality of operationalization of the concept being investigated. To meet the requirement of construct validity, a researcher must use multiple source of evidence, form a chain of evidence and adopt different point of views in order to look at the phenomenon from different perspectives.

(ii) Internal validity refers to only explanatory case studies in which an investigator determines whether a specific event led to another. If he/she fails in concluding that there is a causal relationship between two events knowing also that a third factor caused this then the research design fails in meeting requirement for internal validity. Establishment of causal relationships can be ensured by clear research frame work, explanation building, pattern matching techniques, rival explanations and use of logical models.

(iii) Since sufficient statistical generalization is not available for case studies, external validity refers to the problem of knowing if a study's results can be generalized beyond the immediate case study. However, pattern matching techniques that compare models of empirical studies with theories from literature allow analytical generalization. The researcher should provide a clear justification for case study selection. A theory must be tested by replicating the results in a second or third environment where the theory shows that the same results must occur.

(iv) In order to meet reliability requirement, an investigator who followed the same procedures as described by an earlier investigator and conducted the same case study should arrive at the same results and conclusions with the earlier one. Briefly, the study must be without random error which means it can be repeated with the same results. The aim is to minimize errors and biases in a study. Reliability can be provided by transparency through clarification of research procedure

and replication through a case study database.

To sum up, four aforementioned tests are considered relevant in evaluating the quality of a case study research design. These tests and recommended case study tactics are listed in Table 3.5 (Yin, 2003). In case studies of this thesis, both archival records and interviews are used during data collection phase in order to satisfy the construct validity. A research framework which is explained in next sections and used to analyze the cases was established based on literature in order to improve the internal validity. In research design, multiple case studies are selected among certified green building projects and performed in order to emphasize external validity. To allow replication of the study, a case study database is established so sufficient reliability is aimed to be ensured.

Table 3.5. Case Study Tactics for Four Design Tests (Yin, 2003).

Tests	Case Study Tactic	Phase of Research in which Tactic Occurs
Construct Validity	Use multiple sources of evidence	data collection
	Establish chain of evidence	data collection
	Have key informants review draft case study report	composition
Internal Validity	Do pattern matching	data analysis
	Do explanation building	data analysis
	Address rival explanations	data analysis
	Use logic models	data analysis
External Validity	Use theory in single case studies	research design
	Use replication logic in multiple case studies	research design
Reliability	Use cases study protocol	data collection
	Develop case study database	data collection

3.3.4. Content of the Case Studies

Ozorhon (2013a) proposed a framework to explore various components of innovation at the project level. Figure 3.2 depicts the proposed innovation framework. It defines innovation as a system having several components relating to the participating organizations, as well as project-specific factors and BIM can be count as a kind of innovation. The components of the innovation process and also BIM process lie on one side and the project participants on the other, within a 3-Dimensional project environment. All processes available for innovation can accept are valid for BIM be-

cause it is a type of innovation. The main components of the innovation system and BIM are the drivers, inputs, enablers, barriers, innovative activities, benefits, and impacts. The drivers represent the main motivations for the innovation process to initiate. The inputs are the resources utilized to develop or adopt different types of innovations (product/process/organizational). The barriers act as the obstacles or challenges working against the innovation. The enablers are those factors overcoming the barriers and increasing the rate of innovations. Benefits are considered as the project-level outputs, whereas impacts are considered as wider outputs on the project participants. Each participant contributes to and benefits from the innovations introduced. The process is cyclic since the experience and knowledge gained by the project parties may be transferred to future projects in implementing similar or different innovations.

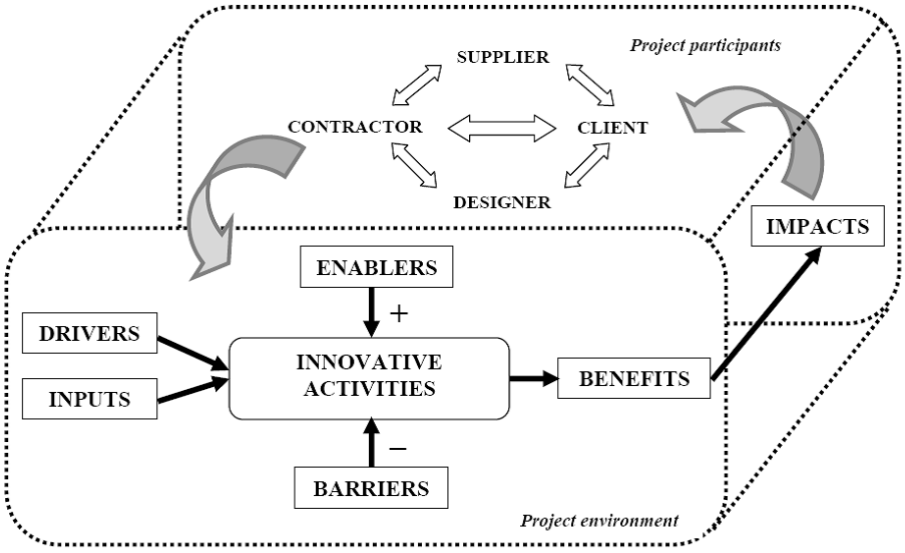


Figure 3.2. Innovation Framework for Project Level (Ozorhon, 2013a).

Figure 3.3 shows the proposed innovation framework, which is developed based on a previous work by Ozorhon (2013a). This framework investigates the BIM process within a construction project setting based on several components including the drivers, inputs, barriers, enablers, benefits, and impacts.

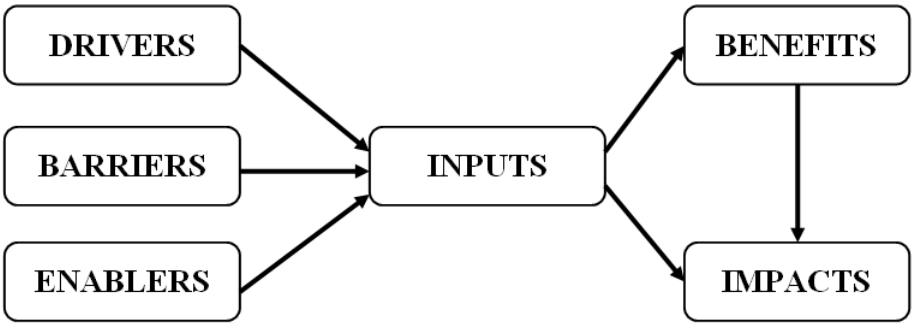


Figure 3.3. Innovation Framework (Ozorhon, *et al.*, 2015).

The main components of the BIM implementations are the drivers, inputs, enablers, barriers, innovative activities, benefits, and impacts. The drivers represent the main motivations for the BIM implementation to initiate. The inputs are the resources utilized to develop or adopt different types of BIM implementation (product/process/organizational). The barriers act as the obstacles or challenges working against the BIM implementation. The enablers are those factors overcoming the barriers and increasing the rate of BIM implementation. Benefits are considered as the project-level outputs, whereas impacts are considered as wider outputs on the project participants. Each participant contributes to and benefits from the BIM implementation introduced.

The core concern of this research study is to investigate the BIM implementation that the Turkish construction companies have applied in their projects and to explore the sector's BIM implementation level. Thus, appropriate performance measures have to be developed, the validity of these measures has to be tested and the direct and indirect influences of several variables on overall BIM implementation have to be examined. For this purpose, a case study has been designed details of which are presented in the forthcoming pages.

The interview has been established covering different topics with some questions. The main topics and questions of the case study about the implementation of BIM are presented in the Table 3.6 below;

Table 3.6. Case Study Issues and Questions

Implementation of Building Information Modeling in Turkish Construction Industry	
General Questions	What is the main field of activity of your company?
	How many years your company has experience on construction sector?
	What is the annual return of your company approximately?
	How many employees work in your company?
	What is your position in the company?
	Which Building Information Modeling (BIM) software do you use in your company?
	Which level of BIM is being used in your company?
	In which phase do you use BIM technology in your projects?
	In which type of projects do you use BIM technology?
	What is your general customer type?
	What is the budget of your BIM Project?
	What is the duration of your BIM Project?
	What is the total area of your BIM Project?
	What is the cost of your BIM Project?
	How much saving of budget have you provided due to BIM application in this project?
	How much saving of time have you provided due to BIM application in this project?
Evaluation Questions with five-point Likert Scale	
Drivers	End-User (Client) Requirement
	Project Performance Improvement
	Increased Coordination
	Corporate Performance Improvement
	Technology
	Regulation
	Sustainability / Green Buildings
Inputs	Human Resources
	Financial Resources
	Information
	Training
	Consulting
Barriers	Lack of Financial Resources
	Lack of Clear Benefits
	Unsupportive Organizational Culture
	Lack of Experience
	Lack of Awareness
	Lack of Qualified Staff
	Lack of Governmental Support
	Fragmented Nature of Construction Industry
	Temporary Nature of Projects
Enablers	Collaborative Partnering
	Supportive Work Environment
	Leadership
	BIM Policy of the Company
	Government Schemes
Benefits	Decrease in Cost
	Decrease in Life Cycle Cost
	Decrease in Duration
	Increase in Quality
	Clash Detection
	Improvement of Client Satisfaction
	Better Documentation
	Increased Integration/Communication/Coordination Among Parties
Impacts	Increase in Organizational Capability/Effectiveness
	Long Term Profitability
	Improvement of Organizational Structure
	Future Business Collaborations with Project Parties

These factors have been investigated to grasp how much importance these factors have in the literature from 48 sources from articles, thesis, magazines, and the report

related BIM. Selected 48 sources and investigation about factors are shown in Appendix C.

The CSFs of BIM implementation are determined based on the same list. Considering the different components of BIM implementation, the success-related ones are filtered and mostly cited factors are selected as the potential CSFs. The list contains a total of 16 factors. Table 3.7 lists the CSFs and the key references for those factors.

Factor	References
Availability of information and technology	(Journal of Building Information Modeling, 2009), (The Salford Centre for Research & Innovation,SCRI, 2011), (Autocad, 2007), (Kenig, *et al.*, 2010), (Khosrowshahi, *et al.*, 2012), (HM Government, 2012), (Bernstein, *et al.*, 2004), (Becerik-Gerber, *et al.*, 2010), (Arayici, *et al.*, 2013), (Sacks, *et al.*, 2010), (Hanna, *et al.*, 2012), (Becerik-Gerber , *et al.*, 2010), (Azhar, 2011), (Boktor, *et al.*, 2013)
Availability of financial resources	(Manning, *et al.*, 2008), (Ganah, *et al.*, 2013), (Bryde, *et al.*, 2012), (Linderoth, 2009), (Succar, *et al.*, 2013), (McGraw Hill Construction, 2009), (Yilmaz, *et al.*, 2010), (Er, *et al.*, 2010)
Availability of qualified staff	(Journal of Building Information Modeling, 2009), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009), (Jung, *et al.*, 2010), (Succar, *et al.*, 2013)
Training of employees	(Suermann, *et al.*, 2009), (Jung, *et al.*, 2010), (Succar, *et al.*, 2013), (McGrawHill Construction, 2009), (Altinöz, *et al.*, 2012), (Konukçu, *et al.*, 2011)
Consulting	(Isikdag, *et al.*, 2009), (Khosrowshahi, *et al.*, 2012), (Gu, *et al.*, 2008), (The Salford Centre for Research & Innovation,SCRI, 2011), (Journal of Building Information Modeling, 2009), (Gee, 2010), (Suermann, *et al.*, 2009)
Supportive organizational culture	(Khosrowshahi, *et al.*, 2012), (Journal of Building Information Modeling, 2009), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009), (Jung, *et al.*, 2010), (Succar, *et al.*, 2013)
Experience level within the firm	(Löf, *et al.*, 2012), (Gu, *et al.*, 2008), (McGraw Hill Construction), (London, *et al.*, 2008), (Journal of Building Information Modeling, 2009))
BIM policy of the company	(The Salford Centre for Research & Innovation,SCRI, 2011), (Kenig, *et al.*, 2010), (Khosrowshahi, *et al.*, 2012), (Becerik-Gerber, *et al.*, 2010), (Jung, *et al.*, 2010)
Effective leadership	(National Institute of Building Sciences, 2010), (Journal of Building Information Modeling, 2009), (Kenig, *et al.*, 2010), (HM Government, 2012), (Autodesk, 2008)
Coordination among project parties	(Eastman, *et al.*, 2011), (Boktor, *et al.*, 2013), (Hergunsel, 2011), (Manning, *et al.*, 2008), (McGraw Hill Construction), (Khosrowshahi, *et al.*, 2012), (Azhar, 2011)
Project size	(Bryde, *et al.*, 2012), (Arayici, *et al.*, 2011), (Journal of Building Information Modeling, 2009), (Ilhan, *et al.*, 2012), (Demir, *et al.*, 2012), (Jung, *et al.*, 2010), (Sebastian, 2010), (Pindukuri, 2011)
Client requirement	(HM Government, 2012), (Journal of Building Information Modeling, 2009), (Ganah, *et al.*, 2013), (Succar, *et al.*, 2013), (National Institute of Building Sciences, 2010), (Linderoth, 2009), (Amponsah, 2010)
Awareness level of the industry	(Arayici, *et al.*, 2011), (Journal of Building Information Modeling, 2009), (The Salford Centre for Research & Innovation,SCRI, 2011), (Autodesk, 2002), (Arayici, *et al.*, 2012)
Knowledge sharing within the industry	(National Institute of Building Sciences, 2010), (Gee, 2010), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009), (Campbell, 2007), (Journal of Building Information Modeling, 2009)
Appropriate legislation	(Eadie, *et al.*, 2013), (Suermann, *et al.*, 2009), (Arayici, *et al.*, 2009), (Journal of Building Information Modeling, 2009))
Governmental schemes	(Eadie, *et al.*, 2013), (Suermann, *et al.*, 2009), (Arayici, *et al.*, 2009), (Journal of Building Information Modeling, 2009)

4. RESEARCH FINDINGS

4.1. Questionnaire Survey

This chapter presents part of the research results from a questionnaire survey. This study explores factors that contribute to the successful procurement of capital projects which is seen as one of the many management practices that contribute to corporate success.

One of the main research questions of this study was - what are the Critical Success Factors of Building Information Modeling?

This chapter presents the data collection process and explains how the data collected from the survey instrument were prepared, administered and statistically analyzed. Data were collected based on a questionnaire survey. The analysis presented in this chapter starts with a reliability test for all the collected data. Two separate statistical analyses were undertaken using the Statistical Package for Social Science (SPSS). The first analysis ranked the factors, based on the mean value of responses, and compared the mean for the six groups and presented associated analysis of variance (ANOVA) for each factor within a series of BIM attributes.

The second analysis explored and detected the underlying relationships among the attributes of BIMs, using factor analysis. The principal component analysis for factor extraction is used in the analysis; the distinctive characteristic being its data-reduction capacity. CSFs are separately determined and extracted, using factor analysis.

4.1.1. Web Survey

The web survey was conducted electronically via a web site administered by drive.google.com. The web survey was conducted from March 11, 2014 through August 25, 2014. As mentioned in the previous chapter, the target population was experts con-

sisting of Specialist Contractor, Principal Contractor, Building User/Occupant, Client, Consultant and Designers in the construction industry. Participants for the survey were mainly enlisted from the Turkish Contractors Association. The potential participants were emailed to seek their permission to participate in the study. The email invitations were personalized to the individuals so as to prevent spamming and to increase the level of response rate for the survey.

Participants were listed from the directories and were invited to participate in the survey and 81 of them responded.

The survey questionnaire contained three parts. The first part asks for personal information on the organization which the respondents worked which included six questions. Data it asked for the core business of the respondent and the population of the organization. Part two requested for critical success factors. Sixteen factors were asked and respondent were asked to select from five points. This part was based on a five-point Likert scale, and were coded as 1= "Not Significant", 2= "Fairly Significant", 3= "Significant", 4= "Very Significant ", 5= "Extremely Significant". Finally the third part asks participants to examine BIM related questions.

4.1.2. Analysis and Ranking

Mean ranking is the most convenient way to identify and compare the importance of factors on an attribute basis. The ranking results of CSF attribute of BIMs are separately listed in below tables. All the respondents' information has been presented in the previous chapter under research methodology section at Section 3.

4.1.3. Respondents' Information

The questionnaire survey study provides coherent information on the state of BIM in Turkey. In this thesis, an internet-based online questionnaire survey is prepared, which respondents can fill in online. The list of targeted respondents was created utilizing several sources, but the main resource is TCA and TCEA. However, consider-

ing the fact that there were other construction companies in the industry which were not members of TCA or TCEA but showing similar characteristics with the member companies of these two associations in terms of size and type of work undertaken, the questionnaire survey was sent to some construction related organizations like project management companies, designers, suppliers, sub-contractors and other middle/large scale contractors. At the end of the survey, a total of 81 completed questionnaires were returned for data analysis out of 244 sent out. The rate of response was 33%.

In the questionnaire part of the investigation, there are 81 input sets from 81 respondents. As mentioned before, in beginning of the survey, all respondents have replied general questions about them and their company. Later, critical success factors questions in the survey are answered according to 1 to 5 scale from "very low" to "very high".

It can be seen Table 4.1 the general descriptive statistics table of the whole questions mentioned in the survey.

Table 4.1. Descriptive Statistics.

	Mean	Std. Deviation	Analysis N
Availability of information and technology	4.1481	0.76012	81
Availability of financial resources	3.8889	0.93541	81
Availability of qualified staff	4.1975	0.78134	81
Training of employees	4.0617	0.78016	81
Consulting	3.3333	0.92195	81
Supportive organizational culture	3.4938	0.96337	81
Experience level within the firm	3.9259	0.77100	81
BIM policy of the company	3.8148	1.17379	81
Effective leadership	4.1605	0.92813	81
Coordination among project parties	4.1481	0.83832	81
Project size	3.3457	1.06255	81
Client requirement	3.6296	1.01790	81
Awareness level of the industry	3.6049	1.00845	81
Knowledge sharing within the industry	3.4815	0.98883	81
Appropriate legislation	3.4938	1.09685	81
Governmental schemes	2.9259	1.19140	81

In order to see whether there is a significant difference between the responses of the BIM implementers and non-implementers in terms of the significance of CSFs, t-test was performed. The results show that there is not a significant difference between those two groups of respondents. The t-test results are given in Appendix D.

4.1.3.1. Respondents' personal information. Table 4.2, Table 4.3 and Table 4.4 present a summary of information on the respondents that completed the questionnaire. The respondents' information from the contractors, public and private clients with overall totals are presented to show disaggregated and aggregated outcomes. This is important to provide a context for the statistical analysis.

All of the 81 participants declared their position, are chairman/member of the engineer (22), chairman (18), project coordinator (10), general manager (7), architect (7), project manager (6), department chief (5), broad member (3), BIM Manager (1) and technician (1), as shown in Table 4.2.

Table 4.2. Respondents' Positions.

Num. of Employee	Chairman	BIM Manager	General Manager	Architect	Engineer	Department Chief	Project Coordinator	Project Manager	Technician	Board Member	Others	Total
0-20	15	0	6	4	7	0	4	1	0	2	0	39
21-50	2	1	0	1	3	1	3	2	1	0	0	14
51-100	1	0	1	0	3	0	0	0	0	0	0	5
101-200	0	0	0	2	2	0	3	0	0	1	0	8
> 200	0	0	0	0	7	4	0	3	0	0	1	15
Total	18	1	7	7	22	5	10	6	1	3	1	81

Most of the respondents have spent a long time in the industry, as indicated in Table 4.3. All respondents provided number of years of experience share an average of

18,74 years of industrial experience (standard deviation = 23.23), as shown in Table 4.4.

Table 4.3. Respondents' Experience.

Experience (year)	Chairman	BIM Manager	General Manager	Architect	Engineer	Department Chief	Project Coordinator	Project Manager	Technician	Board Member	Total
0-5	8	1	2	1	3	3	2	0	0	0	20
5-10	5	0	2	2	4	2	1	0	0	0	16
10-15	1	0	1	0	4	2	0	1	0	0	9
15-20	0	0	1	0	3	2	0	1	1	1	9
20-25	0	0	1	1	1	0	2	0	0	1	6
25-30	2	0	0	0	2	0	0	2	0	1	7
> 30	2	0	0	3	5	2	1	1	0	0	14
Total	10	0	5	6	19	8	4	5	1	3	81

Table 4.4. Experience of Respondents by Core Business.

Position of Respondent in Company	Specialist Contractor		Principal Contractor		Building User/Occupant		Client		Consultant		Designer		Total	
	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Chairman	-	-	32.5	10.61	-	-	10.00	11.27	4.00	4.24	4.25	3.40	10.56	12.18
BIM Manager	-	-	-	-	-	-	-	-	-	-	1	-	1	-
General Manager	8.00	-	14.67	7.57	-	-	4.00	-	-	-	6.50	4.95	9.86	6.69
Architect	-	-	33.50	34.65	-	-	16.00	19.80	-	-	29.67	25.97	26.86	23.41
Engineer	6.00	-	31.78	30.80	-	-	22.89	28.03	13.00	-	10.00	7.07	24.14	27.01
Project Coordinator	6.50	2.12	9.50	9.19	-	-	12.00	9.86	-	-	30.00	-	12.18	9.86
Project Manager	1.00	-	20.00	0.00	-	-	26.5	26.16	-	-	1	-	15.83	16.65
Department Chief	13.00	-	28.00	-	143.00	-	27.00	-	17.00	-	-	-	45.60	54.83
Technician	-	-	19	-	-	-	-	-	-	-	-	-	19	-
Board Member	-	-	15.00	-	-	-	28.00	-	-	-	20.00	-	21.00	6.56
Total	6.83	3.97	25.35	22.12	143.00	-	16.31	18.41	9.50	7.00	12.73	15.41	18.74	23.23

4.1.3.2. Respondents' organization information. Information on the organizations that participated in the questionnaire survey in respect of number of employee, turnover, experience, project type undertaken and the role of the establishment is shown by Table 4.5 and Table 4.6. Also the texts are given to indicate information on the overall response.

The participants' organizations are very diverse, both in terms of annual turnover and employee numbers. The number of employees in the respondents' organizations, with small-scale employment (<100 employee) occupying 66% is shown in Table 4.5. The largest percentage of participation is occupied by small organizations. The only seventeen percent of the respondents are working in large organizations (>200 employees). The organizations having 101-200 and 51-100 employee with a share of 9% and 6% respectively follow them (Table 4.5).

Table 4.5. Organizations Distribution by Number of Employees.

Core Business in Construction Industry							
Number of Employee	Specialist Contractor	Principal Contractor	Building User/ Occupant	Client	Consultant	Designer	Total
0-20	3 8%	7 18%	0 0%	18 45%	2 5%	10 25%	40 49%
21-50	1 7%	3 21%	0 0%	6 43%	1 7%	3 21%	14 17%
51-100	0 0%	3 60%	0 0%	2 40%	0 0%	0 0%	5 6%
101-200	1 13%	2 25%	0 0%	2 25%	1 13%	2 25%	8 9%
>200	1 7%	8 57%	1 7%	4 29%	0 0%	0 0%	14 17%
Total	6 7%	23 28%	1 1%	32 40%	4 5%	15 19%	81 100%

Table 4.6 expresses the annual turnovers of the respondents' organizations. In clients, more participants come from small organizations (0-10) than the others therewithal they generate the big part of the small scale organizations at the same time

with 26 respondents. The research showed that Specialist contractor and consultant are very diverse in terms of annual turnover from the smallest to largest scale.

Table 4.6. Organizations Distribution by Annual Turnovers.

Core Business in Construction Industry							
Annual Turnover (million $)	Specialist Contractor	Principal Contractor	Building User/ Occupant	Client	Consultant	Designer	Total
0-10	5 8%	12 19%	1 2%	26 41%	4 6%	15 24%	63 78%
10-50	1 17%	4 67%	0 0%	1 17%	0 0%	0 0%	6 7%
50-100	0 0%	2 100%	0 0%	0 0%	0 0%	0 0%	2 2%
100-1000	0 0%	5 56%	0 0%	4 44%	0 0%	0 0%	9 11%
>1000	0 0%	0 0%	0 0%	1 100%	0 0%	0 0%	1 1%
Total	6 7%	23 28%	1 1%	32 40%	4 5%	15 19%	81 100%

4.1.3.3. BIM usage information of respondents'. Twenty-one out of eighty-one have used BIM in their project at least once. Table 4.7 shows the general distribution of BIM usage among respondents. Table 4.7, Table 4.8, Table 4.9, Table 4.10, Table 4.11 and Table 4.12, detail this distribution according to the annual turnover and employee numbers.

Table 4.7. BIM Usage by Organization.

Core Business in Construction Industry							
Annual Turnover (million $)	Specialist Contractor	Principal Contractor	Building User/ Occupant	Client	Consultant	Designer	Total
Yes	0 0%	4 19%	0 0%	7 33%	1 5%	9 43%	21 26%
No	6 10%	19 32%	1 2%	25 42%	3 5%	6 10%	60 74%
Total	6 7%	23 28%	1 1%	32 39%	4 5%	15 18%	81 100%

It is indicated by Table 4.7 and Table 4.8 that the case of "BIM usage" happens generally in small organizations. Small organizations appear to have more BIM projects. This is foreseen, since the larger organizations may have struggle with slow adopting market, Legal barriers, technical know-how and risk taking ability etc., in order to participate in BIM projects and circumstances in which move them away from the idea.

