INVESTIGATION OF THE BIM IMPLEMENTATION PROCESS IN THE DESIGN PHASE: CASE OF TURKISH COMPANIES

by

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ABSTRACT

INVESTIGATION OF THE BIM IMPLEMENTATION PROCESS IN THE DESIGN PHASE: CASE OF TURKISH COMPANIES

Innovations due to the increase of the technological developments expose Architectural, Engineering and Construction (AEC) industries into a cultural change. Even if the construction industry is rigid to not accept the innovations due to ongoing traditional approaches, Building Information Modeling (BIM) shows up to make closer the relationships among the project parties. With the support of BIM, industry members collaboratively work on minimizing the overall project efforts spent by each parties. However, keeping up with this new approach requires new steps for the achievement rather than the well known traditional approaches. That is why, this paper aims to investigate the critical success factors (CSFs) for BIM implementations in the design phase. First of all, an extensive literature study realized and as a following step case studies are conducted with Turkish companies. In order to cover all the aspects of BIM implementations a framework which includes 6 groups as; drivers, inputs, barriers, enabler, benefits and impacts is created. Emphasized factors in the literature review are assigned under the proper component as key factors. During the investigation of these CSFs, 25 case studies are conducted with 15 companies in the Turkish AEC industries to evaluate the importance level of the CSFs in their experiences. After these assessments within this study, the factors for successful BIM implementations in the projects were determined.

ÖZET

TÜRK FİRMALARININ TASARIM AŞAMASINDAKİ YAPI BİLGİ MODELLEMESİ UYGULAMALARININ ARAŞTIRILMASI

Teknolojik gelişmelerin artmasından kaynaklanan inovasyonlar, Mimari, Mühendislik ve İnşaat endüstrilerini kültürel bir değişime maruz bırakmaktadır. İnşaat endüstrisi, devam eden geleneksel yaklaşımlar nedeniyle yenilikleri kabul etmeme konusunda katı olsa bile, Yapı Bilgi Modellemesi (YBM) proje tarafları arasındaki ilişkileri daha da yakınlaştıracağını göstermektedir. YBM'nin desteğiyle, endüstri üyeleri her bir tarafça sağlanan toplam proje eforlarını en aza indirgemek için işbirliği içinde çalışılan bir ortam sağlamaktadır. Ancak, bu yeni yaklaşıma ayak uydurmak, iyi bilinen geleneksel yaklaşımdan ziyade başarıya ulaşmak için yeni adımlar gerektirir. Bu nedenle, bu makale tasarım aşamasında kullanılan YBM uygulamaları için kritik başarı faktörlerini incelemeyi amaçlamaktadır. Öncelikle geniş bir literatür taraması yapılmış ve bir sonraki adım olarak Türk firmaları ile vaka çalışmaları yapılmıştır. YBM'si uygulamalarının tüm yönlerini kapsayacak şekilde 6 bileşenden oluşan bir sistem; "itici güçler", "girdiler", "engeller", "etkinleştiriciler", "faydalar" ve "etkiler" oluşturuldu. Literatür taramasında vurgulanan faktörler, anahtar faktör olarak uygun bileşen altında gruplandırıldı. Bu anahtar faktörlerin araştırılması sırasında, Türk Mimari, Mühendislik ve İnşaat endüstrilerinde faaliyet gösteren 15 şirket ile anahtar faktörlerin deneyimlerindeki önem düzeyini değerlendirmek üzere 25 vaka çalışması gerçekleştirilmiştir.Bu çalışmada gerçekleştirilen değerlendirmelerden sonra, YBM ile uygulanan projelerin başarılı olması gereken faktörler belirlenmiştir.

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LIST OF ACRONYMS/ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
4D	Four imensional
5D	Five Dimensional
6D	Six Dimensional
7D	Seven Dimensional
AEC	Architectural, Engineering and Construction
AIA	The American Institute of Architects
AIM	Asset Information Model
API	Application Program Interface
AVG	Average
BEP	BIM Execution Plan
BIM	Building Information Modeling
BREEAM	Building Research Establishment's Environmental Assessment Method
BS	British Standards
CAD	Computer Aided Design
CDE	Common Data Environment
CEN	European Committee for Standardization
COBie	Construction Operations Building information exchange
CSFs	Critical Success Factors
EIRs	Employer's Information Requirements
ENR	Engineering News Record
HSE	Health, Safety and Environment
IAI	International Alliance for Interoperability
ICT	Information Communication Technology
IFC	Industry Foundation Class
IPD	Integrated Project Delivery
ISO	International Organization for Standrds

LEED	Leadership in Energy and Environmental Design
LOD	Level of Detail
MAX	Maximum
MEP	Mechanical, Electrical and Plumbing
MIDP	Master Information Delivery Plan
MIN	Minimum
N/A	Not Applicable
NBIMS	National BIM Standards
NIST	National Institute of Standards and Technology
PM	Project Management
PIM	Project Informatıon Model
PAS	Publicly Available Specification
RFI	Request for Information
ST	Structural
USGBC	United States Green Building Council

1. INTRODUCTION

1.1. Background of the Research

Over a century, it is known that Architectural, Engineering, Construction (AEC) industries have traditional rigid approaches because the nature of the AEC industries is not like the other industries when it comes to adopt new techniques. This can be explained by two most commonly accepted reasons supporting why the industry continues with the traditional approach as; in the industry each project is unique and has a fragmented structure including; designer, main contractor and subcontractors and the consultant groups. And since the regular common methods are accepted by the parties they hesitate to change their methods.

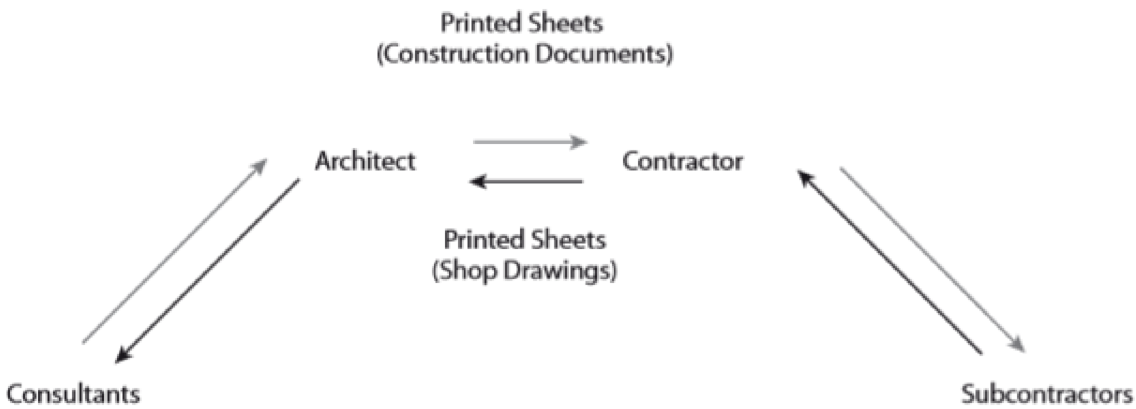

Figure 1.1. Traditional Method for Design Review (Krygiel *et al.*, 2008)

In Figure 1.1, it shows how the communication and knowledge transfer over design is shared among the project parties through the traditional operations. But the traditional operation has started to change in the early 21st century due to the new developments and formations in the technology. Improving technological developments cause the industry members to proceed and communicate through object based designs easily. Object based data modeling has gained popularity in the last decades of the 20th century and its standardization began with the publishing of the Industry

Foundation Classes (IFC) by International Alliance for Interoperability (IAI) formed in 1995. After a decade with the rising of integration due to new developments in the technology, the adoption of innovations in AEC industries started to gain popularity.

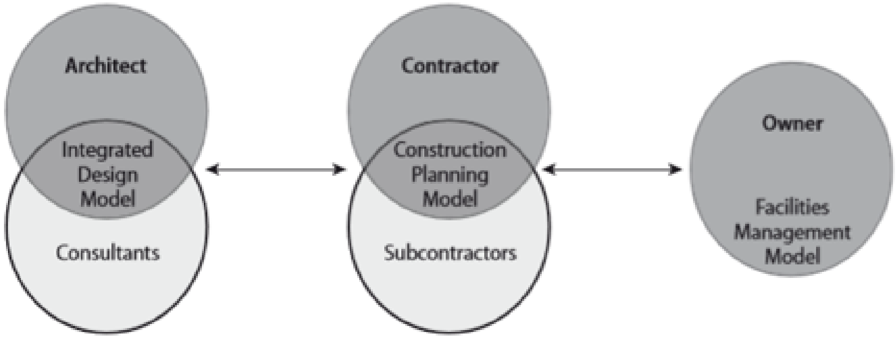

Figure 1.2. Integrated Approach for Design Review (Krygiel *et al.*, 2008)

With the inclusion of these innovative approaches that contribute to the construction sector, our traditional project management perception has also changed. As illustrated in Figure 1.2, a comprehensive management is internalized to increase the efficiency of the processes by decreasing the unproductive communication and poor knowledge transfer among the parties.

In 2004, the National Institute of Standards and Technology (NIST) published a report stating that lack interoperability and poor data management costs approximately 16 billion dollars to AEC industries. (NIST, 2004). Because of this situation, in the upcoming years National Building Information Model Standard (NBIMS) defined the Building Information Modeling (BIM) as “a digital representation of physical and functional characteristics of a facility” (NBIMS, 2007). In the meantime, design tools and other softwares in the AEC industries have been improved to deliver more accurate models aligned with the BIM implementation process which allows the shift to
(i) increase; productivity, efficiency, infrastructure value, quality and sustainability,
(ii) reduce; life-cycle costs, lead times and duplications.

Adoption of the standards, comprehensive thinking and the development of Information Communication Technology (ICT) by the parties helps the BIM users to manage all the processes within the project. And, if the AEC industries become more automated new services can be provided by the professionals.

1.2. Problem Determination

Current construction market continues to grow slowly all around the globe because of the increasing short-term risks. Industry members are concerned about the construction costs keep going to scale up as in recent years. This situation may lead some protectionists' shift their attitude in the industry. A close scenario is available in Turkish market. As Turkish construction industry is scrutinized, it is clearly observed that market carries not just the construction cost risk, but also observing a shrinkage in real estate sector created a fragile appearance in the local market. Regarding to the latest construction industry values; in the third quarter of 2018, the construction sector decreased by 5.3% compared to the same period of 2017 (KPMG, 2019).