Table 4.8. BIM Usage by Organization Annual Turnover Scale.

Core Business in Construction Industry								
BIM Usage	Annual Turnover (million $)	Specialist Contractor	Principal Contractor	Building User/ Occupant	Client	Consultant	Designer	Total
Yes	0-10	0 0%	1 6%	0 0%	5 31%	1 6%	9 56%	16 76%
	10-100	0 0%	1 100%	0 0%	0 0%	0 0%	0 0%	1 5%
	100-1000	0 0%	2 50%	0 0%	2 50%	0 0%	0 0%	4 19%
	Total	0 0%	4 19%	0 0%	7 33%	1 5%	9 43%	21 100%
No	0-10	5 11%	11 23%	1 2%	21 45%	3 6%	6 13%	47 78%
	10-50	1 20%	3 60%	0 0%	1 20%	0 0%	0 0%	5 8%
	50-100	0 0%	2 100%	0 0%	0 0%	0 0%	0 0%	2 3%
	100-1000	0 0%	3 60%	0 0%	2 40%	0 0%	0 0%	5 8%
	>1000	0 0%	0 0%	0 0%	1 100%	0 0%	0 0%	1 2%
	Total	6 10%	19 32%	1 2%	25 42%	3 5%	6 10%	60 100%

Table 4.9 expresses the BIM usage in Turkish construction industry's main business areas from respondent's information. Designers and clients are heavily used BIM occupying respectively 33% and 43% is shown in Table 4.21. Designers may choose to use BIM to intervene early to clashes because of all designers were involved during the early stages except the designer of ventilation, pipes, electricity and the prefabrication designers.

Table 4.9. BIM Usage by Organization Employee Numbers.

Core Business in Construction Industry								
BIM Usage	Number of Employee	Specialist Contractor	Principal Contractor	Building User/ Occupant	Client	Consultant	Designer	Total
Yes	0-20	0 0%	0 0%	0 0%	3 33%	1 11%	5 56%	9 43%
	21-50	0 0%	1 20%	0 0%	2 40%	0 0%	2 40%	5 24%
	51-100	0 0%	1 100%	0 0%	0 0%	0 0%	0 0%	1 5%
	101-200	0 0%	0 0%	0 0%	2 50%	0 0%	2 50%	4 19%
	>200	0 0%	2 100%	0 0%	0 0%	0 0%	0 0%	2 10%
	Total	0 0%	4 19%	0 0%	7 33%	1 5%	9 43%	21 100%
No	0-20	3 10%	7 23%	0 0%	15 48%	1 3%	5 16%	31 52%
	21-50	1 11%	2 22%	0 0%	4 44%	1 11%	1 11%	9 15%
	51-100	0 0%	2 50%	0 0%	2 50%	0 0%	0 0%	4 7%
	101-200	1 25%	2 50%	0 0%	0 0%	1 25%	0 0%	4 7%
	>200	1 8%	6 50%	1 8%	4 33%	0 0%	0 0%	12 20%
	Total	6 10%	19 32%	1 2%	25 42%	3 5%	6 10%	60 100%

Levels of sophistication or maturity start from level 0 where a project has not implemented any BIM principles. Therefore it is described as the pre-BIM status. The following levels implement more BIM principles and present an accumulative progress. Thus, they are also considered as stages and therefore the term "BIM implementation maturity stages" is also commonly used in literature (Khosrowshahi, *et al.*, 2012).

- Level-0: (Unmanaged CAD, in 2D, with paper (or electronic paper) data exchange);
- Level-1: (object-based modeling) or (Managed CAD in 2D or 3D format. Commercial data will be managed by standalone finance and cost management packages with no integration.)

- Level-2: (model-based collaboration) or (A managed 3D environment held in separate discipline "BIM" tools with data attached. This level of BIM may utilize 4D construction sequencing and/or 5D cost information.)
- Level-3: (network-based integration) or (A fully integrated and collaborative process enabled by "web services". This level of BIM will utilize 4D construction sequencing, 5D cost information and 6D project lifecycle management information.)

Respondents' information's shows that BIM principles in proportion as 57% implemented by private companies. Twenty-one out of eight BIM users implement BIM at their companies at Level-2 and detail information indicated at Table 4.10.

Table 4.10. BIM Usage Level by Type of Clients.

		Type of Client							
BIM Usage	Usage Level*	Public	Private	Public and Private	Public-Private Partnership	Private and Public-Private Partnership	Public, Private and Public-Private Partnership	None	Total
Yes	Level-0	1 14%	4 57%	0 0%	1 14%	0 0%	1 14%	0 0%	7 33%
	Level-1	1 25%	2 50%	0 0%	0 0%	1 25%	0 0%	0 0%	4 19%
	Level-2	0 0%	4 50%	3 38%	0 0%	1 13%	0 0%	0 0%	8 38%
	Level-3	0 0%	2 100%	0 0%	0 0%	0 0%	0 0%	0 0%	2 10%
	Total	2 10%	12 57%	3 14%	1 5%	2 10%	1 5%	0 0%	21 100%
No	Level-0	1 50%	0 0%	1 50%	0 0%	0 0%	0 0%	0 0%	2 3%
	None	0 0%	1 2%	0 0%	0 0%	0 0%	0 0%	57 98%	58 97%
	Total	1 2%	1 2%	1 2%	0 0%	0 0%	0 0%	57 95%	60 100%

Table 4.11 shows that BIM approach applied to what types of projects. BIM approach mostly applied at Residential Housing Construction and Institutional and Commercial Building Construction from companies which can be count as small firms.

Table 4.11. Annual Turnover by Type of Project.

Type of the Project [1]													
BIM Usage	Annual Turnover (million $)	RH	ICB	SI	IH	RH and ICB	ICB and SI	SI and IH	RH, ICB and SI	IH, SI and ICB	RH, ICB, SI and IH	None	Total
		4	2	1	0	3	1	0	2	1	2	0	16
Yes	0-10	25%	13%	6%	0%	19%	6%	0%	13%	6%	13%	0%	76%
	10-100	0 0%	0 0%	0 0%	0 0%	1 100%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	1 5%
	100-1000	0 0%	2 50%	1 25%	0 0%	0 0%	0 0%	1 25%	0 0%	0 0%	0 0%	0 0%	4 19%
	Total	4 19%	4 19%	2 10%	0 0%	4 19%	1 5%	1 5%	2 10%	1 5%	2 10%	0 0%	21 100%
No	0-10	1 2%	0 0%	0 0%	1 2%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	45 96%	47 78%
	10-50	0 0%	1 20%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	4 80%	5 8%
	50-100	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	2 100%	2 3%
	100-1000	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	5 100%	5 8%
	>1000	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	1 100%	1 2%
	Total	1 2%	1 2%	0 0%	1 2%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	57 95%	60 100%

Companies in Turkish construction industry which used BIM approach prefer to implement BIM in proportion as 43% at stage of feasibility, design and preconstruction. 19% of companies have chosen to implement BIM approach at the design and construction phase (Table 4.12).

[1]Residential Housing Construction: RH, Institutional and Commercial Building Construction: ICB, Specialized Industrial Construction: SI, Infrastructure and Heavy Construction: IH.

Table 4.12. Annual Turnover by Stage of the Project Life Cycle.

Stage of the Project Life Cycle[1]															
BIM Usage	Annual Turnover (million $)	D	PC	C	OM	PC, C	D and C	D and PC	D, PC	D, PC and C	F, PC, C and OM	F, D, PC and C	F, D, PC, C and OM	None	Total
Yes	0-10	2 13%	2 13%	2 13%	0 0%	0 0%	1 6%	0 0%	4 25%	1 6%	1 6%	1 6%	1 6%	1 6%	16 76%
	10-100	0 0%	1 100%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	1 5%
	100-1000	0 0%	1 25%	1 25%	1 25%	0 0%	0 0%	1 25%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	4 19%
	Total	2 10%	4 19%	3 14%	1 5%	0 0%	1 5%	1 5%	4 19%	1 5%	1 5%	1 5%	1 5%	1 5%	21 100%
No	0-10	1 2%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	46 98%	47 78%
	10-50	0 0%	0 0%	0 0%	0 0%	1 20%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	4 80%	5 8%
	50-100	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	2 100%	2 3%
	100-1000	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	6 100%	6 10%
	>1000	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
	Total	1 2%	0 0%	0 0%	0 0%	1 2%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	58 97%	60 100%

4.1.4. Reliability Test

First of all, whether factor analysis could be used for the collected data should be checked. for this purpose, there are two basic tests. They are "Kaiser-Meyer-Olkin (KMO) adequacy test" and "Barlett's test of sphericity".

According to KMO test, the value of this test varies between 0 and 1. The KMO values greater than 0.5 are acceptable and the values below 0.5 should lead us to either collect more data or rethink which variables to include. However, it is recommended to have a minimum value of 0.6 in order to ensure a healthy factor analysis. KMO values levels as following that the KMO values between 0.5 and 0.7 are mediocre, the KMO value between 0.7 and 0.8 are good, the KMO values 0.8 and 0.9 are great and the KMO values above 0.9 are superb (Field, 2005).

Bartlett's measure tests the null hypothesis that the original correlation matrix is an identity matrix. For factor analysis to work we need some relationships between variables and if the R-Matrix were an identity matrix then all correlation coefficients would be zero. Therefore, we want this test to be significant, such as; significance value less than 0.05. A significant test tells us that the R-Matrix is not an identity matrix; therefore, there are some relationships between the variables we hope to include in the analysis. For these data, Bartlett's test is highly significant ($p < 0.001$), and therefore factor analysis is appropriate (Field, 2005).

It can be seen the KMO and Bartlett's Test table of the questionnaire survey as below (Table 4.13).

Table 4.13. KMO and Bartlett's Test Table - Factor Analysis.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.791
Bartlett's Test of Sphericity	Approx. Chi-Square	455.769
	df	120
	Sig.	.000

If the KMO and Bartlett's Test table is examined, it can be seen that KMO adequacy value is 0.791. This value means that this data set is "good" for factor analysis.

Moreover, if the Bartlett's Test of Sphericity is examined, it can be seen that significance of the test value is 0.000 and less than 0.001 ($p < 0.001$). Thus, it can be said that factor analysis is appropriate for the test.

It can be understood that both KMO and Bartlett's Test approved that the data set at the questionnaire survey is very suitable for the factor analysis.

T-test was performed to determine whether differences in terms of level of significance among respondents. Results and tables about T-test are given in Appendix D. There was no significant difference between respondents using BIM and respondents non-BIM user considering the significance of the individual questions.

4.1.5. Factor Analysis of the Questionnaire Survey

After the approval of the suitability of the factor analysis method, the data set is transferred into SPSS program in order to get factor analysis tables. "Correlation matrix,(Table 4.14)", "total variance explained, (Table 4.15)", "scree plot, (Table 4.1)", "component matrix, (Table 4.16)", "rotated component matrix, (Table 4.17)", "component transformation matrix, (Table 4.18)", and "component plot in rotated space, (Table 4.2)" tables are acquired from the SPSS Output file.

It can be seen the correlation matrix of the factor analysis. In Table 4.14, correlation between factors in the questionnaire survey can be examined.

Table 4.14. Correlation Matrix - Factor Analysis.

	Ava. of inf. Tec.	Ava. Of fin. Res.	Ava. Of qua. Staff	Tra. Of em.	Consulting	Sup. Org. cult.	Exp. Level the firm	BIM policy com.	Effective lead.	Coor. Am. pro. Part.	Proj size	Client req.	Awa. Lev. ind.	Know. sh. Ind.	App. leg.	Gov. sch.
Availability of inf. and tec	1	0.305	0.329	0.322	0.125	0.189	0.211	0.241	0.356	0.22	0.013	0.153	0.355	0.37	0.211	0.192
Availability of fin. Res.	0.305	1	0.253	0.147	0.13	0.103	0.144	0.14	0.222	0.34	0.492	0.298	0.377	0.207	0.286	0.329
Availability of qualified staff	0.329	0.253	1	0.533	0.185	0.218	0.377	0.354	0.438	0.413	0.173	0.282	0.37	0.328	0.249	0.11
Training of employees	0.322	0.147	0.533	1	0.197	0.258	0.423	0.504	0.487	0.234	0.049	0.076	0.317	0.366	0.168	0.193
Consulting	0.125	0.13	0.185	0.197	1	0.53	0.123	0.092	0.083	0.194	0.034	0.133	0.251	0.233	0.021	0
Supportive organ. Cul.	0.189	0.103	0.218	0.258	0.53	1	0.269	0.27	0.176	0.218	0.063	0.189	0.293	0.325	0.145	0.065
Experience level within the firm	0.211	0.144	0.377	0.423	0.123	0.269	1	0.302	0.436	0.365	0.291	0.188	0.316	0.293	0.339	0.157
BIM policy of the company	0.241	0.14	0.354	0.504	0.092	0.27	0.302	1	0.51	0.346	0.072	0.078	0.254	0.476	0.062	0.294
Effective leadership	0.356	0.222	0.438	0.487	0.083	0.176	0.436	0.51	1	0.355	0.108	0.143	0.362	0.446	0.277	0.384
Coor. Am. project parties	0.22	0.34	0.413	0.234	0.194	0.218	0.365	0.346	0.355	1	0.251	0.49	0.455	0.32	0.368	0.324
Project size	0.013	0.492	0.173	0.049	0.034	0.063	0.291	0.072	0.108	0.251	1	0.432	0.292	0.066	0.313	0.149
Client requirement	0.153	0.298	0.282	0.076	0.133	0.189	0.188	0.078	0.143	0.49	0.432	1	0.465	0.366	0.435	0.297
Awareness level of the industry	0.355	0.377	0.37	0.317	0.251	0.293	0.316	0.254	0.362	0.455	0.292	0.465	1	0.594	0.484	0.485
Knowledge sharing within the industry	0.37	0.207	0.328	0.366	0.233	0.325	0.293	0.476	0.446	0.32	0.066	0.366	0.594	1	0.412	0.476
Appropriate legislation	0.211	0.286	0.249	0.168	0.021	0.145	0.339	0.062	0.277	0.368	0.313	0.435	0.484	0.412	1	0.593
Governmental schemes	0.192	0.329	0.11	0.193	0	0.065	0.157	0.294	0.384	0.324	0.149	0.297	0.485	0.476	0.593	1

The total variance explained table is given below. In this table, it can be seen that initial eigenvalues, extraction sum of squared loadings and rotation sum of squared loadings of total variance explained values of the components.

The table shows that along with 5 components of the factor analysis, 66.874% of the total data set is explained. This is a fine percentage to continue (Field, 2000) and apply a 5 components custom factor analysis again and to explain the whole data(Table 4.15).

Table 4.15. Total Variance Explained - Factor Analysis.

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total Total	% of Variance	Cumulative %
1	5.288	33.051	33.051	5.288	33.051	33.051	2.991	18.692	18.692
2	1.866	11.660	44.710	1.866	11.660	44.710	2.627	16.416	35.108
3	1.405	8.781	53.491	1.405	8.781	53.491	2.095	13.092	48.200
4	1.197	7.483	60.974	1.197	7.483	60.974	1.738	10.864	59.063
5	0.944	5.900	66.874	0.944	5.900	66.874	1.250	7.811	66.874
6	0.807	5.046	71.920						
7	0.777	4.856	76.776						
8	0.612	3.823	80.600						
9	0.607	3.791	84.391						
10	0.48	3.002	87.393						
11	0.444	2.775	90.167						
12	0.402	2.510	92.678						
13	0.365	2.284	94.962						
14	0.333	2.081	97.043						
15	0.27	1.685	98.728						
16	0.203	1.272	100.000						
Extraction Method: Principal Component Analysis.									

Furthermore, the scree plot (Figure 4.1) of factor analysis at 5 components is given below. The elbow point of at the 6th components can be seen and it is enough to explain the most of the data (as 66.874%).

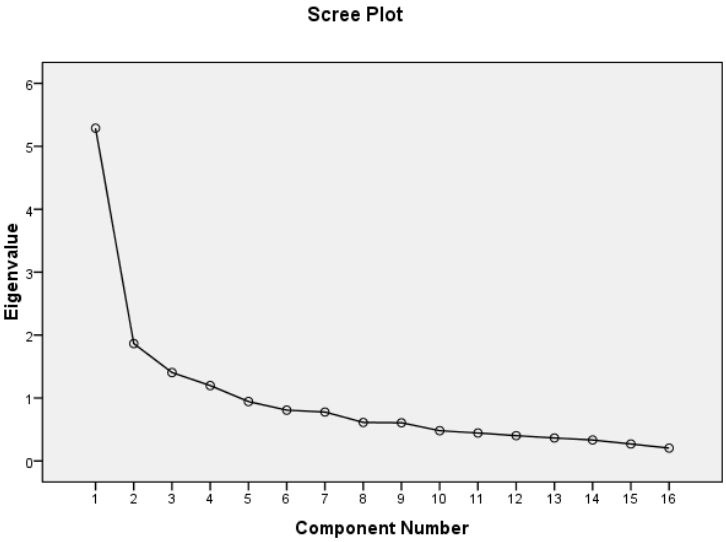


Figure 4.1. Scree Plot - Factor Analysis.

The component matrix of factor analysis is given below. These are the values before rotation. After rotation procedure done and rotated matrix is shown, the better explanation for the factors can be made.

Also, the component plot of the variables in rotated space and component matrix tables can be seen as Figure 4.2.

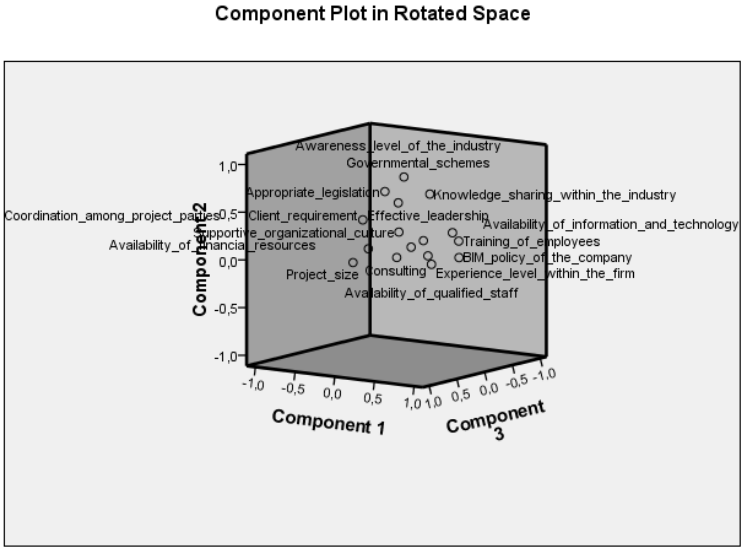


Figure 4.2. Component Plot - Factor Analysis.

Table 4.16. Component Matrix - Factor Analysis.

Component Matrix[1]					
	Component				
	1	2	3	4	5
Availability of information and technology	0.505	-0.187	-0.09	-0.082	0.618
Availability of financial resources	0.505	0.389	0.073	0.238	0.538
Availability of qualified staff	0.058	-0.246	0.013	0.364	0.517
Training of employees	0.589	-0.507	-0.128	0.200	-0.003
Consulting	0.315	-0.247	0.747	-0.193	0.061
Supportive organizational culture	0.437	-0.298	0.620	-0.198	-0.119
Experience level within the firm	0.578	-0.152	-0.017	0.367	-0.387
BIM policy of the company	0.041	-0.448	-0.230	0.561	-0.070
Effective leadership	0.660	-0.297	-0.344	0.084	-0.018
Coordination among project parties	0.658	0.155	0.086	0.138	-0.148
Project size	0.386	0.544	0.166	0.505	-0.011
Client requirement	0.549	0.494	0.223	0.004	-0.140
Awareness level of the industry	0.752	0.192	0.075	-0.228	0.061
Knowledge sharing within the industry	0.716	-0.107	-0.076	-0.426	-0.024
Appropriate legislation	0.605	0.444	-0.156	-0.209	-0.219
Governmental schemes	0.579	0.302	-0.375	-0.436	-0.051
Extraction Method: Principal Component Analysis.					

Moreover, it can be seen "the rotated component matrix table" of factor analysis as given at Table 4.17. These are the values after rotation and it can be interpreted according to their values and component columns.

[1] 5 components extracted.

Table 4.17. Rotated Component Matrix Table - Factor Analysis.

Rotated Component Matrix[1]					
	Component				
	1	2	3	4	5
Availability of information and technology	0.311	0.179	-0.039	0.115	0.737
Availability of financial resources	0.044	0.155	0.571	0.000	0.637
Availability of qualified staff	0.211	0.015	0.305	0.155	0.654
Training of employees	0.782	0.054	-0.010	0.147	0.156
Consulting	0.042	-0.011	0.056	0.861	0.115
Supportive organizational culture	0.215	0.113	0.044	0.810	-0.020
Experience level within the firm	0.655	0.114	0.369	0.106	-0.230
BIM policy of the company	0.083	0.205	-0.104	0.712	0.094
Effective leadership	0.720	0.312	0.021	-0.047	0.173
Coordination among project parties	0.360	0.347	0.471	0.183	0.022
Project size	0.044	0.051	0.846	-0.049	0.062
Client requirement	-0.005	0.458	0.601	0.210	-0.004
Awareness level of the industry	0.227	0.615	0.293	0.284	0.260
Knowledge sharing within the industry	0.373	0.670	-0.068	0.291	0.186
Appropriate legislation	0.107	0.731	0.361	-0.024	-0.039
Governmental schemes	0.129	0.841	0.050	-0.122	0.135
Extraction Method: Principal Component Analysis.					
Rotation Method: Varimax with Kaiser Normalization.					

The rotated component matrix table with bold font dominant value at each component number is presented in Table 4.18. There are 16 variables processed at SPSS Factor Analysis and decided to investigate them in 5 components. It can be seen which variable should be categorized in which components at Table 4.18.

[1]Rotation converged in 6 iterations.

Table 4.18. Rotated Component Matrix Table2 - Factor Analysis.

Rotated Component Matrixa					
Variables	Component				
	1	2	3	4	5
Availability of information and technology	0.311	0.179	-0.039	0.115	0.737
Availability of financial resources	0.044	0.155	0.571	0.000	0.637
Availability of qualified staff	0.211	0.015	0.305	0.155	0.654
Training of employees	0.782	0.054	-0.010	0.147	0.156
Consulting	0.042	-0.011	0.056	0.861	0.115
Supportive organizational culture	0.215	0.113	0.044	0.810	-0.02
Experience level within the firm	0.655	0.114	0.369	0.106	-0.230
BIM policy of the company	0.083	0.205	-0.104	0.712	0.094
Effective leadership	0.720	0.312	0.021	-0.047	0.173
Coordination among project parties	0.360	0.347	0.471	0.183	0.022
Project size	0.044	0.051	0.846	-0.049	0.062
Client requirement	-0.005	0.458	0.601	0.210	-0.004
Awareness level of the industry	0.227	0.615	0.293	0.284	0.260
Knowledge sharing within the industry	0.373	0.670	-0.068	0.291	0.186
Appropriate legislation	0.107	0.731	0.361	-0.024	-0.039
Governmental schemes	0.129	0.841	0.050	-0.122	0.135

When the factor analysis results are to be examined, the process should begin at 5 components or common factors of the variables. First of all, training of employee's, experience level within the firm and effective leadership according to rotated component matrix; are at the same common factor group. Secondly, awareness level of the industry, knowledge sharing within the industry, appropriate legislation and governmental schemes system factors can be grouped in the same common factor group. Thirdly, coordination among project parties, project size and client requirement are at the same common factor group. Fourthly, consulting, supportive organizational culture and BIM policy of the company can be grouped in the same common factor group. Lastly, avail-

ability of information and technology, availability of qualified staff and availability of financial resources can be grouped in the same common factor group (Table 4.19).

Table 4.19. Rotated Component Matrix with Common Factors - Factor Analysis.

Rotated Component Matrix							
Common Factors	Variables Name	Variables	1	2	3	4	5
Common Factor Group 1	Training of employees	VAR00004	0.782	0.054	-0.010	0.147	0.156
	Effective leadership	VAR00009	0.720	0.312	0.021	-0.047	0.173
	Experience level within the firm	VAR00007	0.655	0.114	0.369	0.106	-0.230
Common Factor Group 2	Governmental schemes	VAR00016	0.129	0.841	0.050	-0.122	0.135
	Appropriate legislation	VAR00015	0.107	0.731	0.361	-0.024	-0.039
	Knowledge sharing within the industry	VAR00014	0.373	0.67	-0.068	0.291	0.186
	Awareness level of the industry	VAR00013	0.227	0.615	0.293	0.284	0.260
Common Factor Group 3	Project size	VAR00011	0.044	0.051	0.846	-0.049	0.062
	Client requirement	VAR00012	-0.005	0.458	0.601	0.210	-0.004
	Collaboration/coordination among project parties	VAR00010	0.36	0.347	0.471	0.183	0.022
Common Factor Group 4	Consulting	VAR00005	0.042	-0.011	0.056	0.861	0.115
	Supportive organizational culture	VAR00006	0.215	0.113	0.044	0.81	-0.02
	BIM policy of the company	VAR00008	0.083	0.205	-0.104	0.712	0.094
Common Factor Group 5	Availability of information and technology	VAR00001	0.311	0.179	-0.039	0.115	0.737
	Availability of qualified staff	VAR00003	0.211	0.015	0.305	0.155	0.654
	Availability of financial resources	VAR00002	0.044	0.155	0.571	0	0.637

If it is investigated that there are 5 common factors group of 16 factors (variables) and all of the factors are split into 5 meaningful groups. The first common factors group is very related to organizational subjects and this common factors group can be entitled as “Human Related Factors”. The second common factors group is much related to industrial subjects and this common factors group can be entitled as “Industry Related Factors”, third one can be entitled as “Project Related Factors” and fourth one can be entitled as “Policy Related Factors”. Lastly fifth common factors group is much related to availability related subjects and this common factors group can be entitled as “Resource Related Factors”. New table on rotated component matrix and its factors can be grouped as below.