As indicated that Turkish construction sector has sensitivity to the economical fluctuations, throughout BIM contractors can cut their costs in the highly competitive local market by taking the advantage of the technology. Since the implementation of BIM processes increases the communication among the other parties via parametric and object-based modeling, greater design decisions and better cost estimating results can be achieved. BIM had slow adoption rate in its early stages but within the last 5 years BIM implementations gained pace all over the globe because of the mastering technological infrastructures to present acceptable BIM models to the AEC industries. Even BIM users are increasing in numbers around the World, due to its nature, it is always expected that through new technologies the true potential of BIM will be indicated. Besides the local market opportunities, more than 40 Turkish construction firms are globally present in the international arena by holding the second place after China in terms of international contractors (ENR, 2018). However, Turkish companies revenues in the international market hinders because of several reasons when it is compared with the western countries. That is why in order to overcome the challenges both local and international markets advancing in the integration via BIM processes will be supportive. When the BIM implementations in Turkey at the beginning of the time, a global research that has been carried out by Stanley *et al.*, 2014 indicating the following results. "In the UK, the National BIM Report found that only 39% of survey respondents in 2012 were both aware of, and actually using, BIM (National BIM Survey 2013). In Australia, a survey found that 49% of architects, and 75% of both engineers and contractors used BIM, and on average, that BIM is used on 36% (engineers) to 59% (architects) of projects (BEIIC 2010). New Zealand's only national BIM survey recently found that the proportion of BIM users increased from 34% [2012] to 57% [2013], with a year-on-year increase in overall BIM awareness in the construction industry, from 88% [2012] to 98% [2013] (Masterspec 2012; 2013)" (Stanley *et al.*, 2014).

As a result of the general current scenario, for the Turkish AEC industries it is crucial to have a background in BIM and knowledge on the BIM implementations to identify which critical success factors are significant to adopt in their systems.

1.3. Problem Statement

In this thesis, critical success factors for BIM implementation will be investigated and the current status of the Turkish companies' BIM implementations in design phase will be discussed. All of these studies will be based on real life case experiences to investigate the alterations of the critical success factors among the project types, function utilization.

1.4. Related Studies

There are lots of studies in the fields to understand the benefits and barriers of implementing BIM and the investigate the adoption of BIM processes in AEC industries (Yan *et al.*, 2008; Sun *et al.*, 2015; Stanley *et al.*, 2014; Ghaffarianhouseini *et al.*, 2017; Arayıcı *et al.*, 2012; Eadie *et al.*, 2013; Chien *et al.*, 2014; Mostafa *et al.*, 2018). Although, there are studies realized to explain the importance of BIM processes in the industries; there are limited number of studies that has investigated the analysis of critical success factors for BIM implementations including the drivers, enablers, inputs, barriers and benefits to the companies (Shang *et al.*, 2014; Ozorhon, 2013).

1.5. Aim and Objective of the Research

The aim of this thesis is to evaluate the current Turkish industry in terms of BIM implementations in design phase. In this respect, the critical success factors will be determined based on the appreciation of the industry professionals and real experiences collected through case studies.

The purpose of this study is to courage and orientate the members of Turkish AEC industry to realize BIM implementations in the light of CSFs arisen by current understanding and successful implementations. Regarding to this purpose, objectives of this study are listed below as follows;

- Investigation through literature reviewing to identify the CSFs of BIM implementation.
- Developing a comprehensive framework for the BIM implementation process
- Evaluating the CSFs via real life case experiences with the industry members
- To clarify common CSFs for the BIM implementation process and give recommondations to industry members

1.6. Research Method

In order to evaluate the implementations of BIM and identify the critical success factors for Turkish companies case studies are conducted with the members of Turkish AEC industry. To realize this methodology several steps were followed as listed below;

Firstly, the problem is identified and related literature review is progressed by evaluating the related studies conducted to determine the critical success factors for the BIM implementations such as the barriers, drivers, enablers and benefits of BIM.

Secondly, after the evaluation and verification of the critical success factors prepared interview form is reviewed by an academician and a sector professional for potential modifications prior to finalize it.

Thirdly, for the data collection regarding to the real life experiences, firstly case studies are conducted with the respondents to obtain general information about the company and the general BIM implementations within the company. Then case study questions asked to find out which critical success factors also emphasized in their experiences. Several projects were tried to be discussed with the respondents had convenient background and provided multiple projects regarding to BIM. Case studies are carried out via face to face meetings and not voice records but also visual and written supporting documents for each cases are taken. There were always multiple participants from the companies during the interviews which lead to obtain different views on the topic, if there was.

1.7. Scope and Limitations

The study reflects the experiences and perceptions of the respondents. Some respondents were not willing to share financial information or company/project- specific details. In most cases, there is no monitoring system to evaluate BIM performance, therefore it was difficult to capture the real extent of benefits/impacts.

1.8. Organization of Thesis

The chapters of this thesis are organized and explained as follows;

- In Chapter 1, the general information and the definition of the problem related to the topic is provided emphasizing the aim and constraints in the related topic.
- In Chapter 2, the literature review of the BIM in the AEC industry members and other related topics are presented.
- In Chapter 3, the methodology for achieving the aim of the research is explained.
- In Chapter 4, the findings of the case studies are represented.
- In Chapter 5, findings are criticized to check the validity by comparing the factors found in the literature review to understand the current scenario of Turkey.
- In Chapter 6, the final evaluation of the results and the conclusion of the research are shared.

2. BIM IMPLEMENTATIONS IN AEC INDUSTRIES

2.1. Introduction

AEC industries face a need for integrated procedures to overcome the problems occurred due to the lack collaboration and communication in the existing methods. Traditional methods are not efficient in project delivery. That is why, practitioners looked for a new approach, BIM ie. for knowledge sharing throughout the life cycle of the of the building with the disciplines involving in the planning process of the project. As the foundation of digitalization is based on the improvements in technology, the future of the construction industry has the potential of gaining favors thanks to BIM by connecting all the parties to provide clean structures, efficient processes, low costs, less time and quality throughout the entire life cycle of the projects and solving the problems affecting project performance ahead. Building life-cycle is schematized in figure 2.1 emphasizing that BIM helps to improve each phase on the life-cycle. This digitalization process played a significant role on the productivity in the AEC industries. BIM 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 supports the planning activities, construction activities and operational activities of the buildings/structures digitally. This innovation in the industry provided a connection of all parties and let the process to be managed comprehensively. Therefore using BIM, it should improve the efficiency and the quality of the work done, by decreasing the planning time simultaneously.