Table 4.20. Rotated Component Matrix with respect to Common Factors.

Rotated Component Matrix							
Common Factors	Variables Name	Variables	1	2	3	4	5
Human Related Factors	Training of employees	VAR00004	0.782	0.054	-0.01	0.147	0.156
	Effective leadership	VAR00009	0.720	0.312	0.021	-0.047	0.173
	Experience level within the firm	VAR00007	0.655	0.114	0.369	0.106	-0.230
Industry Related Factors	Governmental schemes	VAR00016	0.129	0.841	0.050	-0.122	0.135
	Appropriate legislation	VAR00015	0.107	0.731	0.361	-0.024	-0.039
	Knowledge sharing within the industry	VAR00014	0.373	0.670	-0.068	0.291	0.186
	Awareness level of the industry	VAR00013	0.227	0.615	0.293	0.284	0.260
Project Related Factors	Project size	VAR00011	0.044	0.051	0.846	-0.049	0.062
	Client requirement	VAR00012	-0.005	0.458	0.601	0.210	-0.004
	Collaboration/coordination among project parties	VAR00010	0.360	0.347	0.471	0.183	0.022
Policy Related Factors	Consulting	VAR00005	0.042	-0.011	0.056	0.861	0.115
	Supportive organizational culture	VAR00006	0.215	0.113	0.044	0.810	-0.020
	BIM policy of the company	VAR00008	0.083	0.205	-0.104	0.712	0.094
Resource Related Factors	Availability of information and technology	VAR00001	0.311	0.179	-0.039	0.115	0.737
	Availability of qualified staff	VAR00003	0.211	0.015	0.305	0.155	0.654
	Availability of financial resources	VAR00002	0.044	0.155	0.571	0.000	0.637

Moreover, before rotation processes, common factors group 1 (Human Related Factors) consists of 33.051% of total extraction sums of squared loadings. Common factors group 2 (Industry Related Factors) consists of only 11.660% of total extraction sums of squared loadings, Common factors group 3 (Project Related Factors) consists of only 8.781% of total extraction sums of squared loadings, Common factors group 4 (Policy Related Factors) consists of only 7.483% of total extraction sums of squared loadings and Common factors group 5 (Resource Related Factors) consists of only 5.900% of total extraction sums of squared loadings of total extraction sums of squared loadings. However, it should also be explained the percentage of variances of "rotation sums of squared loadings" of components (common factors groups) (Table 4.20).

After rotation processes, common factors group 1 (Human Related Factors) consists of 18,692% of total rotation sums of squared loadings. Common factors group 2 (Industry Related Factors) consists of only 15.416% of total rotation sums of squared loadings and common factors. Common factors group 3 (Project Related Factors) consists of only 13.092% of total rotation sums of squared loadings and common factors. Common factors group 4 (Policy Related Factors) consists of only 10.864% of total rotation sums of squared loadings and common factors and common factors group 5

(Resource Related Factors) consists of only 7.811% of total rotation sums of squared loadings (Table 4.21).

Table 4.21. Total Variance Explained.

Total Variance Explained									
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.288	33.051	33.051	5.288	33.051	33.051	2.991	18.692	18.692
2	1.866	11.660	44.710	1.866	11.660	44.710	2.627	16.416	35.108
3	1.405	8.781	53.491	1.405	8.781	53.491	2.095	13.092	48.200
4	1.197	7.483	60.974	1.197	7.483	60.974	1.738	10.864	59.063
5	0.944	5.900	66.874	0.944	5.900	66.874	1.250	7.811	66.874
6	0.807	5.046	71.920						
7	0.777	4.856	76.776						
8	0.612	3.823	80.600						
9	0.607	3.791	84.391						
10	0.48	3.002	87.393						
11	0.444	2.775	90.167						
12	0.402	2.510	92.678						
13	0.365	2.284	94.962						
14	0.333	2.081	97.043						
15	0.27	1.685	98.728						
16	0.203	1.272	100.000						
Extraction Method: Principal Component Analysis.									

4.1.6. Common Factors

- Factor 1 represents Human Related Factors;
- Factor 2 represents Industry Related Factors
- Factor 3 represents Project Related Factors;
- Factor 4 represents Policy Related Factors;
- Factor 5 represents Resource Related Factors.

4.1.6.1. Factor 1. This factor accounts for 18.692% of the total variances of critical success factors. The components of human related factors are, training of employee's, experience level within the firm and effective leadership.

Table 4.22. Human Related Factors.

Common Factors	Variables Name	Variables	1	2	3	4	5
Human Related Factors	Training of employees	VAR00004	0.782	0.054	-0.010	0.147	0.156
	Effective leadership	VAR00009	0.720	0.312	0.021	-0.047	0.173
	Experience level within the firm	VAR00007	0.655	0.114	0.369	0.106	-0.230

The human related factors have many aspects such as training of employee's and effective leadership. These two sub-factors have a high loading, with a significance of 0.782 and 0.720, respectively (Table 4.22).

Effective leadership has a vital role for achievement of process improvement and capacity building for the targeted productivity. Visible support and leadership by the senior management for innovative training programs is important for the successful conduit of the BIM adoption and up skilling the company staff (Arayici & Coates, 2013). Respectively, clients and management teams shall reconsider the organization personnel needs in order to facilitate the BIM implementation.

Concerning personnel needs, they shall consider changes in the organizational structure, new roles and responsibilities, training of the existing personnel or hiring new professionals with the necessary expertise and experience (Karathodoros, *et al.*, 2013).

The other high loading sub-factor is experience level within the firm with a significance of 0.655. The overall BIM training and learning experience also showed that the best way to learn for learners is to construct their own knowledge rather than someone constructing it for them. This experience also coincides with the Constructivist Learning Theory, which states that learning is an active process of creating meaning from different experiences. In other words, students or learners will learn best by trying to make sense of something on their own with the teacher as a guide to help them along the way (Arayici & Coates, 2013).

4.1.6.2. Factor 2. The industry related factors is responsible for 16.416% of the total variances of critical success factors. There are four factors in this category awareness level of the industry, knowledge sharing within the industry, appropriate legislation and governmental schemes system factors.

Table 4.23. Industry Related Factors.

Common Factors	Variables Name	Variables	1	2	3	4	5
Industry Related Factors	Governmental schemes	VAR00016	0.129	0.841	0.050	-0.122	0.135
	Appropriate legislation	VAR00015	0.107	0.731	0.361	-0.024	-0.039
	Knowledge sharing within the industry	VAR00014	0.373	0.670	-0.068	0.291	0.186
	Awareness level of the industry	VAR00013	0.227	0.615	0.293	0.284	0.260

Industry Related Factors have one critical factor namely Governmental schemes with significance of 0.841(Table 4.23). A governmental scheme plays a critical role of proposing innovative solutions to meet government's objectives for the BIM project. The legal status for project implementation should be guaranteed by an appropriate risk framework thus the government examines all aspects of the legal requirements most important to the successful realization of the projects in deciding the use of BIM method.

Appropriate legislation (significance of 0.731) is one of the crucial points to coordinate and standardize the using of BIM systems. BIM systems supporting with legislation can be established more firmly both private and public sectors.

Knowledge sharing within the industry culture is the third important component (significance of 0.670). In many organizations multi-disciplinary teams are experiencing conflicts, complexities, uncertainties and ambiguities with traditional practices (e.g. business models, processes, legal and compensation schemes, etc.) that impede knowledge sharing and supportive organizational environment which cause duplication of processes on a daily basis (Khosrowshahi, *et al.*, 2012).

Another most important sub-factor is Awareness level of the industry, with significance of 0.615. To conduct industry related factors, awareness level of the industry is another important factor with a fairly high loading (significance of 0.602). At the strategic level, lean principles which are: eliminate waste, increase feedback, delay decision, deliver fast, build-in integrity, empower the team, see the whole have been utilized and they formed the seven pillars of the BIM implementation strategy. There was no practical understanding and awareness of BIM in the company at the beginning

of the project. Yet, senior managers of the company had some visionary understanding of BIM for investment to attain competitive advantage and better position in market place and provide sustainable green design solutions in the future (Arayici, *et al.*, 2011).

4.1.6.3. Factor 3. Project related factors component accounts for 13.092% of the total variances in CSFs. There are three variables in this principal factor: coordination among project parties, project size and client requirement.

Table 4.24. Project Related Factors.

Common Factors	Variables Name	Variables	1	2	3	4	5
Project Related Factors	Project size	VAR00011	0.044	0.051	0.846	-0.049	0.062
	Client requirement	VAR00012	-0.005	0.458	0.601	0.21	-0.004
	Collaboration/coordination among project parties	VAR00010	0.360	0.347	0.471	0.183	0.022

Higher loading is associated with project size, with a significance of 0.846 (Table 4.24). The use of BIM would be undertake a more finely grained analysis of on the individual projects to discover the extent to which benefits are contingent upon specific project characteristics, such as project size, value and complexity (Bryde, *et al.*, 2012).

Client requirement is the second important component has a loading with a significance of 0.601. Applications requiring a more long term perspective in the production process, such as planning and scheduling of production and material requirements and purchases, are constrained by short term requirements of immediate actions and clients that characterize the industry (Linderoth, 2009). As stated by Amponsah (2010) lately, client satisfaction with both the products and services delivered by the sector put stress on service providers to improve performance.

The third factor in the project related factors is thorough collaboration/coordination among project parties, which has a significance of 0.471. BIM as an IT-enabled, open standards-based deliverable and collaborative process is referring to Building information Modelling. In this category BIM is considered a process where the model is developed and used to increase the project efficiency. This process intends also to en-

hance collaboration and coordination among disciplines and other activities (Eastman, *et al.*, 2011). BIM uses digital modelling to simulate the planning, design, construction and operation of a project (Azhar, 2011). The main focus of BIM is therefore the design functions and collaboration between project parties.

4.1.6.4. Factor 4. The policy related factors is responsible for 10.864% of the total variances of critical success factors. There are three factors in this category consulting, supportive organizational culture and BIM policy of the company.

Table 4.25. Policy Related Factors.

Common Factors	Variables Name	Variables	1	2	3	4	5
Policy Related Factors	Consulting	VAR00005	0.042	-0.011	0.056	0.861	0.115
	Supportive organizational culture	VAR00006	0.215	0.113	0.044	0.810	-0.020
	BIM policy of the company	VAR00008	0.083	0.205	-0.104	0.712	0.094

Consulting (significance of 0.861) is important to clarify the benefits of BIM on the project. Consulting organizations in the Turkish AEC Industry to determine the industrial state of the art in information and communication technology implementation from a strategic perspective along with the strategic role of information and communication technology within the organizations in the industry (Isikdag, *et al.*, 2009).

Supportive organizational culture is the second important component (significance of 0.810). In many organizations multi-disciplinary teams are experiencing conflicts, complexities, uncertainties and ambiguities with traditional practices (e.g. business models, processes, legal and compensation schemes, etc.) that impede knowledge sharing and supportive organizational environment which cause duplication of processes on a daily basis (Khosrowshahi, *et al.*, 2012).

The third factor in the experience factors is thorough BIM policy of the company, which has a significance of 0.712. BIM complements the company policy to deliver zero loss making projects, zero environmental incidents, zero accidents, zero ethical breaches

and with zero defects (The Salford Centre for Research & Innovation, SCRI, 2011).

4.1.6.5. Factor 5. Administrative factors accounts for 7.811% of the total variables of critical success factors. There are three components under this factor grouping: availability of information and technology, availability of qualified staff and availability of financial resources.

Table 4.26. Resource Related Factors.

Common Factors	Variables Name	Variables	1	2	3	4	5
Resource Related Factors	Availability of information and technology	VAR00001	0.311	0.179	-0.039	0.115	0.737
	Availability of qualified staff	VAR00003	0.211	0.015	0.305	0.155	0.654
	Availability of financial resources	VAR00002	0.044	0.155	0.571	0.000	0.637

Higher loading is associated with availability of information and technology with a significance of 0.737 and another most important sub-factor is availability of qualified staff, with significance of 0.654 (Table 4.26). Building Information Modelling has become an active research area in order to tackle the problems related to information management and interoperability and the solution is related to the level of technological development (Isikdag, *et al.*, 2009). BIM is seen as an efficient information management methodology within construction projects. It heavily involves people's perspective, firstly as creators or collectors of data from the site and other sources, and secondly, as users of processed data, i.e. information or knowledge, from the building models (Arayici, *et al.*, 2009). BIM in construction provides the reader with information regarding new technological innovations and applications that can make the information transfer more effective (Löf, *et al.*, 2012).

Another higher loading is associated with availability of financial resources with a significance of 0.637 (Table 4.26). BIM systems pre-investments are expensive than the traditional methods. Companies should assess their financial availability when implementing BIM systems. BIM is much more useful in the long-term use when considering BIM's return on investment ratio. The immediate beneficiaries are often

junior staff and trainees, while the senior staff is the main contributors in terms of both specialist knowledge and financial resources.

4.2. Case Studies

In this section, answers of the respondent people in construction companies are evaluated. Results of the interviews are presented as case studies since it would be misleading to generalize some perceptions, implementation and applications about BIM due to the BIM level of usage, organizational structure, characteristics, visions and cultures of the construction companies.

Table 4.27 shows some general information about the companies and the interviewees.

Table 4.27. Case Study Interviewee Table.

Company	Main Business Area	Company Age	Annual Turnover	Number of Employees	Position in Company	BIM Maturity Level
A	Consultant	9	10000000	20	Vice General Manager	Level 3
B	Principal Contractor	55	350000000	10000	BIM Manager	Level 1
C	Principal Contractor	58	50000000	30	Architect	Level 1
D	Designer	9	not specified	130	Board Member	Level 1
E	Client	55	150000000	200	Project Coordinator	Level 2
F	Designer	58	not specified	120	Architect	Level 2
G	Designer	9	2000000	35	Project Manager	Level 1
H	Principal Contractor	55	1000000000	13614	Architect	Level 2
I	Principal Contractor	58	850000000	5000	Architect	Level 1
J	Consultant	3	600000	8	Board Member	Level 2
K	Principal Contractor	18	not specified	3000	Engineer	Level 2

All interviewees were the key implementers of BIM stage of their companies during BIM implementation phases.

4.2.1. Administration of the Case Studies

This research consists of eleven face-to-face interviews that were carried out in the companies with the interviewee respondents at the managerial level (Figure 4.3).

Each interview took about 2 hours. There was a case study form given at Appendix B. The construction companies, participated in this study, are key implementers at the implementation phase of BIM in their companies. Therefore, they know what was right and what was wrong about the implementation phase of the systems.

The case study questions were developed through a review of 48 literatures on BIM worldwide and through an internal BIM special interest group meetings and discussions in the Bogaziçi University. These questions reflected the concerns highlighted in the literature and provided us with an opportunity assess equivalent issues in Turkey. Questionnaire for the case studies have been circulated to the industry representatives and the future works for the BIM development status in Turkish construction industry is still continuing and 11 respondents have returned the filled in questionnaire so far. The extracted case studies information will be based on these responses in hand.

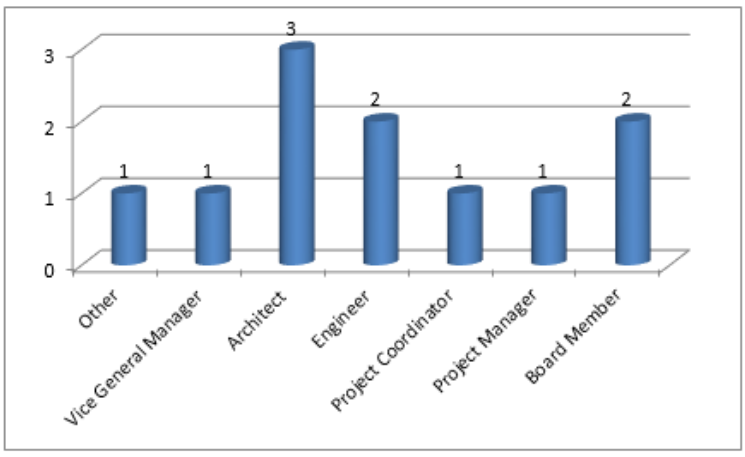


Figure 4.3. Respondents' Position.

Companies use fourteen different BIM tools (Figure 4.4). Company A decided to use Revit architecture, Revit structure, Revit MEP, ArchiCAD, Navisworks, Tekla Structure, Allplan and XPM. Company B use to design their BIM projects with Revit architecture and Revit structure. Company C use Revit architecture and ArchiCAD. Company D uses Revit MEP and ArchiCAD. Company E uses only Allplan and also company F, H and I are using only Revit architecture. Company G and J prefer to use Revit architecture, Revit structure, Revit MEP and Navisworks. And finally Company

K use lots of tools to design BIM projects like Revit architecture, Revit structure, Revit MEP, Bentley architecture, Bentley structure, Bentley mechanical, Bentley electrical, Navisworks, Vico and Synchro.

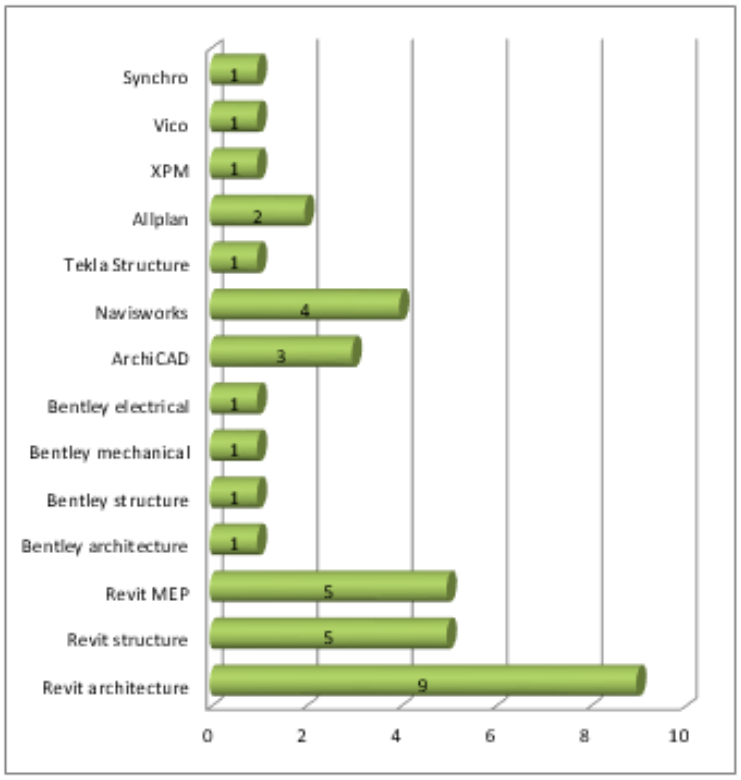


Figure 4.4. Software Usage of BIM.

BIM can be defined differently by various people due to their perceptions, background and experiences. Some consider BIM as object-oriented modeling technology and others assert that IFC as the intermediate data model is itself BIM. Therefore, it is necessary for this research to establish a common definition, which would be based on an analytical framework which describes BIM in terms of maturity level of end use. The BIM maturity stages provided a systematic framework for the classification of the BIM implementation.

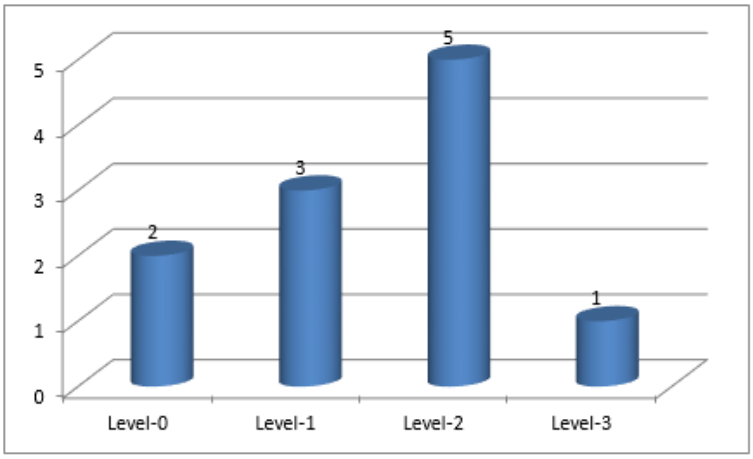


Figure 4.5. BIM Implementation Levels of Firms.

In order to obtain the Turkish construction industry approaches and understanding towards BIM for assessing how much the industry has evolved and for measuring the readiness of the industry for BIM implementation. As a result of surveys conducted by the 11 firms, identification of BIM implementation level based on application requirements as shown as Figure 4.5. Level 0, two project implemented at this stage, is considered the starting level of BIM. Two project managed CAD in 2D or 3D format and commercial data will be managed by standalone finance and cost management packages with no integration as named Level-1. Level-2 is the level of BIM may utilize 4D construction sequencing and/or 5D cost information and also this level of implementation of most projects with five projects. Moreover, only one project implemented as level-3 which mean BIM implemented at the every stage of the project life-cycle. This project stands out as the most detailed and largest project implemented BIM in Turkish industry.

Taking all these into account, implementation level based on one and one questionnaires results shows us BIM implementation level of Turkish construction industry has passed the initial stage to the development stage.

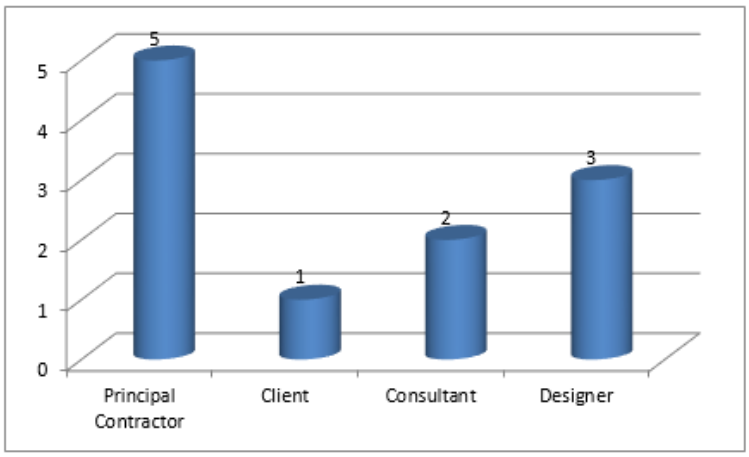


Figure 4.6. Main Business Areas of Firms.

BIM is mostly implemented by the principal contractor with five projects in Turkish construction industry based on survey results. Design firms are following principal contractors carrying out three BIM projects. One client and two consultants are carrying out BIM projects in the eleven sampled case studies (Figure 4.6).

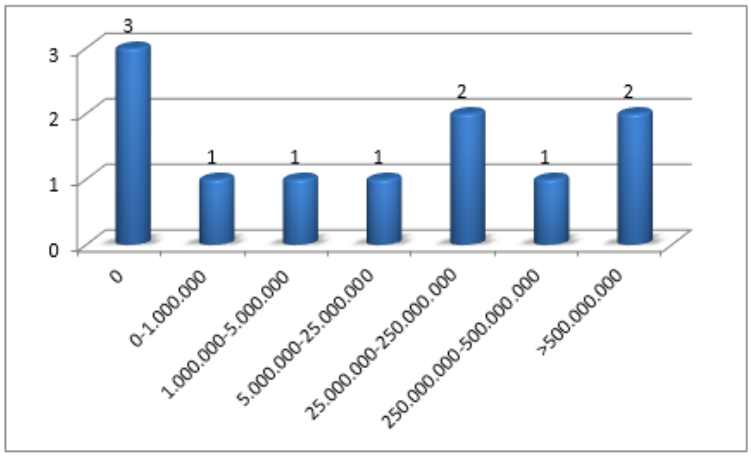


Figure 4.7. Total Turnover of Companies (Dollar).

- Small scale firms: employing less than fifty employees and its annual net sales revenue or financial balance sheet of businesses that do not exceed five million dollar.
- Medium sized firms: employing less than two hundred and fifty employees and its annual net sales revenue or financial balance sheet of businesses that do not exceed twenty five million dollar (KOSGEB, 2005).

Considering the one-one case studies with the eleven firms, it can be said that firms implementing BIM projects are generally large-scale firms. Considering defined conditions above two firms are small scale firms, one firm can be count as medium sized firms and five firms are large scale firms based on one to one survey conducted with eleven firms (Figure 4.7). And also three companies didn't share their annual turnover due to their company policy.