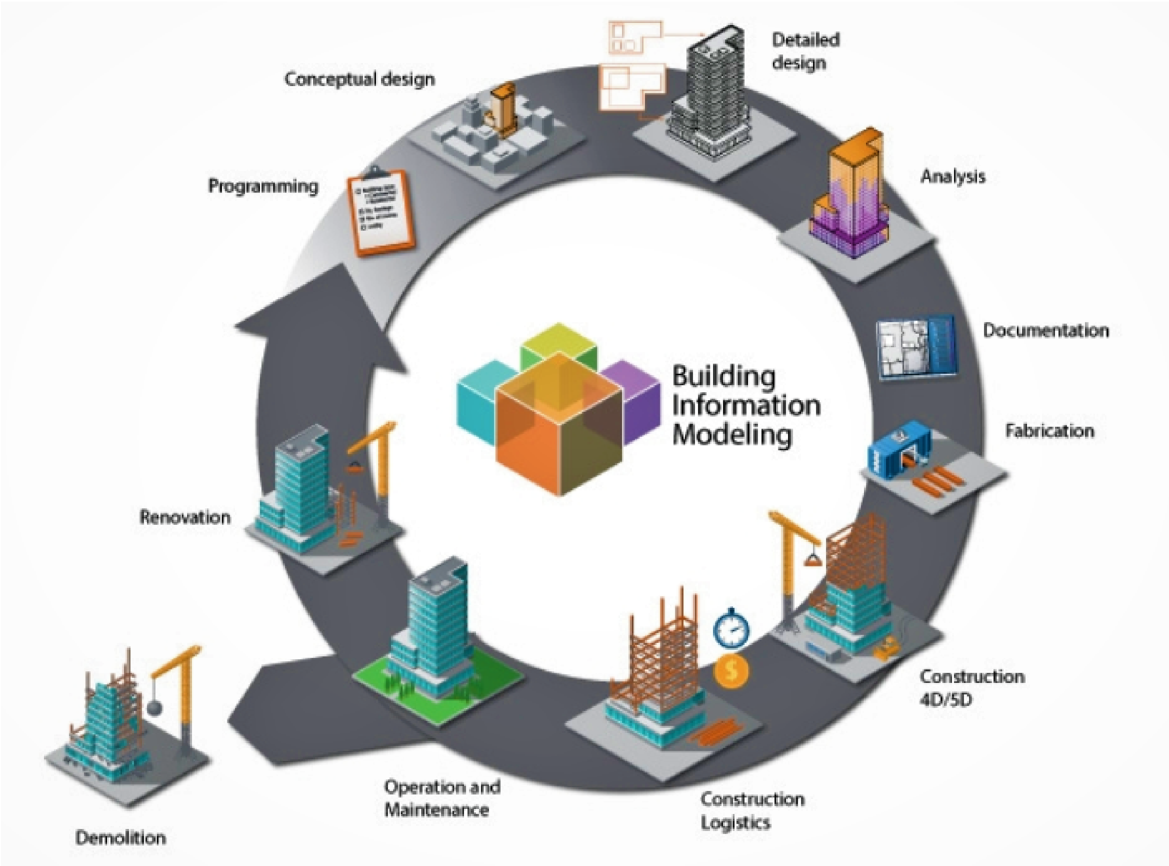

Figure 2.1. Building Life-cycle.

BIM provides an integrated environment and increases the communication between parties via parametric and object based designing in a single model by allowing all the parties including MEP teams, structural designers and architectures to make editings for validating the model every time. As a result of the early collaboration potential problems that may occur in the next stages can be solved in design phase so that more accurate design can be reached when it is compared with the traditional 2D design. Also it is known that owning an accurate design in the construction phase helps for the price estimation. An accurate design provides more accurate quantity take off that enables project managers to plan the project budget and govern the progress payments of the contractors easily. In figüre 2.2 below, the cost influence of having an accurate design before the construction phase is shown visually.

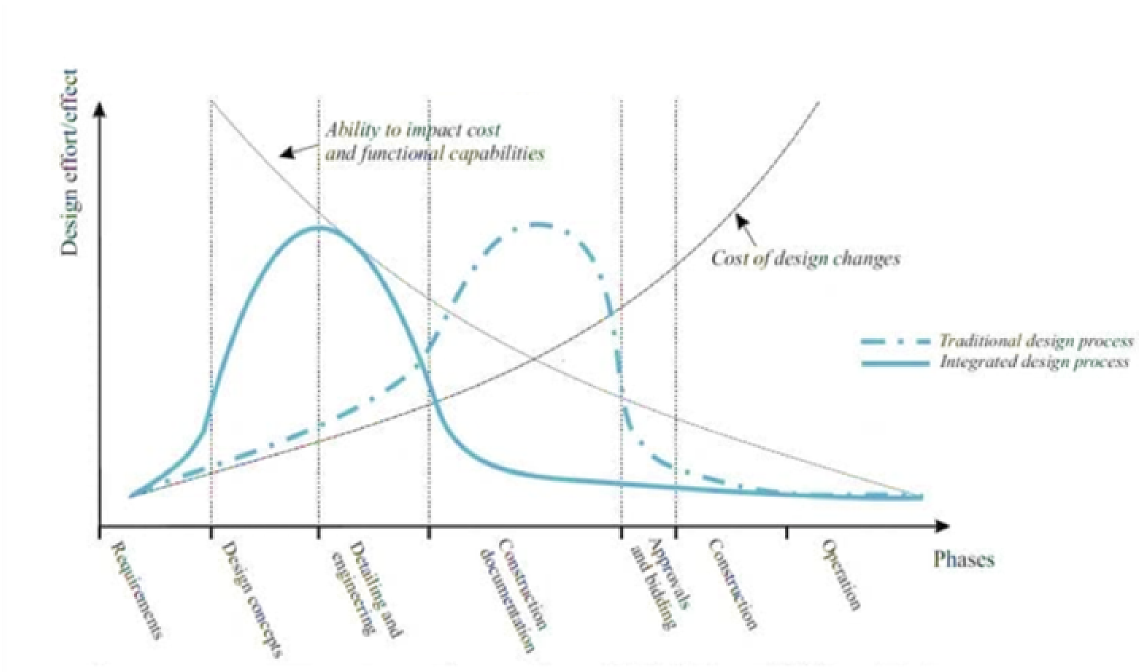

Figure 2.2. MacLeamy Curve (HOK Presentation, 2011)

As seen in the figüre 2.2, the primary steps has the higher influence on the project costs because of the uncertainties cause too many changes during the construction and documentation phase. However, acknowledging that the material cost and rework cost is greater than spending money on design phase through BIM all of the uncertainties and problems can be solved in a digital environment before the construction and documentation phase. That is why BIM models lead contractors to be more competitive in the market by decreasing the contingency range in their bids.

2.1.1. Definition of BIM

Object based designing is not new for the engineers dealing with the structural design. That is why, since they are experienced in object based designing the switch for 3D parametric modeling via BIM was easy in the late twenties century. Lots of definitions have been developed for BIM in the past years. Some of the well-known definitions are as follows;

• According to NBIMS Committee 2007, the definition of BIM is defined as "a digital representation of physical and functional characteristics of a facility" (NBIMS, 2007).

• 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).

• 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).

• 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).

• 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, 2012).

• 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 life cycle – 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).

• BIM is an integrated process that vastly improves Project understanding and allows for predictable outcomes. This visibility enables all of the Project team members to stay coordinated, improve accuracy, reduce waste, and make informed decisions earlier in the process-helping to ensure the project's success (Autodesk, 2012).

• The process of modeling and communicating the structure of a building in detail to benefit the entire building life cycle (Tekla, 2013).

• Discrete set of electronic object-oriented information used for design, construction and operation of a built asset (PAS 1192-5,2015).

• Construction of a model that contains the information about a building from all phases of the building life cycle (ISO 16757-1, 2015).

2.1.2. Characteristic's of BIM

BIM in most simple terms is the utilization of a database infrastructure to encapsulate built facilities with specific viewpoints of stakeholders (Krygiel *et al.*, 2008). Object based design and integrated infrastructure of BIM's nature playes a key role in the creation and use of coordinated, consistent, computable information about in a project's design process. During the design phase stakeholders and architectures can lead the decision making together considering the production, fabrication and management of the facilities with other teams to estimate the activities and the effects on the performance. As a result, through BIM more sustainable designs can be produced to satisfy the project owners.

When all the definitions made for BIM are examined, the realization of the intended targets with the BIM instead of the traditional methods goes through the creation of the desired BIM model in a proper manner. In order to create the desired BIM model, specific characteristics of BIM are emphasized. These dramatic characteristics described in detail are the game changers for the traditional approach.

2.1.2.1. Parametric Modeling. Parametric modeling is the core characteristic of the BIM applications and it differentiates from the traditional 3D objects. Data-based parametric BIM modeling allows designers to view the building and its elements from all angels which leads to an early revealing of the potential problems and the corrections of them. Dynamic parametric elements are automatically structured according to the rules programmed in 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. With BIM, you create a parametric 3D model used to auto-generate traditional building abstractions such as plans, sections, elevations, details, and schedules. Drawings are not collections of manually coordinated lines, but interactive representations of the model (Krygiel *et al.*, 2008). As a result of this characteristic, whether a change occurs in the model because of the parametric rules for the objects it modifies associated geometries automatically (Eastman *et al.*, 2008). That is why, parametric design saves time by creating and editing multiple design portions simultaneously by revealing a more complex model. And, all elements can be enriched adding building information in the digital environment and can be stored as a complete set of design documents in an integrated database environment makes the model accessible to use it in further stages of the project (Autodesk, 2002).

Parametric BIM model is not only useful for the design phase but also keeps functional data for the construction phase. Parametric information are used for construction decision making, production of high-quality construction documents, prediction of building performance, cost estimating, and construction planning.

2.1.2.2. Object-oriented Modeling. Traditional CAD design methods allow users to observe building elements in 2D which hinders to fully understand the form of the designed elements/objects of the building. With the development of object-oriented CAD packages; association, creation of modeling constraints and contacting relationships within the objects and the object properties become present. In other words, CAD models become more intelligent with the support of object-oriented modeling (Ibrahim and Krawczik, 2003; Lee *et al.*, 2003). These constraints and relationships have been used to develop tools and features for performance and cost analysis, clash detection, conflict resolution, scheduling and intelligent documentation (Bajzanac, 2005; Mitchelle *et al.*, 2007; London et. al., 2008)

"More recently, object-oriented CAD systems (OOCAD) replaced 2D symbols with building elements (objects), capable of representing the behavior of common building elements. These building elements can be displayed in multiple views, as well as having non-graphic attributes assigned to them. The inclusion of parametric 3D geometry, with variable dimensions and assigned rules, adds "intelligence" to these objects, permitting the representation of complex geometric and functional relationships between building elements. In this paradigm, walls are objects which can be stretched, joined, have height, be of a specific cross-section type, and "own" associated properties, such as a fire rating or insulation value. Similarly, doors and windows are represented as objects, capable of representing their relationship to the walls in which they are placed and behaving accordingly. More importantly, abstract objects, such as a space, can be defined by the relationships between physical building elements, identified (e.g. room number, room name, etc.), described (e.g. area, volume, use, occupancy, etc.), and referenced (e.g. listed in a room schedule, counted to calculate total floor area, etc.). Capturing these relationships and behaviors and the richness of the intelligence are just not possible in the previous CAD paradigm. Building information modeling (BIM) is the latest generation of OOCAD systems in which all of the intelligent building objects that combine to make up a building design can coexist in a single 'project database' or 'virtual building' that captures everything known about the building. A building information model (in theory) provides a single, logical, consistent source for all information associated with the building" (Adler, 2006).