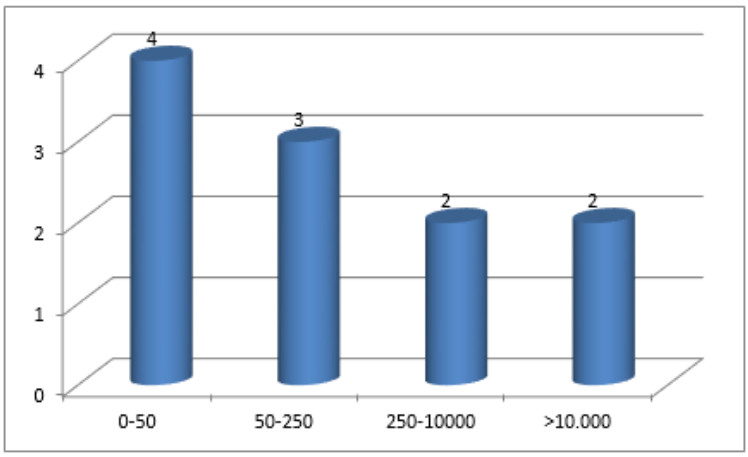


Figure 4.8. Number of Employees in Firms.

When companies classified according to the number of employees four firms considered as small-scale companies, three companies are medium sized companies and four firms considered as large-scale firm based on one to one survey conducted with eleven firms (Figure 4.8). When this table also viewed large-scale and small-scale firms stand out in BIM applications like firms implementing BIM based on their total turnover.

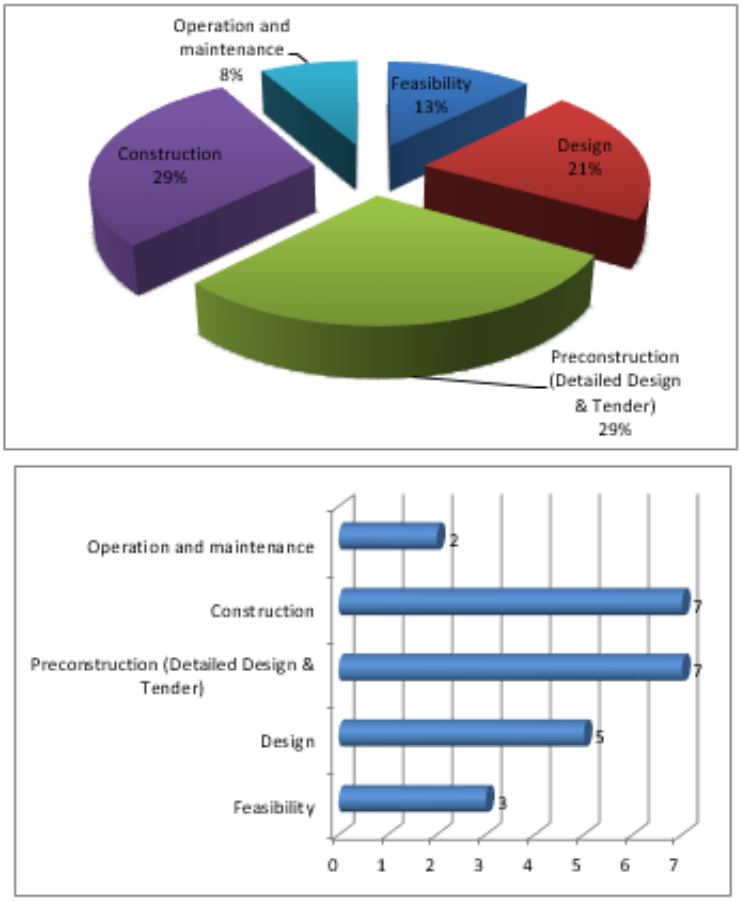


Figure 4.9. Implementation Stage of the Project Life Cycle.

Companies are often implementing construction and preconstruction stages of BIM applications. Design and feasibility stages are the most practical stage of BIM philosophy. BIM implementation of operations and maintenance takes place in a project is executed at the highest level of BIM philosophy (Figure 4.9). The implementation of this phase with two projects in Turkey is an indication of the high size of the BIM philosophy will be applied in the future.

BIM is also introduced in infrastructure projects with LOD 400 level in Turkey shows that Turkey will produce arbiter BIM projects which have a success in the international arena.

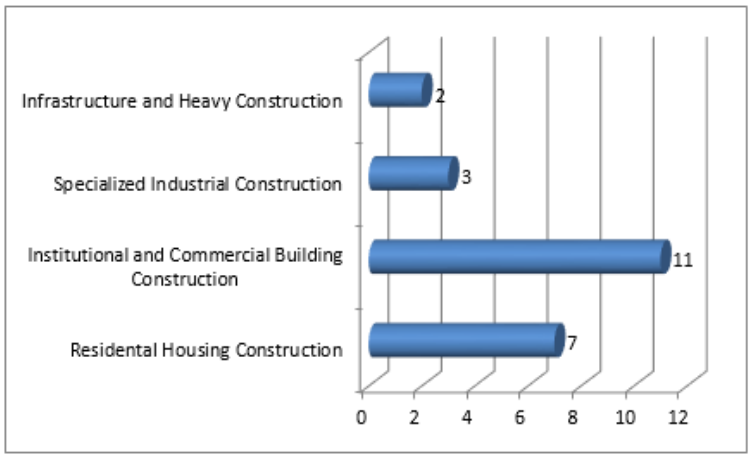


Figure 4.10. Type of the Project.

BIM projects usually was applied at institutional and commercial building construction with eleven projects and residential housing construction with seven projects based on one to one survey conducted with eleven firms (Figure 4.10). Referring to Figure 4.10 it can be easily seen that less of the BIM project implementation tasks that require more specific processes such as infrastructure and heavy construction and specialized industrial construction.

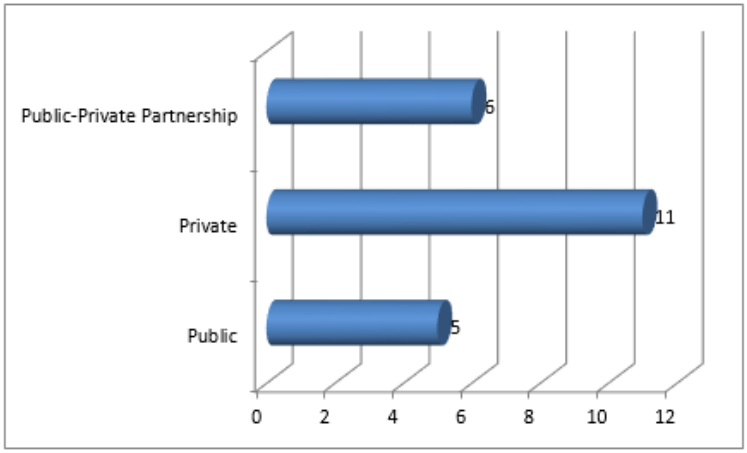


Figure 4.11. Type of the Client of the Project.

Case studies generated with one to one interviews conducted with companies interested in BIM shows that BIM is usually used by the private sector with eleven projects in Turkish construction industry illustrated at the Figure 4.11. It is observed

that in public projects began to be used BIM as a result of the new developments taking place in public institutions with five public projects and 6 public-private partnership projects. Subcontractors used BIM seeing the benefits of the use of BIM by the initiative in public project rather than the procurement requirements. Putting BIM as a precondition in Construction of the rail system tender by the public authority will encourage the use of BIM to use of more projects in all parts of the public sector.

4.2.2. Analysis of the Case Studies

Company A is a consultant firm that has an annual turnover of $ 10 million. The company having 9 years of experience in the sector has 20 employees. Companies that implement BIM project size of $ 250 million and the project took 360 days. Project which has a 250.000 square meters construction area BIM investment cost was 20.000 dollar. Twenty percent cost savings achieved and provided a two-month gain in the project with BIM implementation.

Company B is a principal contractor firm that has an annual turnover of $ 350 million. The company having 55 years of experience in the sector has 10.000 employees. Companies that implement BIM project size of $ 3 billion and the project took 36 month. Project which has a 650.000 square meters construction area BIM investment cost was $ 15 million. For this case BIM income is not calculated from company because the project team was created for to compensate the tender requirements.

Company C is a principal contractor firm that has an annual turnover of $ 50 million. The company having 58 years of experience in the sector has 30 employees. Companies that implement BIM project size of $ 100 million and the project took 36 months. Project has a 70.000 square meters construction area. Further information about the BIM data could not be reached because of privacy policy of firm.

Company D having 58 years of experience in the sector is a design firm. The company has 130 employees. Companies that implement BIM project size of $ 750 million and the project took 36 months. Project has a 450.000 square meters construc-

tion area. Further information about the BIM data could not be reached because of privacy policy of firm.

Company E is an employer firm that has an annual turnover of $ 150 million. The company having 30 years of experience in the sector has 200 employees. Companies that implement BIM project size of $ 60 million and the project took 22 months. Project which has a 85.000 square meters construction area BIM investment cost was 500.000 dollar. Although there is no time saving 500.000 dollar cost savings achieved in the project with BIM implementation.

Company F having 58 years of experience in the sector is a design firm. The company has 120 employees. Companies that implement BIM project size of $ 750 million and the project took 24 months. Project has a 600.000 square meters construction area. Further information about the BIM data could not be reached because of privacy policy of firm.

Company G is a design firm that has an annual turnover of $ 2 million. The company having one year of experience in the sector has 35 employees. Companies that implement BIM project size of $ 250 million and the project took 30 months. Project has a 150.000 square meters construction area. Further information about the BIM data could not be reached because of privacy policy of firm.

Company H is a principal contractor firm that has an annual turnover of $ 1 billion. The company having 58 years of experience in the sector has 13.614 employees. Companies that implement BIM project size of $ 640 million and the project took 24 month. Project which has a 496.000 square meters construction area. Further information about the BIM data could not be reached because of privacy policy of firm.

Company I is a principal contractor firm that has an annual turnover of $ 850 million. The company having 49 years of experience in the sector has 5.000 employees. Companies that implement BIM project size of $ 1.8 billion and the project took

24 month. Project which has a 108.000 square meters construction area. Further information about the BIM data could not be reached because of privacy policy of firm.

Company J is a consultant firm that has an annual turnover of 600.000 dollars. The company having 3 years of experience in the sector has 8 employees. Companies that implement BIM project size of $ 2.3 billion and the project took 36 months. Project which has a 700.000 square meters construction area BIM investment cost was $ 2 million. $ 4 million cost savings achieved and provided a three-month gain in the project with BIM implementation.

Company K is a principal contractor firm. The company having 18 years of experience in the sector has 3.000 employees. Companies that implement BIM project size of $ 409 million and the project took 36 month. Project which has a 650.000 square meters construction area. Further information about the BIM data could not be reached because of privacy policy of firm.

Table 4.28. BIM Drivers Levels of Effects.

DRIVERS	FIRMS											Mean
	A	B	C	D	E	F	G	H	I	J	K	
End-User (Client) Requirement	5	5	1	5	5	5	4	4	3	5	5	4.3
Project Performance Improvement	5	4	4	4	3	5	4	5	3	4	5	4.2
Increased Coordination	5	5	5	4	5	5	5	5	4	5	5	4.8
Corporate Performance Improvement	5	4	4	4	3	4	3	4	1	3	3	3.5
Technology	5	4	4	4	4	4	5	4	3	3	3	3.9
Regulation	5	5	1	1	1	1	2	4	4	1	1	2.4
Sustainability / Green Buildings	4	1	1	1	4	4	4	1	1	1	1	2.1

4.2.2.1. Drivers. Increased coordination emerges as the most important driver when analyzed the responses of 11 companies. Project Performance Improvement, End-User (Client) Requirement, Corporate Performance Improvement and Technology are stand out as other vital drivers.

Table 4.29. Citations of Drivers.

#	Drivers of BIM	Citations
1	End-User (Client) Requirement	11/48
2	Project Performance Improvement	46/48
3	Increased Coordination	40/48
4	Corporate Performance Improvement	41/48
5	Technology	21/48
6	Regulation	17/48
7	Sustainability / Green Buildings	14/48

Considering these factors in literature, results is parallel with the case study work (Table 4.29). Project Performance Improvement, Increased Coordination and Corporate Performance Improvement can be count as high level effect of driven forces.

If what distribution of BIM drivers' levels of effects is examined that, it can be seen at the Table 4.28. When "End-User (Client) Requirement" is examined, it can be seen that End-User (Client) Requirement mean is 4.3 and also only firm C were seen this factor very ineffective for BIM driven force. When "Project Performance Improvement" is examined, it can be seen that Project Performance Improvement mean is 4.2. When "Increased Coordination" is examined, it can be seen that Increased Coordination has a high mean as 4.8. All companies except Firm D and Firm I gave full points for this factors importance.

Also, when "Corporate Performance Improvement" is examined, it can be seen that Corporate Performance Improvement mean is 3.5. A weird result has come from the case study that Technology factors mean is 3.9. Although technology had a low citation in the literature, high level of importance was attributed in the case studies. Finally, Regulation and Sustainability / Green Buildings had a low means in the case with 2.4, 2.1 respectively.

BIM is a new technology that brings with it a new method of working which

is aiming to revolutionize and make the construction process more responsive to of the end-user's needs. Many processes and information exchanges in the construction industry support these broad interests, and so BIM final products focus on the user requirements.

BIM implementation has forced technology change and process change within the organizations which will force much improvement of the organizational capabilities and project or corporate performance. The changes and improvements required to achieve fully integrated project teams which will be possible with increasing coordination. If industry overcomes existing organizational and behavioral barriers, further improvements in project performance are to be fully realized in the future.

With the rise of integrative technology and methods like BIM there will be fundamental changes regarding professional standards of care and how the building process is regulated. Regulations and sustainability issues do not appear as driving forces for BIM as clearly seen from the case studies. Government should developed and formalized legal regulations relating to digital design technology whereas the relevant ministries should started documenting and defining standards for BIM.

Table 4.30. BIM Inputs Levels of Effects.

INPUTS	FIRMS											Mean
	A	B	C	D	E	F	G	H	I	J	K	
Human Resources	5	5	4	5	1	4	4	4	2	4	4	3.8
Financial Resources	5	5	2	4	4	4	4	4	2	4	4	3.8
Information	5	5	4	5	4	5	4	5	3	5	5	4.5
Training	5	5	3	5	2	5	4	3	3	5	5	4.1
Consulting	5	5	1	5	5	4	4	4	4	5	5	4.3

4.2.2.2. Inputs. Information emerges as the most crucial input when analyzed the responses of 11 companies. Training and consulting are stand out as other important inputs (Table 4.30). Considering all these factors in literature, results are nearly same

with the case study work as it can be easily seen in the Table 4.31.

Table 4.31. Citations of Inputs.

#	Inputs of BIM	Citations
1	Human Resources	24/48
2	Financial Resources	17/48
3	Information	43/48
4	Training	27/48
5	Consulting	25/48

When it is examined that how input factors have an effect of companies BIM implementation, it can be seen from the Table 4.30 that about all of the firms have answered as that substantially all the factors listed above have a significance role for implementation. When "Human Resources" is examined, it can be seen that Human Resources mean is 3.8 and also only firm E were seen this factor very ineffective for BIM input. When "Financial Resources" is examined, it can be seen that Financial Resources has the same mean with the Human Resources that is 3.8. When "Information" is examined, it can be seen that Increased Coordination has a high mean as 4.5. All companies except firm D I gave high points for this factors importance. Also, when "Training" is examined, it can be seen that Training mean is 4.1. When "Consulting" is examined, it can be seen that Consulting mean is 4.3. Considering the case study analysis consulting and training are high levels of importance.

The implementation of BIM into a company will require various time, money, training, human resources and consulting. BIM inputs should be dealt with on the basis of factors and it should be evaluated. Companies evaluated the inputs in detail as seen in the case study results. Huge reductions in timescale and the use of material and human resource should be recorded, all of which added value whilst having a very positive affect on profit margins. Moreover mismanages human resources more expensive ones for firms.

Firm A employed 20 people for only as BIM team. The cost of BIM office is approximately 60.000 dollar per month. Company A trains their BIM team constantly and regularly to get maximum efficiency from their BIM concept. The flexibility characteristic is also consistent with the general drive within the construction industry to improve team effectiveness through planned and efficient use of human resources to ensure that Firm A giving consultancy services to other firms to redound awareness and experience. The previous experiences and BIM information of the Company A helped better allocate financial resources and staff to reduce risk.

Firm B employed 150 architects for their BIM team to achieve project target. Firm B spent 5 million dollar for software's, computers and infrastructure of BIM. 3 months spent on information gathered. Company B's BIM manager said about information that "For implementation of information systems to be successful and make an effective contribution to the implementation of a business strategy requires that there is a strategic fit between the business strategy and the external domain". Many experienced and Revit conversant Architects hired within the sector. BIM expert advice received from domestic and overseas during the project and also Revit training received from Firm B.

Firm F spent 500.000 dollar for their BIM implementation. Firm F allocated 2 months for information of CAD integration plans. Firm F paid 500.000 dollar to consulting company as a consulting.

Table 4.32. BIM Barriers Levels of Effects.

BARRIERS	FIRMS											Mean
	A	B	C	D	E	F	G	H	I	J	K	
Lack of Financial Resources	5	1	4	1	4	3	3	1	1	2	2	2.5
Lack of Clear Benefits	5	1	3	3	3	2	3	3	1	2	2	2.5
Unsupportive Organizational Culture	5	5	5	5	4	2	3	4	3	4	4	4.0
Lack of Experience	3	1	4	5	3	3	5	4	4	5	4	3.7
Lack of Awareness	5	5	5	5	2	1	5	4	4	5	4	4.1
Lack of Qualified Staff	4	3	4	5	3	4	5	4	4	5	3	4.0
Lack of Governmental Support	2	5	5	5	5	5	3	5	3	5	5	4.4
Fragmented Nature of Construction Industry	5	1	4	5	5	4	4	1	1	2	2	3.1
Temporary Nature of Projects	1	1	4	1	5	1	3	2	4	2	2	2.4

Lack of Governmental Support emerges as the most vital barriers when analyzed the responses of 11 companies. Lack of Awareness and Lack of Qualified Staff are stand out as other crucial barriers (Table 4.32). Considering all these factors in literature, results show differences between the case study works as it can be easily seen in Table 4-20. When analyzed 48 selected articles it is observed that Fragmented Nature of Construction Industry was mentioned in 25 of 48 articles. Lack of Clear Benefits, Lack of Experience and Lack of Awareness can be count as crucial barriers when considering the number of citations.

Table 4.33. Citations of Barriers.

#	Barriers of BIM	Citations
1	Lack of Financial Resources	13/48
2	Lack of Clear Benefits	21/48
3	Unsupportive Organizational Culture	17/48
4	Lack of Experience	21/48
5	Lack of Awareness	20/48
6	Lack of Qualified Staff	14/48
7	Lack of Governmental Support	13/48
8	Fragmented Nature of Construction Industry	25/48
9	Temporary Nature of Projects	3/48

BIM technology in itself cannot contribute to solving the individual, organizations, or sectors problems; in fact it can be said to create a whole new set of problems. The processes described seek to offer some practical benefits by helping organizations overcome implementation difficulties and thereby enable BIM benefits to be realized. If what dispersion of BIM barriers levels of effects distributed by firm is examined that, it can be seen at the Table 4.32.

When “Lack of Financial Resources” is examined, it can be seen that Lack of Financial Resources mean is 2.5 and also only firm A were seen this factor very effective for BIM barrier. When “Lack of Clear Benefits” is examined, it can be seen that Lack of Clear Benefits mean is also 2.5. When “Unsupportive Organizational Culture” is examined, it can be seen that Unsupportive Organizational Culture has a one of the high mean as 4.0. Firm A, B, C and Firm D gave full points for this factors importance.

Additional barriers to BIM adoption include technical problems (compatibility and reliability of data and data exchange), team fragmentation, and lack of training and business process related issues.

Also, when “Lack of Experience” is examined, it can be seen that Lack of Experi-

ence mean is 3.7. When "Lack of Awareness" is examined, it can be seen that Lack of Awareness mean is also 4.1. A weird result has come from the case study compared to citations that Lack of Qualified Staff mean is 4.0 and Lack of Governmental Support mean is 4.4. When "Lack of Governmental Support" is examined, it can be seen that Lack of Governmental Support has a high mean as 4.4.When looking at the citations Qualified Staff and Lack of Governmental Support do not have a high level of importance considered as a BIM implementation barriers. All companies except Firm A, Firm G and Firm I gave a high points for this factors importance.

BIM and associated integrated activities offers an opportunity to mend something of the fragmented nature of the construction industry. For this reason, when "Fragmented Nature of Construction Industry" is examined, it can be seen that Fragmented Nature of Construction Industry has a mean as 3.1. Finally, Temporary Nature of Projects had a low means in the case with 2.4. Moreover, when looking at the citations Temporary Nature of Projects also has low citations.

Significant barriers to BIM implementation exist in Turkey today. It is clear that there is considerable potential for improvement of construction project organization, and contractual provisions in connection with the use of BIM technology and implementation methodologies. The standardization of supporting mechanisms for strategic BIM implementation may offer a solution to address a number of these barriers. On considering propositions on how we can reduce, remove or change implementation barriers, a first step may be to standardize those mechanisms that are key to implementation and meaningful information authoring and sharing. The supporting mechanisms described may be seen as key to a move towards a more integrated approach.

It has been suggested that in Turkey the drive for BIM implementation is being led by a small number of technical enthusiasts, not by client demand. With this in mind it is difficult to imagine convergence of approach and the production of common implementation standards emerging without some form of standards body taking the initiative. Furthermore, a fragmented sector, with individual organizations looking after their own interests, serves as no vehicle for an easy transition towards a more

integrated approach, quite the opposite. For this reason, the push and pull of BIM implementation in Turkey may need to change its dynamic.

Further effort, within the remit of this study is to identify where BIM implementation is appropriate and how the barriers to up-take can be overcome, with the objective of establishing industry protocols for future ways of working.

Table 4.34. BIM Barriers Levels of Effects.

ENABLERS	FIRMS											Mean
	A	B	C	D	E	F	G	H	I	J	K	
Collaborative Partnering	5	5	4	5	3	4	4	4	3	4	4	4.1
Supportive Work Environment	5	5	3	5	3	5	4	4	1	3	4	3.8
Leadership	5	5	5	5	3	4	3	4	1	5	5	4.1
BIM Policy of the Company	5	3	5	5	1	5	4	4	1	5	5	3.9
Government Schemes	1	1	1	1	1	1	2	1	1	1	1	1.1

4.2.2.3. Enablers. Collaborative Partnering and Leadership occur as the most important enabler when analyzed the responses of 11 companies. Supportive Work Environment, Leadership and BIM Policy of the Company can be count as other important enablers (Table 4.34). Considering all these factors in literature, results are similar with the case study work as it can be easily seen in the Table 4.35.

Table 4.35. Citations of Enablers.

#	Enablers for BIM	Citations
1	Collaborative Partnering	38/48
2	Supportive Work Environment	37/48
3	Leadership	13/48
4	BIM Policy of the Company	31/48
5	Government Schemes	7/48

If what dispersion of BIM enabler's levels of effects distributed by firm is examined that, it can be seen at the Table 4.34. When it is examined that how enablers

factors have an effect of companies BIM implementation, it can be seen from the Table 4.34 that about all of the firms have answered as that substantially all the factors listed above except Government Schemes have not a significance role for implementation. When "Collaborative Partnering" is examined, it can be seen that Collaborative Partnering has a highest mean as 4.1 and also this factor have a high citations from the literature review. Firm F's BIM manager said that to highlight Collaborative Partnering positive effects to implementation BIM "These can be achieved by partnering so that consultants and contractors are appointed early in the process. Framework agreements allowing teams to work together on a series of projects. Design Build and Operate contracts where the benefits of using BIMs can be obtained over the lifetime of the building".

When "Supportive Work Environment" is examined, it can be seen that Supportive Work Environment mean is 3.8. When "Leadership" is examined, it can be seen that Leadership has highest mean as 4.1. All companies except Firm E, Firm I and Firm B gave a high points for this factors importance. Also, when "BIM Policy of the Company" is examined, it can be seen that BIM Policy of the Company mean is 3.9. Also BIM Policy of the Company has a high citation ratio considering literature review. Finally, when "Government Schemes" is examined, it can be seen that Consulting mean has a lowest mean with 1.1 as it understood when viewed in the literature study. All firms gave a low point for Government Schemes that can be easily seen at Table 4.34.

Taking all these results into account, without an organizational environment that promotes collaboration and the open and freely exchange of information, such as partnering, the full potential and implementation of integrated systems cannot be realized. There is a huge need to integrate project teams through giving responsibility for the whole process and partnering. Partnering therefore offers a climate where the appropriate culture can be nurtured over a number of projects. Organizational team capability applies to two or more organizations working together to pursue a common mission or deliver a common project/outcome.

The collection of empirical material by participant observation in a partnering project has mainly been used to gain further knowledge of the project context where operations are organized and BIM would be adopted and used.

Table 4.36. BIM Benefits Levels of Effects.

BENEFITS	FIRMS											Mean
	A	B	C	D	E	F	G	H	I	J	K	
Decrease in Cost	4	4	3	3	4	2	3	2	2	3	5	3.2
Decrease in Life Cycle Cost	5	4	4	4	3	2	3	2	2	1	3	3.0
Decrease in Duration	5	4	1	1	2	1	2	1	1	3	3	2.2
Increase in Quality	5	5	4	5	2	4	4	4	2	4	4	3.9
Clash Detection	5	5	4	5	3	5	4	5	3	5	5	4.5
Improvement of Client Satisfaction	5	5	1	5	4	5	4	4	4	5	3	4.1
Better Documentation	5	5	4	3	4	5	4	4	3	4	4	4.1
Increased Integration Communication / Coordination Among Parties	5	5	4	5	4	5	4	5	4	5	5	4.6

4.2.2.4. Benefits. Increased Integration / Communication / Coordination among Parties occurs as the most important benefit when analyzed the responses of 11 companies. Clash Detection, Improvement of Client Satisfaction and Better Documentation can be count as other important enablers (Table 4.36). Considering all these factors in literature, results show differences between the case study works as it can be easily seen in the Table 4.37. When analyzed 48 selected articles it is observed that Decrease in Cost and Increase in Quality were mentioned in 39 of 48 articles. Increased Integration/Communication/Coordination among Parties and Decrease in Duration can be count as crucial barriers when considering the number of citations.

Table 4.37. Citations of Benefits.

#	Benefits of BIM	Citations
1	Decrease in Cost	39/48
2	Decrease in Life Cycle Cost	22/48
3	Decrease in Duration	31/48
4	Increase in Quality	39/48
5	Clash Detection	20/48
6	Improvement of Client Satisfaction	6/48
7	Better Documentation	14/48
8	Increased Integration/Communication/Coordination Among Parties	32/48

Building Information Modelling is rapidly growing within the Turkish construction industry. BIM's current utilization shows great effects on projects in terms of performance, time and cost. If what dispersion of BIM benefits levels of effects distributed by firm is examined that, it can be seen at the Table 4.36.

When "Decrease in Cost" is examined, it can be seen that Decrease in Cost mean is 3.2. Although Decrease in Cost mean is 3.2 strongly focused on the literature as seen at the Table 4.37. When "Decrease in Life Cycle Cost" is examined, it can be seen that Decrease in Life Cycle Cost mean is 3.0. Spirited collaboration between AEC participants has shown significant gains in project outcomes in terms of both time and cost. By working together to achieve common goals, project teams can optimize output by sharing ideas and delivery solutions with the benefit of diverse perspectives. A weird results has come from the case study compared to citations that Decrease in Duration mean is 2.2. When looking at the citations Decrease in Duration have a high level of importance considered as a BIM implementation benefits. The fact that companies focus on the duration of contracts in the bidding works which can be count as a reason for the low score of Decrease of Duration. To sum up, that can be clearly understood that companies emphasis on more quality and cost instead time.

Also, when "Increase in Quality" is examined, it can be seen that Increase in

Quality mean is 3.9. When "Clash Detection" is examined, it can be seen that Clash Detection has a one of the high mean as 4.5. All companies except Firm E and Firm I gave a high points for this factors importance. When "Better Documentation" is examined, it can be seen that Better Documentation mean is 4.1. When "Improvement of Client Satisfaction" is examined, it can be seen that Improvement of Client Satisfaction mean is also 4.1. However, when looking at the citations Better Documentation and Improvement of Client Satisfaction have a low level of importance considered as a BIM implementation barriers.

When "Increased Integration/Communication/Coordination among Parties" is examined, it can be seen that Increased Integration/Communication/Coordination among Parties has a highest mean as 4.6. When looking at the Increased Integration / Communication / Coordination among Parties have a highest level of importance considered as BIM implementation barriers.

BIM project implemented by the Company A led to a 25% cost savings. Company A has a motto that is "The goal is to ensure that the resulting facility meets the intended requirement while achieving the least life cycle cost". BIM projects, which save time by 2%, reduce life cycle cost approximately 50% from the advantages of the accurate data entry. BIM manager of Firm A said that "At an earlier phase integrated teams make bigger design efforts and produce greater effects. In this way, they have the ability to affect more the final cost and functional capabilities of the facility and simultaneously they have the possibility to make changes with low cost". A large number of clash resolved in project phase. The quality had increased 100% with all these achievements. Firm A that manages the entire process of the project on BIM models kept all project details on a models. Thus, the model can provide access to the requested information upon request. Client satisfaction has increased significantly with these methods.

BIM project implemented by the Company B led to a 100% quality improvement. Firm B believe that the early-design stage is vital for adoption of BIM. In this stage, when merely 1% of the project cost is used, the key decisions that commit 70%

of the life-cycle cost of the building are taken. A large number of clashes resolved in project phase. Clash detection alone can save up to 10% of the contract value by preventing possible problems that in a non-BIM project would have to be fixed on construction site. The quality had increased 100% with the gains of BIM applications. Company B presented to their clients include visualization of design & marketing material, alternative design solutions and cost comparisons, building permission process, better functional design, energy and environmental simulation, and obtaining of area information with their BIM model.

Table 4.38. BIM Impacts Levels of Effects.

IMPACTS	FIRMS											Mean
	A	B	C	D	E	F	G	H	I	J	K	
Increase in Organizational Capability/Effectiveness	5	5	5	5	1	5	3	3	3	4	4	3.9
Long Term Profitability	5	3	4	4	3	4	3	3	1	4	3	3.4
Improvement of Organizational Structure	5	3	4	5	1	4	3	3	1	5	4	3.5
Future Business Collaborations with Project Parties	5	1	4	5	3	4	4	4	4	4	5	3.9

4.2.2.5. Impacts. Increase in Organizational Capability/Effectiveness and Future Business Collaborations with Project Parties appear as the most important benefit when analyzed the responses of 11 companies. Improvement of Organizational Structure and Long Term Profitability can be count as other important enablers (Table 4.38). Considering all these factors in literature, results are similar with the case study work as it can be easily seen in the Table 4.39.

Table 4.39. Citations of Impacts.

#	Impacts of BIM	Citations
1	Increase in Organizational Capability/Effectiveness	31/48
2	Long Term Profitability	8/48
3	Improvement of Organizational Structure	15/48
4	Future Business Collaborations with Project Parties	7/48

When it is examined that how impact factors have an effect of companies BIM implementation, it can be seen from the Table 4.38 that about all of the firms have

answered as that substantially all the factors listed above have a significance role for implementation. When “Increase in Organizational Capability/Effectiveness” is examined, it can be seen that Increase in Organizational Capability/Effectiveness has a one of the highest mean is 3.9. When looking at the citations Increase in Organizational Capability/Effectiveness has a high level of importance considered as a BIM implementation impacts. When “Long Term Profitability” is examined, it can be seen that Long Term Profitability mean is 3.4. When “Improvement of Organizational Structure” is examined, it can be seen that Improvement of Organizational Structure mean is 3.5.

A weird results has come from the case study compared to citations that Future Business Collaborations with Project Parties mean is the another highest mean as 3.9. When looking at the citations Qualified Staff and Lack of Governmental Support do not have a high level of importance considered as a BIM implementation impacts.

5. SUMMARY AND DISCUSSIONS

5.1. Summary

This thesis has two research methods in its research methodology that try to explain how the implementation of a BIM approach should be implemented successfully. The first one is the questionnaire survey and second one is case study. The discussion chapter is based on these two analyses. In this chapter, major findings will be summarized and how the findings agree or disagree with the previous findings will be discussed.

The questionnaire survey analysis is based on exploratory factor analysis and is made by using SPSS analysis and data reduction factor analysis tools. The case study is made one and one conversation in the guidance of case study question table given at the part 3. The discussion part at below is critical in terms of comparing the questionnaire survey results that comes from SPSS results, and the results of eleven case studies.

5.2. Discussion on Questionnaire Survey

This chapter has produced exploratory results regarding reasons for adopting construction BIMs in terms of critical success factors for construction based on a questionnaire survey. These analyses were undertaken using mean value and ranking statistical methods. In addition, factor analyses were undertaken to determine the underlying relationships between the factors.

Table 5.1. Descriptive Statistics.

	Mean	Rank	Criticality	Std. Deviation
Availability of qualified staff	41.975	1	Very Significant	0.78134
Effective leadership	41.605	2	Very Significant	0.92813
Availability of information and technology	41.481	3	Very Significant	0.76012
Coordination among project parties	41.481	4	Very Significant	0.83832
Training of employees	40.617	5	Very Significant	0.78016
Experience level within the firm	39.259	6	Significant	0.771
Availability of financial resources	38.889	7	Significant	0.93541
BIM policy of the company	38.148	8	Significant	117.379
Client requirement	36.296	9	Significant	10.179
Awareness level of the industry	36.049	10	Significant	100.845
Supportive organizational culture	34.938	11	Significant	0.96337
Appropriate legislation	34.938	12	Significant	109.685
Knowledge sharing within the industry	34.815	13	Significant	0.98883
Project size	33.457	14	Significant	106.255
Consulting	33.333	15	Significant	0.92195
Governmental schemes	29.259	16	Significant	11.914

The five factors perceived as very significant, with mean values approximately 4.0 and over are Availability of qualified staff, Effective leadership, Availability of information and technology, Coordination among project parties, Training of employees. There are eleven factors that can be regarded as significant success factors for BIM implementation. In descending order, based on their mean values, these factors are: Experience level within the firm, Availability of financial resources, BIM policy of the company, Client requirement, Awareness level of the industry, Supportive organizational culture, Appropriate legislation, Knowledge sharing within the industry , Project size, Consulting, Governmental schemes. All these factors mentioned above have been reviewed in detail below.

One of the study's objectives is to investigate the critical success factors for BIM systems. The survey results show that there are many factors that are responsible for successful BIM projects. However, there are four factors consulting; project size, governmental schemes and supportive organizational culture that are regarded as being highly critical factors. These four factors are highly critical for the success of BIM. Five other factors are regarded as being critical: training of employees, availability

of information and technology, appropriate legislation, effective leadership and BIM policy of the company. There are another six factor regarded as an important for the success which are knowledge sharing within the industry, experience level within the firm, availability of qualified staff, availability of financial resources and awareness level of the industry. And finally collaboration/coordination among project parties can be count as the important other factor.

5.2.1. Factor 1: Human Related Factors

Human related factors gather for 18.692% of the total variances of critical success factors. The components of human related factors can be count as training of employee's, experience level within the firm and effective leadership shown in Table 5.2.

Table 5.2. Human Related Factors.

Common Factors	Variables Name	Variables	1	2	3	4	5
Human Related Factors	Training of employees	VAR00004	0.782	0.054	-0.01	0.147	0.156
	Effective leadership	VAR00009	0.720	0.312	0.021	-0.047	0.173
	Experience level within the firm	VAR00007	0.655	0.114	0.369	0.106	-0.230

Training staff on new process and workflow and training staff (significance of 0.782) on new software and technology are the critical point for the BIM implementation success. The authors of more recent studies have proposed that one of the main changes required in enhancing BIM usage at the project level is the training of staff. This view is further verified by Yan and Damian found that very few within the Architecture, Engineering and Construction (AEC) industry in UK and USA have knowledge about BIM and its capabilities.(e.g., (Suermann, *et al.*, 2009), (Jung, *et al.*, 2010), (Succar, *et al.*, 2013))

Effective leadership (significance of 0.720) has a vital role for achievement of process improvement and capacity building for the targeted productivity. Visible support and leadership by the senior management for innovative training programs is important for the successful conduit of the BIM adoption and up skilling the company staff

(Arayici & Coates, 2013). A key element of success is leadership and awareness by facility owners in requiring BIM on all facilities. Kenig (2010) give an emphasis on that Trust is essential to a strong team and leadership behavior should be substituted with ownership mentality (e.g., (National Institute of Building Sciences, 2010), (Journal of Building Information Modeling, 2009), (Kenig, *et al.*, 2010), (HM Government, 2012), (Autodesk, 2008)).

The other high loading sub-factor is experience level within the firm with a significance of 0.655. The overall BIM training and learning experience also showed that the best way to learn for learners is to construct their own knowledge rather than someone constructing it for them. This experience also coincides with the Constructivist Learning Theory, which states that learning is an active process of creating meaning from different experiences. (e.g., (Löf, *et al.*, 2012), (Gu, *et al.*, 2008), (McGraw Hill Construction), (London, *et al.*, 2008), (Journal of Building Information Modeling, 2009)).

5.2.2. Factor 2: Industry Related Factors

The industry related factors is responsible for 16.416% of the total variances of critical success factors. There are four factors in this category shown in Table 5.3. Factor 2 consists of awareness level of the industry, knowledge sharing within the industry, appropriate legislation and governmental schemes system factors.

Table 5.3. Industry Related Factors.

Common Factors	Variables Name	Variables	1	2	3	4	5
Industry Related Factors	Governmental schemes	VAR00016	0.129	0.841	0.05	-0.122	0.135
	Appropriate legislation	VAR00015	0.107	0.731	0.361	-0.024	-0.039
	Knowledge sharing within the industry	VAR00014	0.373	0.670	-0.068	0.291	0.186
	Awareness level of the industry	VAR00013	0.227	0.615	0.293	0.284	0.260

Industry Related Factors have one critical factor namely governmental schemes with significance of 0.841. Some organizations are actively implementing BIM in an effort to meet the government deadlines. The legal status for project implementation should be guaranteed by an appropriate risk framework thus the government examines

all aspects of the legal requirements most important to the successful realization of the projects in deciding the use of BIM method. Organizations tendering for larger government schemes can be count as in this category. Arayici (2009) said that today in many organizations multi-disciplinary teams are clashing with traditional methodologies such as business models, processes, legal and compensation schemes that impede knowledge sharing which cause reinventing the matters and processes on a daily basis. Appropriate legislation (significance of 0.731) is one of the crucial points to coordinate and standardize the using of BIM systems. BIM systems supporting with legislation can be established more firmly both private and public sectors (e.g., (Eadie, *et al.*, 2013), (Suermann, *et al.*, 2009), (Arayici, *et al.*, 2009), (Journal of Building Information Modeling, 2009)).

Terry Jordan (Journal of Building Information Modeling, 2009) said that groups are construction industry of professional's architects, engineers, building owners, contractors, facility managers, attorneys, real property owners, university faculty and students, and even first responders who share an interest in exploiting technology to enhance quality and improve efficiency in the built environment. These groups meet informally each month for the exclusive purpose of professional networking and knowledge sharing (significance of 0.670). Employers should support a diverse and inclusive work environment as well as equal opportunities for successful BIM implementation. The influence of collaborative partnering, communication and supportive work environment on BIM were found to be moderate which is supported by other studies such as those by (National Institute of Building Sciences, 2010), (Gee, 2010), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009), (Campbell, 2007), (Journal of Building Information Modeling, 2009).

A key element of success is leadership and awareness by facility owners in requiring BIM on all facilities. Autodesk mentioned that greater awareness (significance of 0. 615), owner mandates, and industry initiatives are critical to the widespread adoption of BIM. To conduct industry related factors, awareness level of the industry is another important factor with a fairly high loading. There was no practical understanding and awareness of BIM in the company at the beginning of the project. Yet, senior managers

of the company had some visionary understanding of BIM for investment to attain competitive advantage and better position in market place and provide sustainable green design solutions in the future (e.g., (Arayici, *et al.*, 2011), (Journal of Building Information Modeling, 2009), (The Salford Centre for Research & Innovation,SCRI, 2011), (Autodesk, 2002), (Arayici, *et al.*, 2012)).

5.2.3. Factor 3: Project Related Factors

Project related factors component accounts for 13.092% of the total variances in CSFs. Coordination among project parties, project size and client requirement are variables of this principal factor shown in Table 5.4.

Table 5.4. Project Related Factors.

Common Factors	Variables Name	Variables	1	2	3	4	5
Project Related Factors	Project size	VAR00011	0.044	0.051	0.846	-0.049	0.062
	Client requirement	VAR00012	-0.005	0.458	0.601	0.210	-0.004
	Collaboration/coordination among project parties	VAR00010	0.360	0.347	0.471	0.183	0.022

The use of BIM would be undertake a more finely grained analysis of on the individual projects to discover the extent to which benefits are contingent upon specific project characteristics, such as project size (significance of 0. 615), value and complexity (Bryde, *et al.*, 2012), (Arayici, *et al.*, 2011), (Journal of Building Information Modeling, 2009).

BIM is a new technology that brings with it a new method of working which is aiming to revolutionize and make the construction process more responsive to of the end-user's needs (significance of 0. 601). Applications requiring a more long term perspective in the production process, such as planning and scheduling of production and material requirements and purchases, are constrained by short term requirements of immediate actions and clients that characterize the industry (Linderoth, 2009). As stated by Amponsah (2010) lately, client satisfaction with both the products and services delivered by the sector put stress on service providers to improve performance. (e.g.,

(HM Government, 2012), (Journal of Building Information Modeling, 2009), (Ganah, *et al.*, 2013), (Succar, *et al.*, 2013), (National Institute of Building Sciences, 2010), (Linderoth, 2009), (Amponsah, 2010))

Collaboration/coordination among project parties (significance 0.471) is the third factor in the project related factors. Curtis (1992) said that one of the key elements of the BIM processes utilized is to empower understanding and communication among the participants. McGraw Hill Construction defined the benefits of increased communication with that clause, "The most important contributor to measuring ROI for BIM is its ability to improve communication among project team members". BIM as an IT-enabled, open standards-based deliverable and collaborative process is referring to Building information Modelling. In this category BIM is considered a process where the model is developed and used to increase the project efficiency. This process intends also to enhance collaboration and coordination among disciplines and other activities (e.g., (Eastman, *et al.*, 2011), (Boktor, *et al.*, 2013), (Hergunsel, 2011), (Manning, *et al.*, 2008), (McGraw Hill Construction), (Khosrowshahi, *et al.*, 2012), (Azhar, 2011)).

5.2.4. Factor 4: Policy Related Factors

The policy related factors clarified 10.864% of the total variances of critical success factors. There are three factors in this category consulting, supportive organizational culture and BIM policy of the company shown in Table 5.5.

Table 5.5. Policy Related Factors.

Common Factors	Variables Name	Variables	1	2	3	4	5
Policy Related Factors	Consulting	VAR00005	0.042	-0.011	0.056	0.861	0.115
	Supportive organizational culture	VAR00006	0.215	0.113	0.044	0.810	-0.020
	BIM policy of the company	VAR00008	0.083	0.205	-0.104	0.712	0.094

Consulting (significance of 0.861) is important to clarify the benefits of BIM on the project. BIM experience and awareness holds a very important place that companies need to seek BIM consulting companies to accelerate their BIM development.

Information sharing between sectors and firms is the critical point at BIM diffusion that possible with the consulting system. However, having a clear strategy along with the correct guidance will assist this process if the circumstances which promote adoption are laid. Consulting organizations in the Turkish AEC Industry to determine the industrial state of the art in information and communication technology implementation from a strategic perspective along with the strategic role of information and communication technology within the organizations in the industry (e.g., (Isikdag, *et al.*, 2009), (Khosrowshahi, *et al.*, 2012), (Gu, *et al.*, 2008), (The Salford Centre for Research & Innovation, SCRI, 2011), (Journal of Building Information Modeling, 2009), (Gee, 2010), (Suermann, *et al.*, 2009)).

Supportive organizational culture is the second important component (significance of 0.810). The construction industry in the international context has been broadly criticized as slow to absorb both new management practices and new technologies. Baiden (2006) underlines supportive organizational culture with that individual from various organizations' work together to achieve common attainable project goals through the sharing of information. This means that different company processes and organizational cultures have to be aligned in a collaborative manner. Integration is often recognized as a continuous process with the objective of improving team culture and professional attitudes. In many organizations multi-disciplinary teams are experiencing conflicts, complexities, uncertainties and ambiguities with traditional practices (e.g. business models, processes, legal and compensation schemes, etc.) that impede knowledge sharing and supportive organizational environment which cause duplication of processes on a daily basis (e.g., (Khosrowshahi, *et al.*, 2012), (Journal of Building Information Modeling, 2009), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009), (Jung, *et al.*, 2010), (Succar, *et al.*, 2013)).

BIM policy of the company (significance of 0.712) has a vital role for the success of BIM applications. Architects and engineering companies in Turkey also should start systematic BIM implementation as an official organizational policy. Tiina Koppinen (2011) support this thesis with that BIM complements the company policy to deliver zero loss making projects, zero environmental incidents, zero accidents, zero ethical

breaches and with zero defects. Moreover, Jung (2010) suggested that utilization research incorporating the strategy and policy for specific levels of perspective coupled with automated reasoning needs to be strongly encouraged in order to accelerate practical BIM implementation. (e.g., (The Salford Centre for Research & Innovation, SCRI, 2011), (Kenig, *et al.*, 2010), (Khosrowshahi, *et al.*, 2012), (Becerik-Gerber, *et al.*, 2010), (Jung, et al., 2010))

5.2.5. Factor 5: Resource Related Factors

Administrative factors are responsible for 7.811% of the total variables of critical success factors. There are three components under this factor grouping: availability of information and technology, availability of qualified staff and availability of financial resources shown in Table 5.6.

Table 5.6. Resource Related Factors.

Common Factors	Variables Name	Variables	1	2	3	4	5
Resource Related Factors and technology	Availability of information	VAR00001	0.311	0.179	-0.039	0.115	0.737
	Availability of qualified staff	VAR00003	0.211	0.015	0.305	0.155	0.654
	Availability of financial resources	VAR00002	0.044	0.155	0.571	0.000	0.637

Higher loading is associated with availability of information and technology with a significance of 0.737. BIM is seen as an efficient information management methodology within construction projects. It heavily involves people's perspective, firstly as creators or collectors of data from the site and other sources, and secondly, as users of processed data, i.e. information or knowledge, from the building models (Arayici, *et al.*, 2009). BIM in construction provides the reader with information regarding new technological innovations and applications that can make the information transfer more effective (Löf, *et al.*, 2012). The implementation of BIM which knowledge-based information system into a firm will require various time, money, training, human resources and consulting. The result of the healthy and consistent transmission of information ensue to support better business decisions with better quality buildings, lower construction and operating costs, shorter project turnaround times. With the rise of integrative technology and methods like BIM there will be fundamental changes regarding professional stan-

dards of care and how the building process is regulated. Linderoth (2009) mentioned that "When adoption and use of new BIM technology is analyzed it is well known in research that the interplay between the context in which technology is deployed and the technology itself will have a significant impact on the further deployment of the BIM" (e.g., (Ganah, *et al.*, 2013), (Bryde, *et al.*, 2012), (Linderoth, 2009), (Jung, *et al.*, 2010), (Barlish, *et al.*, 2012), (Eadie, *et al.*, 2013), (Howard, *et al.*, 2007), (Isikdag, *et al.*, 2009), (Journal of Building Information Modeling, 2009), (Suermann, *et al.*, 2009), (Löf, *et al.*, 2012), (Succar, *et al.*, 2013)).

Another most important sub-factor is availability of qualified staff, with significance of 0.654. Growing demand for BIM implementation in the industry will force construction industry to be more competitive in attracting talented professionals which may be one of the biggest obstacles of BIM applications (e.g., (Journal of Building Information Modeling, 2009), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009), (Jung, *et al.*, 2010), (Succar, *et al.*, 2013)).

Another higher loading is associated with availability of financial resources with a significance of 0.637. BIM systems pre-investments are expensive than the traditional methods. Companies should assess their financial availability when implementing BIM systems. Neil Steinkamp said that certain hurdles to the application of BIM in greater capacities have been the limitations of financial measurement. Adoption of standards will provide the level of direct financial support necessary to rapidly establish and operate the neutral consensus adoption of BIM. BIM is much more useful in the long-term use when considering BIM's return on investment ratio. The immediate beneficiaries are often junior staff and trainees, while the senior staff is the main contributors in terms of both specialist knowledge and financial resources (e.g., (National Institute of Building Sciences, 2010), (Suermann, *et al.*, 2009), (Campbell, 2007), (Journal of Building Information Modeling, 2009)).

5.3. Discussion on Case Studies

5.3.1. Discussion on the Drivers of BIM

According to extensive literature research; End-User (Client) Requirement, Project Performance Improvement, Increased Coordination, Corporate Performance Improvement, Technology, Regulation and Sustainability / Green Buildings were determined as most important drivers of BIM (Figure 5.1).

Citations	Drivers	Mean
11/48	End-User (Client) Requirement	4.3
46/48	Project Performance Improvement	4.2
40/48	**Increased Coordination**	**4.8**
41/48	Corporate Performance Improvement	3.5
21/48	Technology	3.9
17/48	Regulation	2.4
14/48	Sustainability / Green Buildings	2.1

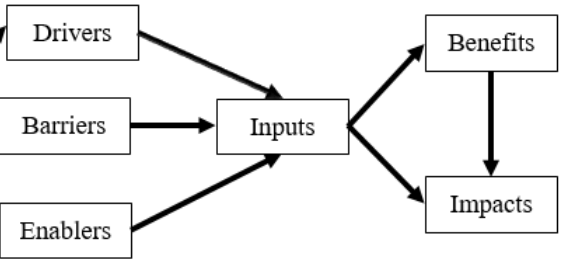


Figure 5.1. Effects of Drivers on BIM Implementation.

Drivers as a construct have a moderate positive effect on inputs of BIM. The primary goal of BIM implementation is to increasing collaboration and coordination (mean 4.8) for the entirety of the project, and this coordination is the vehicle that allows these goals to be reached successfully without being complicated. According to Hanna (2010) rework is typically caused by poor coordination and conflicts of systems, which is why these problems are most visible in labor intensive trades such as mechanical, electrical, and plumbing construction. Because of their direct effect on the efficiency of work flow of a construction project, MEP contractors are expected to continue having a strong influence on project success, especially with the increase in complexity of building systems and the growth of green-building construction. It is also supported by other studies in the literature (e.g., (Journal of Building Information Modeling, 2009), (Autodesk, 2002), (Kenig, *et al.*, 2010), (Khosrowshahi, *et al.*, 2012), (Bernstein, *et al.*, 2004), (Sacks, *et al.*, 2010), (Hanna, *et al.*, 2012), (Becerik-Gerber, *et al.*, 2010), (Azhar, *et al.*, 2008)).