A conceptual framework for automating the design objects is shown in the figure 2.3 and is exemplified by a form work design to clearly explain how model automates. (Singh *et al.*, 2017)

"A system of traditional form work for walls consisting of sheeting, studs, wales and tie rods has been used in this research. API programme performs design computations and generates the information, using that form work elements are created in the model. Form work elements are developed as parametrically constrained objects whose size, the number of sub-elements, and alignment, can be adjusted using dimensional parameters. After computing dimensional information in the API environment, form work elements are placed along the wall length and are adjusted using the calculated parameters. These form work elements are information-rich BIM elements/objects. The information associated with them can be utilized further for visualization and developing schedules of quantities."

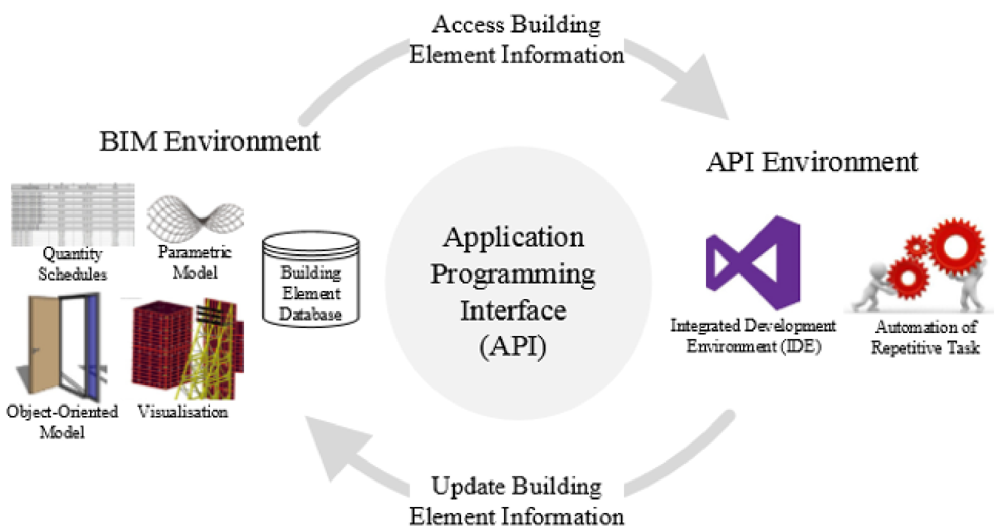

Figure 2.3. Information Exchange Between BIM Environment and API Environment (Singh *et al.*, 2017)

2.1.2.3. Interoperability. Interoperability is defined by the National Institute of Standards and Technology (NIST) 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).

Since BIM increases multi-disciplinary and interdisciplinary collaboration through the digital environment by allowing users to work on a single parametric and object oriented model, data exchange and compatibility is one of the most technical collaborative way in BIM implementations. By nature, design process is illusive and iterative within the same discipline, and between the other AEC disciplines. That is why working on a common interoperable data format like standardized IFC format plays a significant role in the prevention of sever problems related to data acquisition and management. Often, design team members including those from the same discipline, use different software tools and work in parallel (Arayici and Aouad, 2010). For example, a building can be divided into three different sections amongst three different architects to design. Architects can be using a different software tool, needing to incorporate their work at the end (Nour 2007). When considering the whole construction life cycle, including the design process, the complexity, uncertainty and ambiguity will increase (Arayici *et al.*, 2012).

2.2. Implementation OF BIM

In a standard project, architects prepare the drawings and share the information among the consultants. Consultants use the shared design and information to draw their own designs. Then, architects collect each design from the consultants to coordinate their own work and finalize the drawings that will be submitted to the contractor and distributed to the subcontractors. At the end of the project, the contractor will create new sets of drawings with added detail, but all based on the original set of documents. Against to the standard method, BIM allows users to understand the needs of customers from outset to focus on accurate by providing what they need. Integrated environment that BIM creates brings all the teams by each parties to work together on an equal footing without the constraints of their organizations processes or objectives, but with a shared common goal. In the AEC industries, BIM implementation hierarchy is explained as;

- Architects work on a single model together with the consultants while eliminating the phases of distributing the drawings to consultants and gathering the the drawings from the consultants. Consequently, supporting the improvements in interconnection among the parties is the main milestone for shifting to BIM implementations.
- Contractor takes over the accurate model to commence the construction phase, after the collaboration to finalize the model.
- Whether changes occur in construction phase can be adjusted in the model, before sharing the model with the client for the operational usage.

Therefore, BIM has power to overcome the things like poor collaboration, competitive tendering, risk transfer, late engagement of specialists. Successful implementation of BIM can address these issues meanwhile delivering benefits for both individuals and the organizations that they work for.

2.2.1. BIM Maturity Levels

BIM maturity levels run from 0 to 3 which measures the construction supply chains' ability to operate and exchange information.As the maturity enhances, likelihood of the non-predicted events' realization decreases. In order to actualize a successful BIM implementation, all project parties should encounter a certain level of BIM capability (Giel and Issa, 2013). According to the PAS 1192-5, figüre 2.4 provides the maturity map visually.

2.2.1.1. Level 0 BIM. This is the elementary step of the information generating process. In this level, CAD drawings and drawn elements are shared with the Project parties. This level of maturity is inefficient and non-interoperable because of the low communication when it is compared with the further levels.

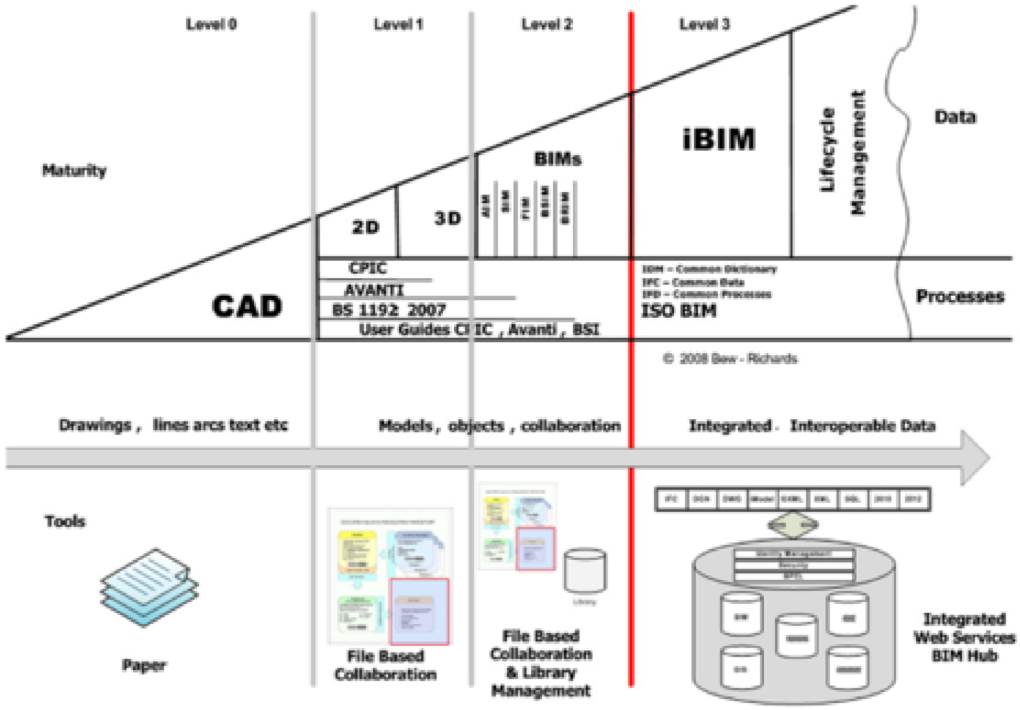

Figure 2.4. BIM Maturity Map (PAS 1192-5, 2015)

2.2.1.2. Level 1 BIM. Within this level, Project parties are focusing on the transition from CAD files to 2D and 3D information generation. When it is compared with the Level 0 BIM implementations, there is a partial collaboration to exchange the generated information in level 1 BIM implementations.

2.2.1.3. Level 2 BIM. This level of BIM implementation supports collaboration among the Project parties. For this knowledge sharing a common data environment is used by the parties. There should be a present existing common file type like IFC, so that each party members can easily track the knowledge sharing. Also, the softwares that are going to be selected by the parties should be interoperable means that each party should be able to export the created information in common file types. Therefore, level 2 can be defined as "file based collaboration" and the data set or "information model" is called as a "Project Information Model".

2.2.1.4. Level 3 BIM. Level 3 BIM implementation covers the full integration of the information in a cloud-based environment allowing to be accessible by each members of the Project for editing the files in real time. A Level 3 model can be used in the life-cycle management as an "Asset Information Model".

2.2.2. BIM Dimesions

BIM is not a tool chain to shift from 2D to 3D modeling. As it is stated that it provides knowledge sharing and communication through object based design, it is possible to share characteristic information of the objects like indicated in figure 2.5 BIM models have a range between 3D and 7D. For each BIM models features and contributions are explained in details below.

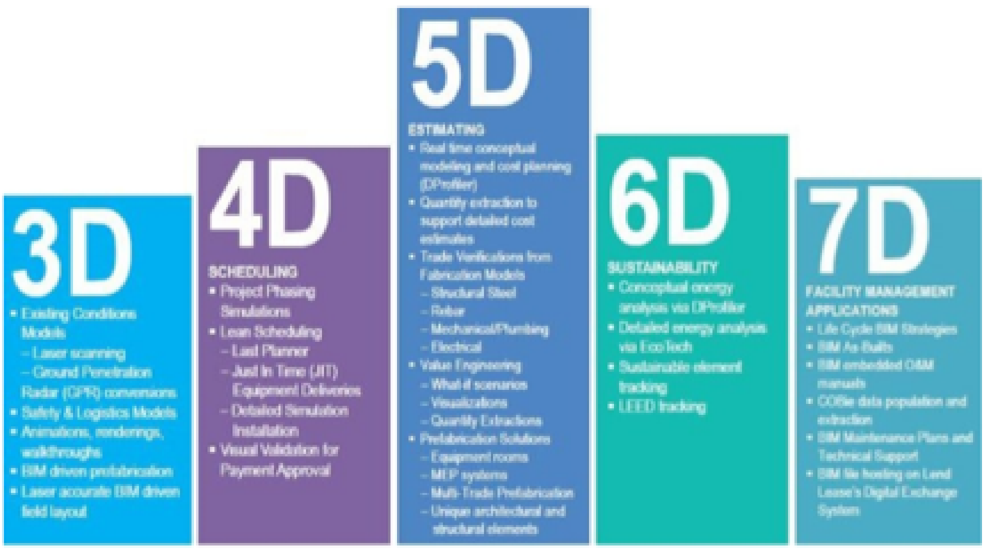

Figure 2.5. Levels of BIM (Rancane, 2014)

2.2.2.1. 3D BIM Model. 3D level means the three dimensional model that is useful for the visualization. Through visualization BIM models ease the understanding and place a key role on making decisions on design phase. A 3D BIM model provides walk-throughs for the project parties to identify the problems and solving them on model before facing the problem on site during the construction and documentation phase.