Project performance (mean 4.2) measurement is critical to benefits realization which is critical for the management of BIM to deliver higher levels of project performance. Main objective is to identify outcomes from the use of BIM on project performance. According to Boktor (2013) BIM is increasingly used throughout the industry there is a need to continue with this research to determine its impact upon overall project performance including demolition. . It is also supported by other studies in the literature (e.g., (Journal of Building Information Modeling, 2009), (Kenig, *et al.*, 2010), (Hanna, *et al.*, 2012), (Barlish, *et al.*, 2012), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009)).

BIM is a new technology that brings with it a new method of working which is aiming to revolutionize and make the construction process more responsive to of the end-user's needs. According to Edwards and Maguire (2013) BIM is a new technology that brings with it a new method of working which is aiming to revolutionize and make the construction process more responsive to of the end-user's needs (mean 4.3) (e.g., (HM Government, 2012), (Journal of Building Information Modeling, 2009), (Ganah, *et al.*, 2013), (Succar, *et al.*, 2013), (National Institute of Building Sciences, 2010)).

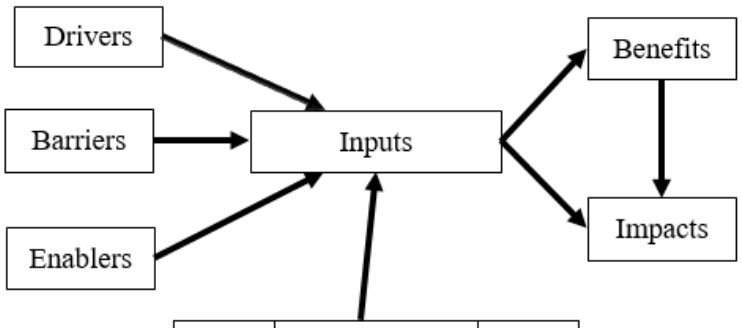
Technology (3.9), corporate performance improvement (3.5), are the other main drivers of BIM with mean and citations. With the rise of integrative technology and methods like BIM there will be fundamental changes regarding professional standards of care and how the building process is regulated. Linderoth (2009) mentioned that "When adoption and use of new BIM technology is analyzed it is well known in research that the interplay between the context in which technology is deployed and the technology itself will have a significant impact on the further deployment of the BIM" (e.g., (Ganah, *et al.*, 2013), (Bryde, *et al.*, 2012), (Linderoth, 2009), (Jung, *et al.*, 2010), (Barlish, *et al.*, 2012), (Eadie, *et al.*, 2013), (Howard, *et al.*, 2007), (Isikdag, et al., 2009))

It is interesting to note that two variables "Regulations (2.4)" and "Sustainability/Green Buildings (2.1)" do not have significant effect on BIM implementation. Gee (2010) insisted on standing that the American Institute of Architects (AIA) and the

National Institute of Building Science (NIBS) are part of only a few organizations that have started to address these issues. The AIA has developed and formalized legal regulations relating to digital design technology whereas the NIBS have started documenting and defining standards for BIM. Regulations and sustainability issues do not appear as driving forces for BIM as clearly seen from the case studies. Regulations and sustainability issues do not appear as driving forces for BIM as clearly seen from the case studies (e.g., (Gee, 2010), (Suermann, *et al.*, 2009), (Löf, *et al.*, 2012), (National Institute of Building Sciences, 2010), (Campbell, 2007), (McGraw Hill Construction), (London, *et al.*, 2008), (Journal of Building Information Modeling, 2009)).

5.3.2. Discussion on the Inputs of BIM

According to extensive literature research; Human Resources, Financial Resources, Information, Training and Consulting were determined as most important inputs of BIM (Figure 5.2).



Citations	Inputs	Mean
24/48	Human Resources	3.8
17/48	Financial Resources	3.8
43/48	**Information**	**4.5**
27/48	Training	4.1
25/48	Consulting	4.3

Figure 5.2. Effects of Inputs on BIM Implementation.

The implementation of BIM which knowledge-based information system into a firm will require various time, money, training, human resources and consulting. The result of the healthy and consistent transmission of information (mean 4,5) ensue to support better business decisions with better quality buildings, lower construction and

operating costs, shorter project turnaround times (e.g., (Journal of Building Information Modeling, 2009), (Suermann, *et al.*, 2009), (Löf, *et al.*, 2012), (Jung, *et al.*, 2010), (Barlish, *et al.*, 2012), (Eadie, *et al.*, 2013), (Howard, *et al.*, 2007), (Isikdag, *et al.*, 2009), (Ganah, *et al.*, 2013), (Succar, *et al.*, 2013)).

BIM experience and awareness holds a very important place that companies need to seek BIM consulting companies to accelerate their BIM development. Information sharing between sectors and firms is the critical point at BIM diffusion that possible with the consulting system (mean 4.3). However, having a clear strategy along with the correct guidance will assist this process if the circumstances which promote adoption are laid (e.g., (Khosrowshahi, *et al.*, 2012), (Gu, *et al.*, 2008), (The Salford Centre for Research & Innovation,SCRI, 2011), (Journal of Building Information Modeling, 2009), (Gee, 2010), (Suermann, *et al.*, 2009)).

The authors of more recent studies have proposed that one of the main changes required in enhancing BIM usage at the project level is the training of staff. This view is further verified by Yan and Damian found that very few within the Architecture, Engineering and Construction (AEC) industry in UK and USA have knowledge about BIM and its capabilities. It therefore becomes important to provide adequate employee support and training in regards to motivate them in adopting the new technology. Training staff on new process and workflow and training staff on new software and technology are the critical point for the BIM implementation success. Furthermore, to provide sufficient training is an organizational and managerial task. Therefore, mangers need to create an environment based on trial and error learning (Löfgren, 2007). A present problem is that to practice such learning may be hard in the project environment, due to the project traits of a limited timeframe and economical recourses (Alshawi, *et al.*, 2003). The costs associated with relevant training in terms of resources and time wastage has also contributed to reluctance towards effective implementation (e.g., (Löf, *et al.*, 2012), (Gu, *et al.*, 2008), (McGraw Hill Construction), (London, *et al.*, 2008), (Journal of Building Information Modeling, 2009), (Suermann, *et al.*, 2009), (National Institute of Building Sciences, 2010), (Campbell, 2007)).

One of the success factors of BIM implementation is the financial resources (mean 3.8). The success of BIM applications depend on Turkish government's massive financial resources and a myriad of industries associated with its daily operations. Neil Steinkamp said that certain hurdles to the application of BIM in greater capacities have been the limitations of financial measurement. Adoption of standards will provide the level of direct financial support necessary to rapidly establish and operate the neutral consensus adoption of BIM. (e.g., (National Institute of Building Sciences, 2010), (Suermann, *et al.*, 2009), (Campbell, 2007), (Journal of Building Information Modeling, 2009))

Organization's working in the construction markets are effectively converting their processes to utilize BIM technologies implicating the leveraging of BIM in competitive incursion. The requirements of such strategic change are substantial. Such change is non-trivial requiring investment in both technology and human resources (mean 3.8) development. (e.g., (The Salford Centre for Research & Innovation,SCRI, 2011), (Khosrowshahi, *et al.*, 2012), (Jung, *et al.*, 2010), (Succar, *et al.*, 2013), (Gee, 2010), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009))

5.3.3. Discussion on the Barriers of BIM

According to extensive literature research; Lack of Financial Resources, Lack of Clear Benefits, Unsupportive Organizational Culture, Lack of Experience, Lack of Awareness, Lack of Qualified Staff, Lack of Governmental Support, Fragmented Nature of Construction Industry and Temporary Nature of Projects were determined as most important barriers of BIM. In this section, 13 unrelated paper were excluded from citation evaluation (Figure 5.3).

Citations	Barriers	Mean
13/35	Lack of Financial Resources	2.5
21/35	Lack of Clear Benefits	2.5
17/35	Unsupportive Organizational Culture	4
21/35	Lack of Experience	3.7
20/35	Lack of Awareness	4.1
14/35	Lack of Qualified Staff	4
13/35	**Lack of Governmental Support**	**4.4**
25/35	Fragmented Nature of Construction Industry	3.1
3/ 3 5	Temporary Nature of Projects	2.4

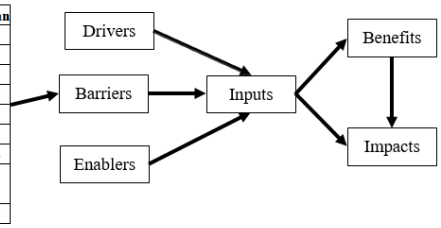


Figure 5.3. Effects of Barriers on BIM Implementation.

Construction companies stated that lack of governmental support (mean 4.4) of BIM is the main barrier. The construction industry is also a low capital intensity industry. Insufficient profits, heavy operating expenses and burdensome institutional debt as the most significant factors affecting construction companies' survival. AEC industry has a very large number of small and medium size players and the great incentives from government have a crucial point of the success of BIM implementation small incentives may not be sufficient for this segment. Therefore Turkish government should give a sufficient support to firms if it is desired to ensure success in this regard (e.g., (Khosrowshahi, *et al.*, 2012), (Gu, *et al.*, 2008), (Succar, *et al.*, 2013), (Gee, 2010), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009))

A key element of success is leadership and awareness by facility owners in requiring BIM on all facilities. Autodesk mentioned that greater awareness (mean 4.1), owner mandates, and industry initiatives are critical to the widespread adoption of BIM. National Building Information Model Standard (NBIMS) has initiated US project, which aimed to raise awareness of using BIM systems which should be model for Turkish Government (e.g., (Journal of Building Information Modeling, 2009), (The Salford Centre for Research & Innovation,SCRI, 2011), (Autodesk, 2002), (Khosrowshahi, *et al.*, 2012)).

The construction industry in the international context has been broadly criticized as slow to absorb both new management practices and new technologies. Baiden (2006) underlines supportive organizational culture (mean 4) with that individual from various organizations' work together to achieve common attainable project goals through the sharing of information. This means that different company processes and organizational cultures have to be aligned in a collaborative manner. Integration is often recognized as a continuous process with the objective of improving team culture and professional attitudes. Other looming barriers of BIM implementation is the inability to provide enough qualified engineers (mean 4). Growing demand for BIM implementation in the industry will force construction industry to be more competitive in attracting talented professionals which may be one of the biggest obstacles of BIM applications (e.g., (Journal of Building Information Modeling, 2009), (Baiden, *et al.*, 2005), (Suermann,

et al., 2009), (Jung, *et al.*, 2010), (Succar, *et al.*, 2013)).

The fragmented nature of the construction industry (mean 3.1) precludes widespread change of any kind, particularly to design tools that are based on the traditions of paper. Hergünsel (2011) said that the main causes of the lack of labor productivity in the construction industry are related to its fragmented nature due to traditional project delivery approach (e.g., (Bernstein, *et al.*, 2004), (Suermann, *et al.*, 2009), (Jung, *et al.*, 2010), (Succar, *et al.*, 2013), (Arayici, *et al.*, 2013), (Bryde, *et al.*, 2012), (Hergunsel, 2011)).

Lack of financial resources (mean 2.5) and lack of clear benefits (mean 2.5) are found important barriers to implement BIM. Contractors need to make sure to have sufficient financial resources to complete the project by arranging solid financing schedule to meet their cash flow requirements and reduce the cost for financing (Jiang, 2011). In order to ensure the project is completed on time, there are many functions that the building contractors need to be responsible for: (1) implement a proper plan to deliver the project on time, (2) review the progress and implement any changes in project delivery on the way to ensure on time completion, (3) establish the budget and follow the budget as closely as possible, (4) make sure to have sufficient financial resources to successfully complete the project (5) and develop a proper plan for manpower and materials needed for the execution of the project (e.g., (National Institute of Building Sciences, 2010), (Suermann, *et al.*, 2009), (Campbell, 2007), (Journal of Building Information Modeling, 2009)).

The temporary nature of projects (mean 2.4) means that groupings of discrete businesses coalesce and then separate around the delivery of relatively short-term projects. Although some continuity is provided by the tendency to work with groups where there is some connection from a previous project, the temporary nature of the relationship can lead to suspicion about the sharing of information. This is not an atmosphere conducive to the diffusion of successful BIM implementations (e.g., (Jung, *et al.*, 2010), (Succar, *et al.*, 2013), (Gee, 2010), (Baiden, *et al.*, 2005)).

5.3.4. Discussion on the Enablers of BIM

According to extensive literature research; Collaborative Partnering, Supportive Work Environment, Leadership, BIM Policy of the Company and Government Schemes were determined as most important enablers of BIM (Figure 5.1).

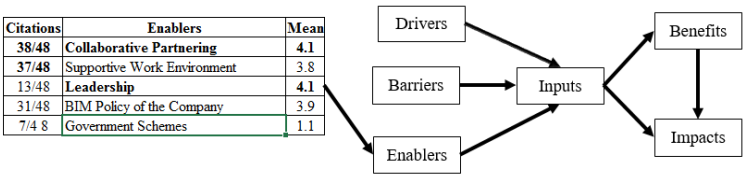


Figure 5.4. Effects of Enablers on BIM Implementation.

Collaborative partnering (mean 4.1) and coordination of industry initiatives is solution to reduce the time and resources. Succar (2013) said that "Organizational team capability applied to two or more organizations working together through collaborative partnering to pursue a common mission or deliver a common project/outcome" to highlight the importance of collaborative partnering. Howard (2007) pointed that the process in which BIMs can provide most benefit implies that there are long term relationships between those involved. These can be achieved by collaborative partnering where the benefits of using BIMs can be obtained over the lifetime of the building (e.g., (Howard, *et al.*, 2007), (Succar, *et al.*, 2013), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009), (National Institute of Building Sciences, 2010)).

A key element of success is leadership (mean 4.1) and awareness by facility owners in requiring BIM on all facilities. Effective Leadership has become the essential to manage consistently process of BIM implementation. Team behavior is crucial for a successful BIM and IPD projects. Kenig (2010) give an emphasis on that Trust is essential to a strong team and leadership behavior should be substituted with ownership mentality (e.g., (National Institute of Building Sciences, 2010), (Journal of Building Information Modeling, 2009), (Kenig, *et al.*, 2010), (HM Government, 2012), (Autodesk, 2008)).

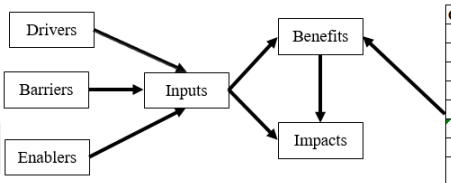
BIM policy of the company (mean 3.9) has a vital role for the success of BIM applications. Tiina Koppinen (2011) claims that BIM complements the company policy to deliver zero loss making projects, zero environmental incidents, zero accidents, zero ethical breaches and with zero defects. Architects and engineering companies in Turkey also should start systematic BIM implementation as an official organizational policy. Jung (2010) suggested that utilization research incorporating the strategy and policy for specific levels of perspective coupled with automated reasoning needs to be strongly encouraged in order to accelerate practical BIM implementation (e.g., (The Salford Centre for Research & Innovation,SCRI, 2011), (Kenig, *et al.*, 2010), (Khosrowshahi, *et al.*, 2012), (Becerik-Gerber, *et al.*, 2010), (Jung, *et al.*, 2010)).

Employers should support a diverse and inclusive work environment as well as equal opportunities for successful BIM implementation. The influence of collaborative partnering, communication and supportive work environment (mean 3.8) on BIM were found to be moderate which is supported by other studies such as those by (National Institute of Building Sciences, 2010), (Gee, 2010), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009), (Campbell, 2007), (Journal of Building Information Modeling, 2009).

It is interesting that in this study, Government Schemes it was found that enablers do not have a significant effect on BIM implementation with a mean of 1.1. However, some organizations are actively implementing BIM in an effort to meet the government deadlines. Organizations tendering for larger government schemes can be count as in this category. Also there is logical evidence about Government Schemes which should be significant from literature. Arayici (2009) said that today in many organizations multi-disciplinary teams are clashing with traditional methodologies such as business models, processes, legal and compensation schemes that impede knowledge sharing which cause reinventing the matters and processes on a daily basis (e.g., (Eadie, *et al.*, 2013), (Suermann, *et al.*, 2009), (Arayici, *et al.*, 2009), (Journal of Building Information Modeling, 2009)).

5.3.5. Discussion on the Benefits of BIM

According to extensive literature research; Decrease in Cost, Decrease in Life Cycle Cost, Decrease in Duration, Increase in Quality, Clash Detection, Improvement of Client Satisfaction, Better Documentation and Increased Integration / Communication / Coordination Among Parties were determined as most important benefits of BIM (Figure 5.5).



Citations	Benefits	Mean
39/48	Decrease in Cost	3.2
22/48	Decrease in Life Cycle Cost	3
31/48	Decrease in Duration	2.2
39/48	Increase in Quality	3.9
20/48	Clash Detection	4.5
6/4 8	Improvement of Client Satisfaction	4.1
14/48	Better Documentation	4.1
32/48	**Increased Integration / Communication / Coordination Among Parties**	**4.6**

Figure 5.5. Effects of Benefits on BIM Implementation.

It should be noted that different benefits might accrue depending on the project objectives. For instance, BIM implementation might bring financial benefits in one case, whereas it might only improve quality performance in another. The extent BIM implementation is successful should be measured against the initial targets set by the project teams.

Increased integration, communication and coordination among parties (mean 4.6) are the benefits of BIM coordination among different parties to the project, the amount of staff members needed to implement BIM and its relationship to project size, the predominant BIM tools, the cost of using BIM on a project, and the associated risks when implementing BIM. Curtis (1992) said that one of the key elements of the BIM processes utilized is to empower understanding and communication among the participants. McGraw Hill Construction defined the benefits of increased communication with that clause, "The most important contributor to measuring ROI for BIM is its ability to improve communication among project team members" (e.g., (Boktor, *et al.*, 2013), (Hergunsel, 2011), (Manning, *et al.*, 2008), (McGraw Hill Construction), (Khosrowshahi, *et al.*, 2012)).

Reduce the number of field coordination errors by integrating the design models of the major design disciplines early in the design process and using clash detection (mean 4.5) software to facilitate interdisciplinary design coordination thereby solving coordination issues virtually rather than in the field. This result is in line with Hanna (2012) research that indicated better visualization and clash detection are top benefits when using BIM. There are numerous BIM benefits for construction projects execution, including reduction in field conflicts, improved coordination, easier clash detection, and enhanced facility-design visualization. Also according to Azhar (2011) most companies used BIM for 3D and 4D clash detections and for planning and visualization services (e.g., (Journal of Building Information Modeling, 2009), (Autocad, 2007), (Khosrowshahi, *et al.*, 2012), (Hanna, *et al.*, 2012), (Azhar, 2011), (Boktor, *et al.*, 2013)).

According to the Salford Centre for Research and Innovation, an internal study of the benefits of BIM conducted between 2007-2010 shown that BIM contributed to reductions in accidents and waste, whilst contributing to an increase in client satisfaction (mean 4.1). Tocoman Professional Services of Finland claims that they have facilitated over 200 projects each with reasonable savings due to the utilization of BIM within building construction lifecycle activities, producing significantly better infrastructures with improved client satisfaction (e.g., (Eadie, *et al.*, 2013), (Arayici, *et al.*, 2011), (The Salford Centre for Research & Innovation,SCRI, 2011), (Baiden, *et al.*, 2005))

Leverage BIM to reestablish accuracy and precision, and improve the level of construction cognition and assembly understanding with better documentation on the part of the architects, engineers, and owners. Arayici (2011) were encouraged to note down any added-value BIM services to be offered such as better documentation. An effective knowledge management strategy can also make it possible for knowledge acquisition via sharing at a variety of levels including maintaining up-to-date documentation about processes and procedures (e.g., (Journal of Building Information Modeling, 2009), (Autocad, 2007), (Khosrowshahi, *et al.*, 2012), (Becerik-Gerber, *et al.*, 2010), (Arayici, *et al.*, 2013), (Sacks, *et al.*, 2010)).

Nowadays, BIM process is required because there are pressures from clients to improve quality (mean 3.9), reduce costs and speed up construction processes. According to Salmon (2009) new BIM software and Lean Construction tools have proven their truly revolutionary ability to increase quality, reduce costs and improve schedules. Suermann (2009) said that their primary goal for adopting a BIM approach was to "advocate and employ value-adding digital visualization, simulation and optimization technologies to increase quality and efficiency throughout project lifecycles and beyond". Also according to National Building Information Modeling Standard, Building Information Management (business structures of work and communication that increase quality and efficiency), BIM is a critical element in reducing industry waste, adding value to industry products, decreasing environmental damage, and increasing the functional performance of occupants (e.g., (Succar, *et al.*, 2013), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009), (National Institute of Building Sciences, 2010), (Journal of Building Information Modeling, 2009), (The Salford Centre for Research & Innovation,SCRI, 2011), (Kenig, *et al.*, 2010), (HM Government, 2012), (Azhar, 2011), (Bryde, *et al.*, 2012), (Howard, *et al.*, 2007), (Khosrowshahi, *et al.*, 2012), (Becerik-Gerber, *et al.*, 2010), (Jung, *et al.*, 2010)).

There are many net benefits in fostering BIM implementation in the construction sector. BIM implementation in construction may become a fourth competitive dimension to be added to the existing dimensions of cost, quality and time. Azhar (2011) mentioned that the AEC industry participants indicated that BIM use resulted in time and cost savings. It is important to note that BIM may also provide for cost savings through reduced repair and maintenance expense. Bryde (2012) indicated the benefits of cost saving with that this increased cost savings is a result of different hourly rates and the learning curve required to understand the current operational practices and organizational divisions before working through the existing space utilization calculations. Decrease in cost (mean 3.2) is also supported by other studies such as those by (Journal of Building Information Modeling, 2009), (The Salford Centre for Research & Innovation,SCRI, 2011), (Kenig, *et al.*, 2010), (HM Government, 2012), (Azhar, 2011), (Bryde, *et al.*, 2012), (Howard, *et al.*, 2007), (Succar, *et al.*, 2013), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009), (National Institute of Building Sciences, 2010),

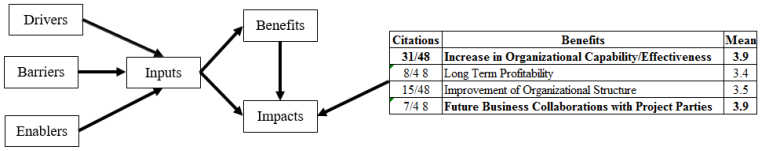
(Khosrowshahi, *et al.*, 2012), (Becerik-Gerber, *et al.*, 2010), (Jung, *et al.*, 2010).

The benefits of BIM for design and construction are well known. According to Harry Singh (2009), the cost-saving potential at project stage of the life cycle is highest when all the information is collected and made available in early stages during planning, design, and construction. However, continuous accumulation of information is necessary to mine maximum savings and reduce the total life cycle costs (mean 3) of ownership. Using BIM for design does not by itself provide sufficient benefit from a facility management perspective (e.g., (Journal of Building Information Modeling, 2009), (Barlish, *et al.*, 2012), (Suermann, *et al.*, 2009), (Ningappa, 2011), (National Institute of Building Sciences, 2010)).

It is interesting that in this study, decrease in duration it was found that benefits do not have a significant effect on BIM implementation with a mean of 2.2. BIM Handbook provides definition of BIM "BIM facilitates a more integrated design and construction process that results in better quality buildings at lower cost and reduced project duration". Moreover, organizations are generally implementing BIM in an effort to meet deadlines. Also there is logical evidence about decrease in duration which should be significant from literature. According to Hanna (2012) The BIM can be defined as a more integrated design and construction process that results in better quality buildings at lower cost and reduced project duration (e.g., (Eadie, *et al.*, 2013), (Suermann, *et al.*, 2009), (Arayici, *et al.*, 2009), (Journal of Building Information Modeling, 2009), (Hanna, *et al.*, 2012), (Boktor, *et al.*, 2013), (Sacks, *et al.*, 2010), (Ningappa, 2011), (National Institute of Building Sciences, 2010), (Succar, *et al.*, 2013), (Baiden, *et al.*, 2005)).

5.3.6. Discussion on the Impacts of BIM

According to extensive literature research; Increase in Organizational Capability/Effectiveness, Long Term Profitability, Improvement of Organizational Structure and Future Business Collaborations with Project Parties were determined as most important impacts of BIM (Figure 5.6).



Citations	Benefits	Mean
31/48	**Increase in Organizational Capability/Effectiveness**	**3.9**
8/4 8	Long Term Profitability	3.4
15/48	Improvement of Organizational Structure	3.5
7/4 8	**Future Business Collaborations with Project Parties**	**3.9**

Figure 5.6. Effects of Impacts on BIM Implementation.

Inputs and benefits are found to enhance impacts of BIM implementation. The positive influence of inputs and benefits are supported by other studies in the literature. Based on the means and citations in Figure 5.6, it can be stated that Increase in Organizational Capability/Effectiveness, Long Term Profitability, Improvement of Organizational Structure and Future Business Collaborations with Project Parties are important impacts of BIM. BIM implementation may also provide significant benefits that cannot be adequately measured in direct monetary savings and gain, but can, nonetheless, add to a company's competitive position (Slaughter, 1998).

Salmon (2009) pointed that BIM and Lean Construction encourage collaboration and will provide the best results when collaboration (mean 3.9) is at its best. Kenig (2010) characterized the difficulties experienced on typical projects as artifacts of a construction process fraught by lack of cooperation and poor information integration. BIM will fix this problem with fully integrated future business collaborations with project parties with effective solution in their own methods (e.g., (Konukçu, *et al.*, 2011), (Journal of Building Information Modeling, 2009), (Kenig, *et al.*, 2010), (Suermann, *et al.*, 2009)).

There is a strong synergy between BIM derived data and the future organizational effectiveness and efficiency (mean 3.9) of the construction process and operational evaluation of performance. Arayici (2013) stated that the goal is to ensure that the lessons learnt on one project are built into the next projects for continuous improvement in efficiency (cost and time) and effectiveness (quality and sustainability) (e.g., (HM Government, 2012), (Autodesk, 2002), (Arayici, *et al.*, 2013), (Sacks, *et al.*, 2010)).

In the construction industry on the other hand changing data ownership is not an

issue because of an integrated and more fixed organizational structure (mean 3.5) with implementing BIM. Löf (2012) said that BIM implementation will contribute to nature of the organizational structure with the change of new technological enhancement (e.g., (Journal of Building Information Modeling, 2009), (Gu, *et al.*, 2008), (Löf, *et al.*, 2012), (National Institute of Building Sciences, 2010)).

Tatum (1987) stated a strong interaction with the field forces using the new technology is an excellent opportunity to gain user input to refinement. BIM implementation also cost benefits the participating organizations in the long run (mean 3.4). Azhar (2011) said that as the use of BIM accelerates, collaboration within project teams should increase, which will lead to improved profitability, reduced costs, better time management, and improved customer-client relationships. Experience in using BIM technology also provides information to assist in planning and estimating for use on future projects. Successful BIM implementation can influence the business planning and long-term direction of the firm if it provides a technology that can give a competitive advantage (e.g., (Azhar, 2011), (Baiden, *et al.*, 2005), (Suermann, *et al.*, 2009), (National Institute of Building Sciences, 2010), (Khosrowshahi, *et al.*, 2012), (Becerik-Gerber, *et al.*, 2010), (Jung, *et al.*, 2010)).

Therefore, construction professionals should not be reluctant to innovate and discouraged by the initial challenges and additional costs incurred (Özorhon, 2012).

6. CONCLUSIONS

6.1. Scope of the Thesis

It is aimed in this study to investigate BIM in Turkish Construction Industry. Case study and online survey are chosen as the research methodology. Questionnaire survey participants were listed from the directories and were invited to participate in the survey and 81 of them responded. Eleven projects are selected and analyzed as case studies. BIM manuals in 25 countries were evaluated to demonstrate BIM diffusion in Turkish construction industry. In order to analyze the BIM process of firms and projects, a research framework is established. Based on this framework, a total of eleven case studies and questionnaire surveys are investigated. Findings of the research are compared with the results reported in literature review.

6.2. Conclusions Based on Research Findings

There are many uses of BIM for each team member of construction projects. For designer; by using BIM designers can make code validation, LEED evaluation, structural analysis, lighting analysis, and energy analysis, Design authoring and Design reviews. Although BIM has many uses for the other phases of the construction projects the highest influence on cost is highest at the design phase of the projects. Construction team of the project can make 3D controls of the project and planning, digital fabrication, construction system design and site utilization planning. During the operation phase of the building BIM can be used for; disaster planning, space management, asset management, building system analysis, maintenance scheduling etc.

It can be seen that the construction industry is benefiting from the advancements in the technology to develop their performance (lowering costs, increasing productivity etc.). BIM and its tools are started being used widely every day. The design and 3D coordination of the project reduces the problems and conflicts in the construction projects during the design phase before the construction starts. By using BIM it is

possible to use offsite production of the construction components. In a controlled environment the production quality increases and productivity rate increases which reduces the problems and costs. Although, there are some challenges and barriers for BIM use in construction industry the benefits of the BIM eliminate the problems in construction site and increase the low productivity rate of construction labor.

Moreover, many firms have ongoing projects like monitoring firms which has BIM projects and another way for those projects might be observing the evolution of those BIM projects over time. This approach could bring about valuable data on the advancements of innovations, especially for the open-source projects, because it enables comprehending whether collective invention happens and innovations are transformed into functional applications. Even if the innovation fails to become a functional tool, the process that it has developed would still be a valuable contribution to comprehending and learning about user-innovation in BIM. Not only Revit but also other cases of user innovations could illuminate if the user innovation in BIM is similar among different applications or there exists some specific conditions that affect users' innovations.

BIM is beneficial to construction projects and BIM utilizations such as coordination, planning, prefabrication etc. increases the project efficiency of the construction projects. In conclusion, although there are problems such as, interoperability, collaborative work problems etc. and some of the BIM tools need improvements. The BIM saves time and reduces the costs and increases the quality of the construction projects.

A BIM-based framework will be used to help organize lifecycle information to support facility management activities and promote needed information exchange between operations and facility management. The designed framework takes into account facility management information that is needed for facility managers to respond to events within healthcare. Their quick and effective response can help save money and reduce health threats to patient safety.

Finally, knowledge transfer provided the opportunity to realize which theoretical knowledge from academia is practical in operation and helped for what extent the

theoretical knowledge can be measured in operation and facilitated to acquire implicit knowledge from the real practical context, which helped to improve the theoretical knowledge towards a more practical strategic vision for the systematic BIM implementation.

6.3. Recommendations for BIM Promotion

Turkey is one of the main contributors to the global construction industry; it is vital that the Turkish Construction Industry embraces such technologies as BIM in order to remain competitive. Moreover, in order to facilitate this adoption it is advocated that an industry wide strategy is needed. Hence, the first step is to identify the Turkish construction industry's current position in the global market is to determine existing and new trajectories for further adoption and implementation. Second step shall constitute a national BIM guideline for arranging and standardize the process and mechanism. The BIM guide provides users with template documents to help record and develop their project-specific BIM implementation plans. This system should include three phases which can be count as;

- Organization
- Plan & Schedule
- Implementation Actions

To achieve his goal the policies and strategies adopted by the Singapore and UK show a mature and workable working framework for promotion programs of BIM, and some of them could be utilized directly while the others might need to be modified at first to fit Turkish construction industry.

6.3.1. Organization

In terms of organization, the Turkish Government can institute two individual divisions, an official department and a Non-Governmental Office (NGO), responsible for its BIM promotion programs. The framework of BIM organization is shown in

Figure 6.1 (Wenqi, 2013).

The official department, the Department of BIM Business and Innovation, is proposed to be a multi-department organization in charge of BIM policy making and implementation. Its staff would consist of governments' officials, lawyers, engineers, economists, etc. Its duties would be:

(i) Collaborating and coordinating with the associated Government's departments, the Ministry of Environment and Urban Planning, the Ministry of Energy, the Ministry of Internal Affairs, Metropolitan Municipalities and Municipality's science affairs directorate;
(ii) Making and issuing the BIM Implementation Plan and BIM Maturity Level;
(iii) Developing submission templates and guidelines for easing the transition from 2D CAD drawings to 3D BIM;
(iv) Managing BIM pilot projects for public sectors and infrastructures;
(v) Approving and granting BIM funds for BIM adoption; and,
(vi) Making BIM standards or codes (Wenqi, 2013).

The Non-Governmental Office (NGO), the BIM Council, would serve as the business voice of Turkey's BIM community. It is supposed to recruit volunteers, students and professionals who are interested in BIM for the purpose of popularizing the concept of BIM and educating the industry. Its jobs would include:

1. Organizing an internet-based database on BIM sharing among BIM professionals; 2. Collaborating with other NGOs (e.g., Turkish Green Building Council-ÇEDBIK, Turkish Contractors Association-TCA, Union of Chambers of Turkish Engineers and Architects-UCTEA) or private firms for on the use of BIM; 3. Publishing BIM journals covering successful case studies and best practices to educate the industry on BIM; 4. Arranging BIM seminars, workshops and conferences regularly on the use of BIM for the industry; and; 5. Launching BIM training programs and issuing BIM Specialist Certificate or Diploma for BIM trainees. (Wenqi, 2013)

(i) Organizing an internet-based database on BIM sharing among BIM professionals;

(ii) Collaborating with other NGOs (e.g., Turkish Green Building Council-ÇEDBIK, Turkish Contractors Association-TCA, Union of Chambers of Turkish Engineers and Architects-UCTEA) or private firms for on the use of BIM;

(iii) Publishing BIM journals covering successful case studies and best practices to educate the industry on BIM;

(iv) Arranging BIM seminars, workshops and conferences regularly on the use of BIM for the industry; and;

(v) Launching BIM training programs and issuing BIM Specialist Certificate or Diploma for BIM trainees (Wenqi, 2013).

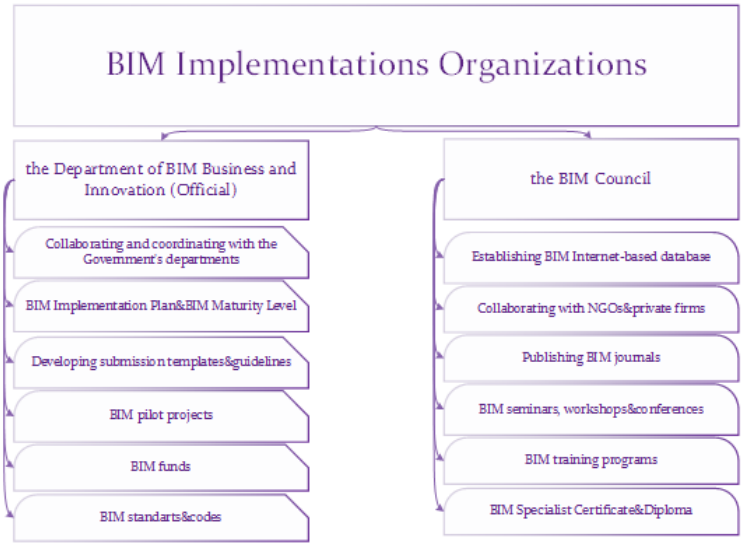


Figure 6.1. The Proposed Framework of Ontario BIM Organization (Wenqi, 2013).

6.3.2. Plan & Schedule

In order for industry professionals to get the best out of BIM tools and work efficiently, one needs a big picture understanding of information need, honing individual tools and processes towards greater efficiency and certainty. Key to doing this is a thorough documentation of one's own business processes - use of a BIM-Info Deliveries Protocol as part of a BIM-Implementation Plan may offer an immediate and tangible solution.

According to UK's BIM Maturity Level and BIM Level 2 adoption in 2016, Figure 6.1 shows the projected BIM Adoption Plan and schedule (Joe, 2011).

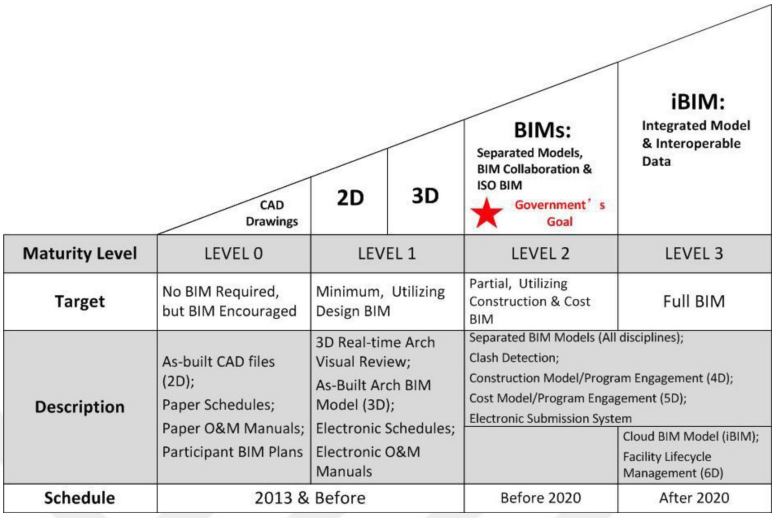


Figure 6.2. Proposed BIM Implementation Plan & Schedule.

The fact that: with the new technology and processes associated with BIM implementation, new forms of collaboration are inevitable. Guidance is needed to support teams into making meaningful decisions towards common goals. These concepts recommends functional rather than prescriptive specifications; development and publication of guidelines documenting best practice; and an appended BIM-Addendum enabling team decisions to be made on:

- BIM Delivery Schedule
- BIM Uses Schedule
- Level of detail at project stages
- Model Authorship
- Model Use Authorization

BIM-supporting mechanisms may produce scenarios that remove some of the most contrary obstacles to BIM collaboration, namely, strategic sharing of intelligent BIM data an ability to work towards common goals for the good of the project (Martin, 2012).

6.3.3. Implementation Actions

Implementation plan constitutes a structured methodology to develop effective plans for BIM adoption into the processes and BIM utilization during the lifecycle of a facility. The purpose is to develop structured standardized planning procedures. This systematic BIM plan is necessary for the industry to maximize the value of BIM implementation. (Messner, 2012).

6.3.3.1. Setting-up of Plan and BIM Maturity. A comprehensive illustration of BIM maturity as the UK BIM Maturity Level described in Table 6.1, which defines a professional's BIM skill levels, is supposed to be used as the industry standard (McGraw-Hill Construction, 2013). In addition, given the Turkish Construction industry is larger than UK's or Singapore's, the Turkish government needs to establish a five-year or longer plan to achieve 100% BIM adoption in the building industry (Özorhon, 2012).

Table 6.1. BIM Maturity Level and Definition in UK (BIM Management, 2011).

Level	Definition
0	Unmanaged CAD probably 2D with paper or electronic paper as the most likely data exchange mechanism
1	Managed CAD in 2 or 3D format with collaboration tool providing a common data environment, possibly some standard data structures and formats; Commercial data management by stand-alone finance and cost management packages with no integration.
2	Managed 3D environment held in separate discipline "BIM" tools with attached data; Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as "pBIM" (proprietary); The approach may utilize 4D program data and 5D cost elements as well as feed operational systems.
3	Fully open process and data integration enabled by "web services" compliant with the emerging IFC/IFD standards, managed by a collaborative model server; Could be regarded as integrated BIM potentially employing concurrent engineering processes.

6.3.3.2. Pilot Projects. Many of the interviewees stressed the importance of pilot projects where BIM is utilized. Through pilot projects, the benefits with BIM can be experienced. The municipal facilities should be encouraged to take the lead of BIM adoption. The Turkish Government can carry out several BIM pilot projects, and then publish journals introducing the lessons and the successful cases in those pilot projects to educate the whole industry. According to the (BIM Project Execution Planning Guide, 2009), practical studies in pilot projects, where the economic benefits of BIM are proven, are necessary to bring the utilization of BIM further. For the Turkish Government, it can also accumulate first-hand data and results for further revise and update on its policies and strategies.

6.3.3.3. Submission Templates and Guidelines. Information exchanges should be analyzed in earlier steps; however it is helpful to document them all in one place. For the firms short of experience in BIM and entrenched in 2D drafting practices, the Turkish Government needs to develop a suite of submission templates and guidelines to help professionals ease the transition from traditional 2D CAD drawings to 3D BIM, understand the new process of regulatory submission using BIM. The suite of submission templates covers architectural, structural and M&P submissions (Wenqi, 2013).

6.3.3.4. Workshop Opportunities. Work with other organizations like ÇEDBIK, the Turkish Government should organize BIM seminars, workshops and conferences on the use of BIM for the industry to share and exchange the first-hand information of the technology. Especially, some universities have a courses related innovation and some specific BIM lessons and also arranging BIM certification programs. Moreover, the private sector in collaboration with Autodesk and Microsoft organized conferences also some firms arrange web based seminars. However, these newest development should be accelerated and number of BIM organizations need to be increased by a government incentive.

6.3.3.5. Education Programs. According to Gu and London (2010) there is lack of training in how to use BIM applications and lack of awareness of possible benefits of

BIM. This view is further verified in Benefits and Barriers of Building Information Modelling article who in their study of benefits and barriers with BIM found that very few within the Architecture, Engineering and Construction (AEC) industry in UK and USA have knowledge about BIM and its capabilities (Yan, *et al.*, 2010).

Education Programs in using new technologies is a primary organizational factor and essential for successful implementation. A large shortage of BIM professionals is a barrier for most of firms that intend to adopt BIM, so the Turkish Government should collaborate with institutes of education, encouraging them to include BIM software operation as a new practical course or an intensive training program. In addition, a BIM Specialist Certificate or Diploma definitely would attract more and more professionals of the construction industry or students to engage in this area with the hand of Turkish Universities.

6.3.3.6. Encouragement for BIM Adaption. For incentivizing new BIM adopters, the Turkish Government should establish a special fund for BIM adoption in projects. The fund would be awarded to the firms that intend to pursuit BIM. The fund covers costs on training, consultancy services, purchase of software and hardware.

6.3.3.7. Supporting Services. For the beginner firms of BIM, the Turkish Government should invite and institute organizations to provide and arrange supporting services to assist them in their first several BIM projects and regulatory submissions and avoid chaos at first.

6.3.3.8. Collaboration with Turkish Green Building Association (ÇEDBIK). Turkish Green Building Association; which was established in 2007, conducts its activities buildings and settlements designed and constructed with an ecological sensibility. Turkish Green Building Association evaluates the green projects with selection available in 5 different alternatives namely Green Building Certification System. Leadership in Energy and Environmental Design-LEED, Building Research Establishment Environmental Assessment Method-BREEAM, German Society for Sustainable Construction-DGNB,

Green Building Council Australia-Greenstar-GBCA and Comprehensive Assessment for Building Environmental Efficiency-CASBEE can be count as the Green Building Certification Systems of ÇEDBIK.

Considering the great success of green building projects based on Istanbul, the Turkish government should start with green building projects and utilize the mature green building projects policies for the drafting of BIM policies. In addition, BIM could be used in municipal projects and public sectors to see more clearly benefits of BIM.

Government can encourage developers to use BIM in their new constructions; require all new municipal facilities or public sectors to adopt BIM in their whole life-cycle; Collaborate and coordinate with Turkish Green Building Association to modify or update rating system, the bonus points by using BIM will increase and in the future the clause could be mandatory.

6.4. Further Research

In accordance with the literature review, it is possible to say that the real capacity of BIM technology has not been known due to limited business environment and less number of case studies. Fortunately, people are aware of future potential of BIM environment including facility management, sustainability and work scheduling in addition to 3D tools. Nevertheless, it is significant to define all the related standards and propose a formal methodology for all kind of BIM related projects.

The research in this report is subject to various limitations and leaves opportunity for further and more extensive research. The use of Building Information Modelling in facilities management, the creation of BIM Roadmap and National Building Information Modeling Standard, The effect of Building Information Modelling on the legal aspects of the construction industry can be count as one of the most vital research topics. Moreover, by using the same parameters and research methods in this study, data from companies of other sectors or other nationalities can also be collected in order to examine the results of different sectors or same sector of different countries.

People, technology and the world are living organisms which change every minute without stopping. Today, all of them provide the necessary conditions to meet the requirements of a perfect BIM system but here the main actor is human who will decide to integrate the existing technology to the traditional work system or not.

APPENDIX A: A SAMPLE OF THE QUESTIONNAIRE ONLINE SURVEY

Dear Participant,

An MSc thesis is being conducted in the Civil Engineering Department at Bogazici University entitled "The Critical Success Factors of Building Information Modeling (BIM) in the Turkish Construction Industry". The major objective of this study is to understand the approach of the Turkish construction industry towards BIM. By this way, it is aimed at measuring the level of knowledge and experience at the national level, presenting the existing BIM applications and the relevant future expectations, and finally recommending strategies to enhance the current situation.

BIM is an information technology (IT) enabled approach to managing design data in the AEC/FM (Architecture, Engineering and Construction/Facilities Management) industry. BIM enables improved interdisciplinary collaboration across distributed teams, intelligent documentation and information retrieval, greater consistency in building data, better conflict detection and enhanced facilities management.

Please find attached a short survey form composed of 19 questions aimed at collecting first hand data. All of the responses will be kept strictly confidential and only be used for academic purposes. Please get in contact with me if you would like to get detailed information about the subject and/or the research results.

Sincerely,

Ugur KARAHAN
Bogazici University

Phone: 0538 622 85 37
E- mail: ugur.karahan@boun.edu.tr

1) What is the name of your company? (Optional) _____

2) What is the main business area of your company?

☐ Client ☐ Designer ☐ Consultant ☐ Principal Contractor ☐ Specialist Contractor
☐ Facilities Manager ☐ Software Vendor ☐ Building User/Occupant ☐ Supplier

3) How long has your company been operating in the construction sector? _____

4) What is the total turnover of your company (in Million USD) _____

5) What is the total number of employees in your company? _____

6) What is your position in your company?

☐ Chairman ☐ Board Member ☐ General Manager
☐ Vice General Manager ☐ Project Coordinator ☐ Project Manager
☐ Department Chief ☐ Engineer ☐ Architect
☐ Facility Manager ☐ Technician ☐ Other: _____

7) Please indicate the importance level of below listed factors in the success of BIM implementation.

Variables	Very low 1	Low 2	Medium 3	High 4	Very high 5
Availability of information and technology	☐	☐	☐	☐	☐
Availability of financial resources	☐	☐	☐	☐	☐
Availability of qualified staff	☐	☐	☐	☐	☐
Training of employees	☐	☐	☐	☐	☐
Consulting	☐	☐	☐	☐	☐
Supportive organizational culture	☐	☐	☐	☐	☐
Experience level within the firm	☐	☐	☐	☐	☐
BIM policy of the company	☐	☐	☐	☐	☐
Effective leadership	☐	☐	☐	☐	☐
Collaboration/coordination among project parties	☐	☐	☐	☐	☐
Project size	☐	☐	☐	☐	☐
Client requirement	☐	☐	☐	☐	☐
Awareness level of the industry	☐	☐	☐	☐	☐
Knowledge sharing within the industry	☐	☐	☐	☐	☐
Appropriate legislation	☐	☐	☐	☐	☐
Governmental schemes	☐	☐	☐	☐	☐

8) In your company, is there any BIM system that you have been currently using?

☐ Yes ☐ No

Figure A.1. A Sample of the Questionnaire Online Survey Pages 1.

If your answer is NO to the above question, you can skip the rest of the questionnaire.

9) What is the name of the BIM software used in your company?

☐ Revit architecture ☐ Revit structure ☐ Revit MEP ☐ AutoCAD ADT
☐ Bentley architecture ☐ Bentley structure ☐ Bentley mechanical ☐ Bentley electrical
☐ Archi CAD ☐ Navies works ☐ Tekla Structure ☐ All plan
☐ Other: _____

10) What is the level of implementation of BIM in your company?

☐ Level 0 (Unmanaged CAD, in 2D, with paper (or electronic paper) data exchange)
☐ Level 1 (object-based modeling) or (Managed CAD in 2D or 3D format. Commercial data will be managed by standalone finance and cost management packages with no integration.)
☐ Level 2 (model-based collaboration) or (A managed 3D environment held in separate discipline 'BIM' tools with data attached. This level of BIM may utilize 4D construction sequencing and/or 5D cost information.)
☐ Level 3 (network-based integration) or (A fully integrated and collaborative process enabled by 'web services'. This level of BIM will utilize 4D construction sequencing, 5D cost information and 6D project lifecycle management information.)

11) Please indicate the stage of the project life-cycle you have implemented BIM?

☐ Feasibility ☐ Design ☐ Preconstruction (Detailed design & Tender)
☐ Construction ☐ Operation and maintenance

12) Please indicate the type of the project you have implemented BIM?

☐ Residential Housing Construction ☐ Institutional and Commercial Building Construction
☐ Specialized Industrial Construction ☐ Infrastructure and Heavy Construction

13) Please indicate the type of client of the project?

☐ Public ☐ Private ☐ Public-Private Partnership

14) Please indicate the size of the project you have implemented BIM. _____(USD)

15) Please indicate the duration of the project you have implemented BIM. _____(months)

16) Please indicate the area of the building you have implemented BIM. _____(m^2)

17) Please indicate the cost of using BIM in this project. _____(USD)

18) Please indicate the cost saving based on using BIM in this project. _____(USD)

19) Please indicate the time saving based on using BIM in this project. _____(month)

Figure A.2. A Sample of the Questionnaire Online Survey Pages 2.

APPENDIX B: A SAMPLE OF THE CASE STUDY

1) Please write the name of your company. _____

2) What is the main field of activity of your company?

☐ Employer ☐ Designer ☐ Consultant ☐ Prime Contractor ☐ Subcontractor
☐ Facility Director ☐ Software Supplier ☐ Building User ☐ Supplier

3) Please write how many years your company has experience on construction sector. _____

4) What is the annual return of your company approximately? _____ (USD)

5) Please write how many employees work in your company. _____

6) Please write your position in the company.

☐ Chairman ☐ Member of Board ☐ General Manager
☐ Deputy General Manager ☐ Project Coordinator ☐ Project Manager
☐ Unit Head ☐ Engineer ☐ Architect
☐ Facility Manager ☐ Technician ☐ Other: _____

7) Which Building Information Modeling (BIM) software do you use in your company?

☐ Revit Architecture ☐ Revit Structure ☐ Revit MEP ☐ AutoCAD ADT
☐ Bentley Architecture ☐ Bentley Structure ☐ Bentley Mechanical ☐ Bentley Electrical
☐ Archi CAD ☐ Navies works ☐ Tekla Structure ☐ All plan
☐ Other: _____

8) Which level of BIM is being used in your company?

☐ Level 0: 2D CAD Design
☐ Level 1: Object Based Modeling (Independent Finance and Cost Management packages manage commercial information in 2D or 3D format)
☐ Level 2: Model Based Modeling (integrated design is used in 3rd dimension, information about construction process is used in 4th dimension and cost information is used in 5th dimension).
☐ Level 3: Network Based Integration (Full integration and collaboration process by web services. Information about construction process is used in 4th dimension, cost information is used in 5th dimension and project life cycle management information is used 6th dimension).

9) In which phase do you use BIM technology in your projects?

☐ Feasibility ☐ Design ☐ Preconstruction (Detailed Design and Tender)
☐ Construction ☐ Operation and Management

Figure B.1. A Sample of the Case Study Pages 1.

10) In which type of projects do you use BIM technology?

☐ Housing Projects ☐ Corporate or Commercial Objectives
☐ Industrial Purposes ☐ Infrastructure

11) Please define your general customer type.

☐ Public ☐ Private Sector ☐ Public-Private Sector Cooperation

12) Please write the budget of your BIM Project. _____ (USD)

13) Please write the duration of your BIM Project._____(months)

14) Please write the total area of your BIM Project. _____(m^2)

15) Please write the cost of your BIM Project. _____ (USD)

16) How much saving of budget have you provided due to BIM application in this project?
_____ (USD)

17) How much saving of time have you provided due to BIM application in this project?
_____(month)

18) Please write the level of effect of below driven forces in your BIM application?

Drivers	Very Low 1	Low 2	Medium 3	High 4	Very High 5
End-User (Client) Requirement	☐	☐	☐	☐	☐
Project Performance Improvement	☐	☐	☐	☐	☐
Increased Coordination	☐	☐	☐	☐	☐
Corporate Performance Improvement	☐	☐	☐	☐	☐
Technology	☐	☐	☐	☐	☐
Regulation	☐	☐	☐	☐	☐
Sustainability / Green Buildings	☐	☐	☐	☐	☐

Figure B.2. A Sample of the Case Study Pages 2.

19) Please write how much did you use the below factors in your BIM application.

Inputs	Very Low 1	Low 2	Medium 3	High 4	Very High 5
Human Resources	☐	☐	☐	☐	☐
Financial Resources	☐	☐	☐	☐	☐
Information	☐	☐	☐	☐	☐
Training	☐	☐	☐	☐	☐
Consulting	☐	☐	☐	☐	☐

Please write financial values or ratios for each FACTOR;

Employee: How many? What kind of?

Financial: How much was the cost?

Information: How much time was spent o gather the information?

Training: What was the cost and duration of trainings?

Consultancy: What was the duration and cost of received consultancy? Who was the consultant?

20) What was the level of effect of critical barriers in your BIM application?

Barriers	Very Low 1	Low 2	Medium 3	High 4	Very High 5
Lack of Financial Resources	☐	☐	☐	☐	☐
Lack of Clear Benefits	☐	☐	☐	☐	☐
Unsupportive Organizational Culture	☐	☐	☐	☐	☐
Lack of Experience	☐	☐	☐	☐	☐
Lack of Awareness	☐	☐	☐	☐	☐
Lack of Qualified Staff	☐	☐	☐	☐	☐
Lack of Governmental Support	☐	☐	☐	☐	☐
Fragmented Nature of Construction Industry	☐	☐	☐	☐	☐
Temporary Nature of Projects	☐	☐	☐	☐	☐

Figure B.3. A Sample of the Case Study Pages 3.

21) What was the level of benefit of critical enablers in your BIM application?

Enablers	Very Low 1	Low 2	Medium 3	High 4	Very High 5
Collaborative Partnering	☐	☐	☐	☐	☐
Supportive Work Environment	☐	☐	☐	☐	☐
Leadership	☐	☐	☐	☐	☐
BIM Policy of the Company	☐	☐	☐	☐	☐
Government Schemes	☐	☐	☐	☐	☐

22) What was the effect of main benefits in your BIM application at project level?

Benefits	Very Low 1	Low 2	Medium 3	High 4	Very High 5
Decrease in Cost	☐	☐	☐	☐	☐
Decrease in Life Cycle Cost	☐	☐	☐	☐	☐
Decrease in Duration	☐	☐	☐	☐	☐
Increase in Quality	☐	☐	☐	☐	☐
Clash Detection	☐	☐	☐	☐	☐
Improvement of Client Satisfaction	☐	☐	☐	☐	☐
Better Documentation	☐	☐	☐	☐	☐
Increased Integration/Communication/Coordination Among Parties	☐	☐	☐	☐	☐

Please write financial values or ratios for each advantage;

Cost Reduction
Life Cycle Cost Reduction
Time Decrease
Quality Increase
Clash Detection
Customer Satisfaction Increase
Better Documentation
Integration and Coordination Increase between Project Parties

Figure B.4. A Sample of the Case Study Pages 4.

23) Please write the level of long time benefits due to BIM application in the project process?

Impacts	Very Low 1	Low 2	Medium 3	High 4	Very High 5
Increase in Organizational Capability/Effectiveness	☐	☐	☐	☐	☐
Long Term Profitability	☐	☐	☐	☐	☐
Improvement of Organizational Structure	☐	☐	☐	☐	☐
Future Business Collaborations with Project Parties	☐	☐	☐	☐	☐

24) Please write the importance level of below variables for a successful BIM application.

Variables	Very Low 1	Low 2	Medium 3	High 4	Very High 5
Availability of information and technology	☐	☐	☐	☐	☐
Availability of financial resources	☐	☐	☐	☐	☐
Availability of qualified staff	☐	☐	☐	☐	☐
Training of employees	☐	☐	☐	☐	☐
Consulting	☐	☐	☐	☐	☐
Supportive organizational culture	☐	☐	☐	☐	☐
Experience level within the firm	☐	☐	☐	☐	☐
BIM policy of the company	☐	☐	☐	☐	☐
Effective leadership	☐	☐	☐	☐	☐
Collaboration/coordination among project parties	☐	☐	☐	☐	☐
Project size	☐	☐	☐	☐	☐
Client requirement	☐	☐	☐	☐	☐
Awareness level of the industry	☐	☐	☐	☐	☐
Knowledge sharing within the industry	☐	☐	☐	☐	☐
Appropriate legislation	☐	☐	☐	☐	☐
Governmental schemes	☐	☐	☐	☐	☐

25) COMMENTS

(Please write your comments about the other subjects not shown under the above items and please explain why you prefer BIM technology)

Figure B.5. A Sample of the Case Study Pages 5.

APPENDIX C: THE KEY SOURCES USED IN THE STUDY

(i) Becerik-Gerber, and Kent, 2010

(ii) McGrawHill Construction, 2009*

(iii) Baiden, Price, and Dainty, 2005

(iv) Yilmaz, Arditi, and Korkmaz, 2010*

(v) Er, and Kazaz, 2010*

(vi) McGraw Hill Construction, 2009*

(vii) London, Singh, Taylor, Gu, and Brankovic, 2008

(viii) Arayici, Khosrowshahi, Ponting, and Mihindu, 2009

(ix) Altinöz, and Ergen, 2012*

(x) Konukçu, Köseoglu, and Dalci, 2011

(xi) Journal of Building Information Modeling, 2009

(xii) Ilhan, and Yaman, 2012*

(xiii) Demir, and Bryde, 2012*

(xiv) The Salford Centre for Research & Innovation,SCRI, 2011

(xv) Autocad, 2007

(xvi) Kenig, Allison, and Black, 2010

(xvii) Khosrowshahi, and Arayici, 2012

(xviii) HM Government, 2012

(xix) Bernstein, and Pittman, 2004

(xx) Arayici, and Coates, 2013

(xxi) Sacks, Koskela, Dave, and Owen, 2010

(xxii) Hanna, Boodai, and El Asmar, 2012

(xxiii) Becerik-Gerber, and Kensek, 2010

(xxiv) Azhar, 2011

(xxv) Boktor, Hanna, and Menassa, 2013

(xxvi) Manning, and Messner, 2008

(xxvii) Ganah, and John, 2013

(xxviii) Bryde, Broquetas, and Volm, 2012

(xxix) Linderoth, 2009

(xxx) Jung, and Joo, 2010*

(xxxi) Barlish, and Sullivan, 2012

(xxxii) Succar, Sher, and Williams, 2013

(xxxiii) Eadie, Browne, Odeyinka, McKeown, and McNiff, 2013

(xxxiv) Howard & Björk, 2007

(xxxv) Sebastian, 2010*

(xxxvi) Isikdag, Underwood, and Kuruoglu, 2009

(xxxvii) Arayici, Coates, Koskela, and Kagioglou, 2011

(xxxviii) Gu, Singh, Taylor, London, and Brankovic, 2008

(xxxix) Gee, 2010

(xl) Hergunsel, 2011

(xli) Suermann, and Issa, 2009

(xlii) Ningappa, 2011

(xliii) Pindukuri, 2011*

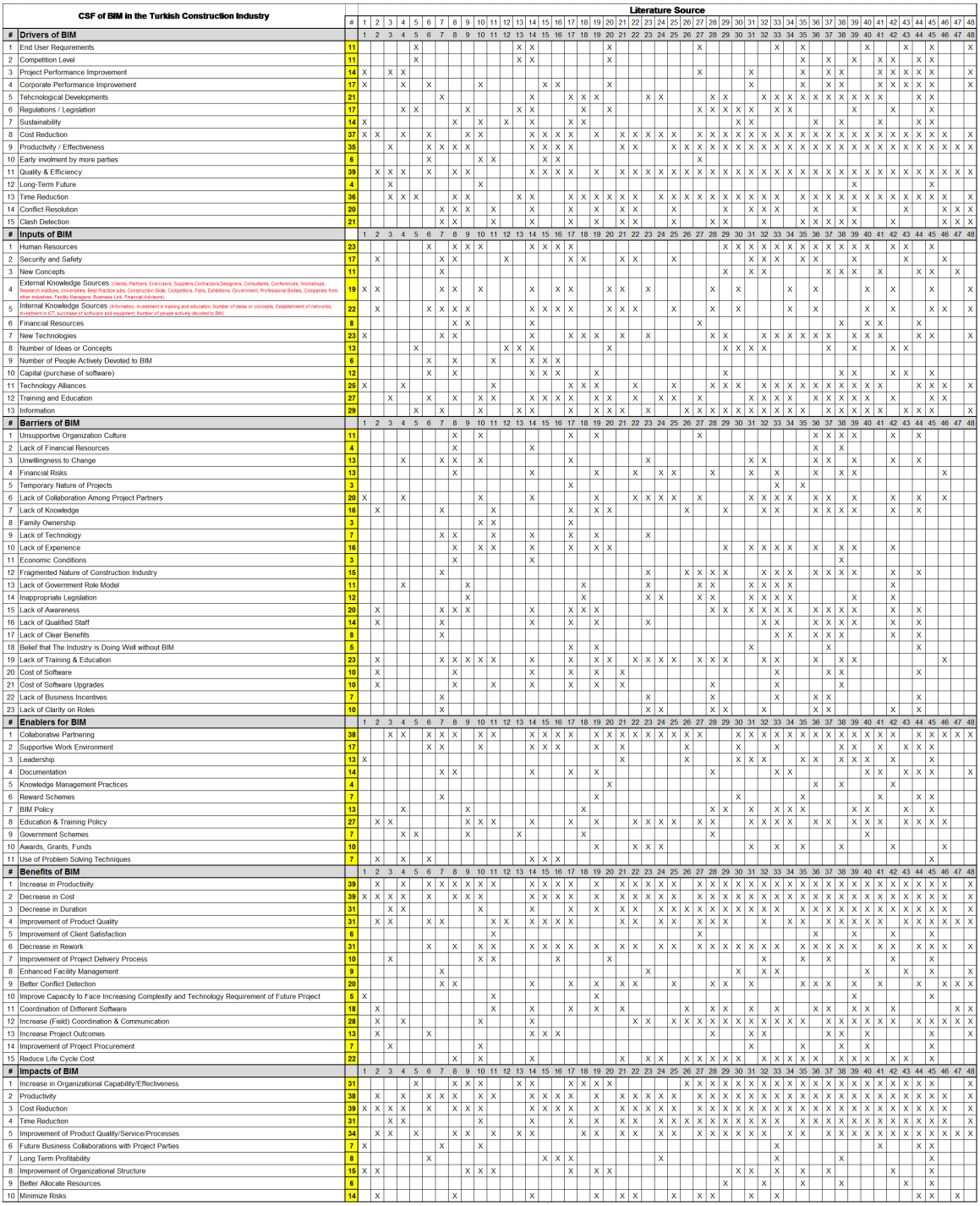
(xliv) Löf, and Kojadionovic, 2012

(xlv) NBIMS, 2007

(xlvi) Dave, 2010

(xlvii) Fogg, 2010

(xlviii) Campbell, 2007



| CSF of BIM in the Turkish Construction Industry | | Literature Source | | |

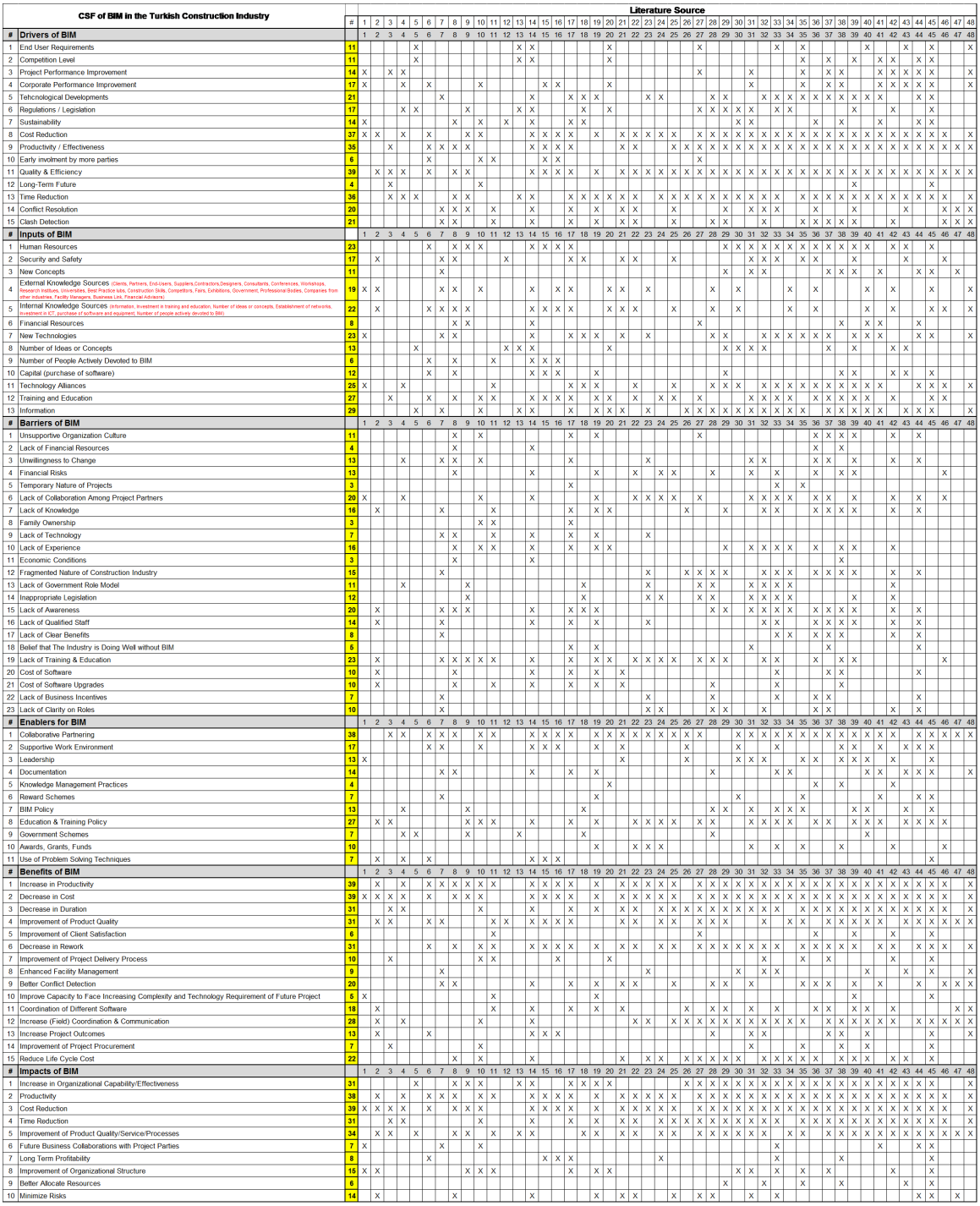
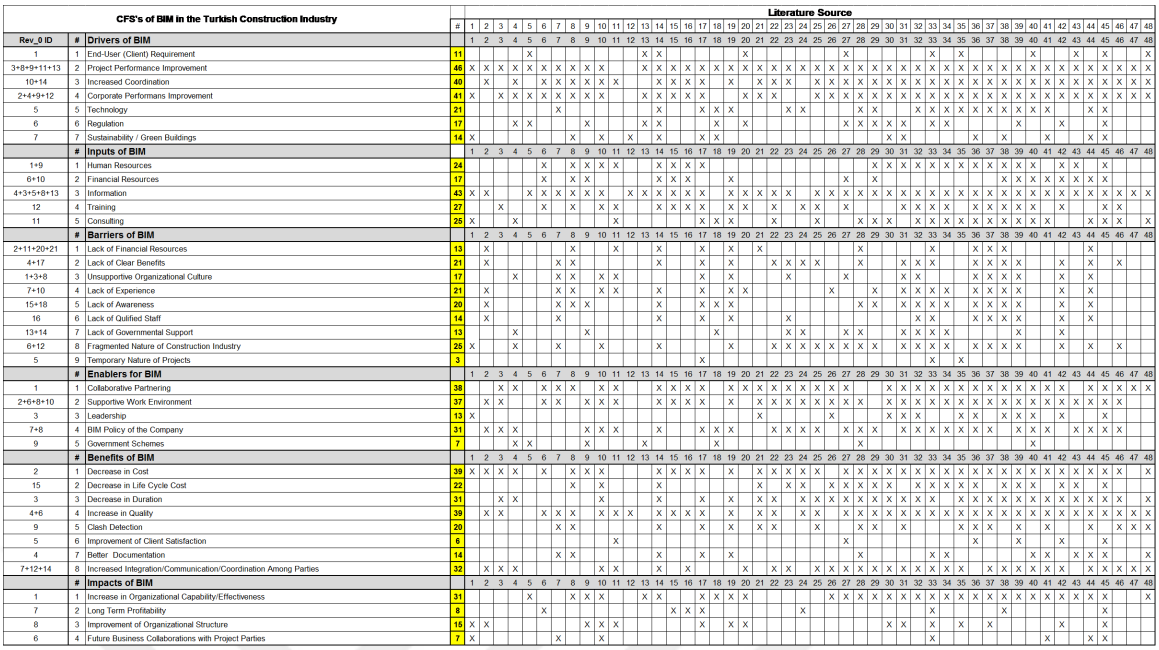


Figure C.2. The Initial List of Factors Pages 2.



| CFS's of BIM in the Turkish Construction Industry | | | Literature Source | | |

APPENDIX D: INDEPENDENT SAMPLES T-TEST

Table D.1. Group Statistics.

	BIM Usage?	N	Mean	Std. Deviation	Std. Error Mean
Availability of information	Yes	21	4.1500	0.74516	0.16662
and technology	No	60	4.1695	0.76907	0.10012
Availability of financial	Yes	21	37.500	0.7864	0.17584
resources	No	60	3.9661	0.96430	0.12554
Availability of qualified	Yes	21	4.2500	0.78640	0.17584
staff	No	60	4.2034	0.73765	0.09603
Training of employees	Yes	21	4.3000	0.97872	0.21885
	No	60	4.0169	0.65631	0.08544
Consulting	Yes	21	34.500	0.94451	0.21120
	No	60	3.3051	0.93319	0.12149
Supportive organizational	Yes	21	36.000	0.94032	0.21026
culture	No	60	3.5254	0.91644	0.11931
Experience level within	Yes	21	40.500	0.88704	0.19835
the firm	No	60	3.9322	0.63962	0.08327
BIM policy of the	Yes	21	4.1000	120.961	0.27048
company	No	60	3.7797	113.058	0.14719
Effective leadership	Yes	21	4.1500	0.98809	0.22094
	No	60	4.2542	0.77889	0.10140
Coordination among	Yes	21	4.1500	0.9333	0.20869
project parties	No	60	4.2034	0.71389	0.09294
Project size	Yes	21	3.7000	103.110	0.23056
	No	60	3.2373	105.600	0.13748
Client requirement	Yes	21	3.8000	105.631	0.23620
	No	60	3.6271	0.96308	0.12538
Awareness level of	Yes	21	3.5000	119.208	0.26656
the industry	No	60	3.6949	0.89547	0.11658
Knowledge sharing	Yes	21	3.2500	0.96655	0.21613
within the industry	No	60	3.5932	0.98469	0.12820
Appropriate legislation	Yes	21	3.3500	122.582	0.27410
	No	60	3.5593	105.489	0.13734
Governmental schemes	Yes	21	2.6000	109.545	0.24495
	No	60	3.0847	119.320	0.15534

Table D.2. Independent Samples Test.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Diff.	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Diff.	Lower	Upper
Availability of information and technology	Equal variances assumed	0.045	0.832	-0.099	77	0.922	-0.0195	0.19748	-0.4127	0.37375
	Equal variances not assumed			-0.1	33.757	0.921	-0.0195	0.19439	-0.4147	0.37566
Availability of financial resources	Equal variances assumed	0.846	0.361	-0.904	77	0.369	-0.2161	0.23897	-0.692	0.25976
	Equal variances not assumed			-1.000	39.908	0.323	-0.2161	0.21606	-0.6528	0.2206
Availability of qualified staff	Equal variances assumed	0.563	0.455	0.24	77	0.811	0.04661	0.19405	-0.3398	0.43302
	Equal variances not assumed			0.233	31.117	0.818	0.04661	0.20036	-0.362	0.45518
Training of employees	Equal variances assumed	13.116	0.001	1.461	77	0.148	0.28305	0.19377	-0.1028	0.66889
	Equal variances not assumed			1.205	25.043	0.24	0.28305	0.23494	-0.2008	0.76687
Consulting	Equal variances assumed	0.081	0.776	0.598	77	0.551	0.14492	0.24218	-0.3373	0.62717
	Equal variances not assumed			0.595	32.489	0.556	0.14492	0.24365	-0.3511	0.64092
Supportive organizational culture	Equal variances assumed	0.006	0.936	0.312	77	0.756	0.07458	0.23866	-0.4007	0.54982
	Equal variances not assumed			0.308	32.114	0.76	0.07458	0.24175	-0.4178	0.56695
Experience level within the firm	Equal variances assumed	3.116	0.081	0.642	77	0.523	0.1178	0.18338	-0.2474	0.48296
	Equal variances not assumed			0.548	26.023	0.589	0.1178	0.21512	-0.3244	0.55996
BIM policy of the company	Equal variances assumed	0.052	0.82	1.076	77	0.285	0.32034	0.29771	-0.2725	0.91315
	Equal variances not assumed			1.040	31.028	0.306	0.32034	0.30793	-0.3077	0.94835
Effective leadership	Equal variances assumed	0.807	0.372	-0.482	77	0.631	-0.1042	0.21615	-0.5347	0.32618
	Equal variances not assumed			-0.429	27.448	0.671	-0.1042	0.2431	-0.6027	0.39418
Coordination among project parties	Equal variances assumed	0.82	0.368	-0.267	77	0.79	-0.0534	0.20023	-0.4521	0.34531
	Equal variances not assumed			-0.234	26.937	0.817	-0.0534	0.22845	-0.5222	0.41541
Project size	Equal variances assumed	0.055	0.815	1.703	77	0.093	0.46271	0.27166	-0.0782	100.365
	Equal variances not assumed			1.724	33.525	0.094	0.46271	0.26844	-0.0831	100.853
Client requirement	Equal variances assumed	0.079	0.779	0.677	77	0.5	0.17288	0.25536	-0.3356	0.68136
	Equal variances not assumed			0.646	30.425	0.523	0.17288	0.26741	-0.3729	0.71869
Awareness level of the industry	Equal variances assumed	3.430	0.068	-0.771	77	0.443	-0.1949	0.25281	-0.6983	0.3085
	Equal variances not assumed			-0.67	26.645	0.509	-0.1949	0.29094	-0.7922	0.40241
Knowledge sharing within the industry	Equal variances assumed	0.193	0.662	-1.353	77	0.18	-0.3432	0.25363	-0.8483	0.16183
	Equal variances not assumed			-1.366	33.368	0.181	-0.3432	0.25129	-0.8543	0.16781
Appropriate legislation	Equal variances assumed	0.393	0.533	-0.736	77	0.464	-0.2093	0.2845	-0.7758	0.35719
	Equal variances not assumed			-0.683	29.135	0.5	-0.2093	0.30658	-0.8362	0.41758
Governmental schemes	Equal variances assumed	0.083	0.774	-1.601	77	0.113	-0.4848	0.30269	-108.748	0.11799
	Equal variances not assumed			-1.671	35.476	0.103	-0.4848	0.29005	-107.330	0.10381

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