Moreover, 3D BIM model helps to accelerate the pace of the work on construction site by the utilization of prefabrication. This will increase the construction performance decreasing the cost and time. Also, visualization is used as a tool for marketing purposes.

2.2.2.2. 4D BIM Model. 4D level means that Scheduling information is added to the 3D model. Through the scheduling information each can track when that object needs to be built, to be transferred to the site and used in the project. Within this level efficiency on the site operations increases and the produced waste on site decreases since well planned Schedule can let to gain a favor via fabrication of some project elements.

2.2.2.3. 5D BIM Model. 5D level means that the cost information is added to the 4D model. By adding the cost aspect in objects it provides real time estimating and whether a change occurs it estimates the cost simultaneously. And so it will make easy to track the material costs. This allows designers to conduct value engineering. And also automatically realized cost adjustments will lead a better productivity on site. Also, 5D models bring transparency for the allocation and distribution of the money during the life cycle of the Project.

2.2.2.4. 6D BIM Model. 6D level corresponds to energy analysis implementations on the model. As the certification of LEED is the main target to obtain for the design, energy analysis can be performed to check the energy use of the building and material's selection regarding to sustainability can be done.

2.2.2.5. 7D BIM Model. 7D level corresponds to the operational activities because it is a digital representation of the as-built BIM Model. And, due to the rich information provided within the model, it allows easy facility management and asset management activities for the owner. That is why maintenance and operational costs decrease through the life cycle of the building because of an easy identification of the objects.

2.2.3. Level of Details(LODs) of BIM

Level of Detail or Level of Development (LOD) is defined to measure the service level of BIM model and objects for each stage of the project to demonstrate how and what is going to be constructed. This clear articulation allows model authors to define what their models can be relied on for, and allows downstream users to clearly understand the usability and the limitations of models they are receiving. The objectives of defining LOD before the design stage;

- helps to assign the clear pictures of what will be included in the BIM deliverables.
- helps design managers to coordinate the design process regarding to the need provided in different design stages.
- Brings a standardization in a contractual way which can be referred in BIM execution plans.

Regarding to AIA, there exists 5 LODs shown in the table 2.1 below regarding to the content of the BIM model.Also, these LODs are explained in details below (AIA, 2013).

2.2.3.1. LOD 100 – Conceptual Level. Whit-in this service level a conceptual model can be created. The created model indicates the object's parameters like area, height, volume, location and orientation on a basic level which are useful for analysis, cost estimating and scheduling activities.

2.2.3.2. LOD 200 – Schematic Level. This level can be defined as the approximate geometric level. In this service level modeled objects have the parameters of approximate quantities, size, shape, location and orientation including the non-geometric information as well. LOD 200 also allows users to make analysis, cost estimating and scheduling over the model.

2.2.3.3. LOD 300 – Documentation Level. This level can be defined as the precise geometry level. LOD 300 model's objects includes the parameters of precise quantities, size, shape, location and orientation. In addition to LOD 200, this model provides accurate modeling, documents and shop drawing which are helpful for the construction phase activities. Also shows how building objects interface with different systems and other building objects.

2.2.3.4. LOD 400 – Fabrication and Assemblies. This stage refers to the fabrication level because modeled objects assembly and detailed information are included in a LOD 400 model in addition to LOD 300 model.

2.2.3.5. LOD 500 – As Built Level. LOD 500 model is the representation of digital twin of what will be constructed for the maintenance and operation phases. In addition to actual and accurate in size, shape, location, quantity, and orientation, non-geometric information is attached to the objects.

2.3. Concept of BIM Implementation

On a typical construction project, a lot of information is produced. The trouble is that information is often unstructured, poorly co-ordinated and difficult to find. This leads to decrease the efficiency for the work in completion. Through adopting and implementing BIM, the efficiency can be gained which will lead to an improvement in time and cost saving as well. The reason behind this is the integrated environment of BIM. As stated in the definitions and characteristics of BIM, the creation and use of coordinated, consistent, computable information about a building project in design process requires all parties to collaborate and share the information they create in a mutually accessible online space known as a common data environment (CDE). In this way, all the members who have permission by each party will have the access to the information. Data within the CDE will be used to create the "information model" which can be used in the whole stages of the life cycle of a facility from inception to demolish.

Table 2.1. Summary Table of LODs

LODs	**100**	**200**	**300**	**400**	**500**
Model Content					
Design and Coordination	Non-geometric data or line, work, areas etc.	Generic elements shown in 3D	Specific elements Confirmed 3D	Shop drawing/ fabrication	As-built
Authorized Uses					
4D Scheduling	total construction duration	Time-scaled, ordered major activities	Time-scaled ordered, detailed assemblies	Fabrication and assembly detail including construction means and methods	
Cost Estimating	Conceptual cost allowance	Estimated cost based on measurement of generic element	Estimated cost based on measurement of specific assembly	Committed purchase price of specific assembly at buyout	Record costs
Program Compliance	Gross departmental areas	Specific room requirements	FFE, casework utility connections		
Sustainable Materials	LEED strategies	App. quantities of materials by LEED categories	precise quantities of materials with % of recycled/locally purchased material	Specific manufacturer selection	Purchase documentation
Environmental	Strategy and performance criteria based on volumes and areas	Conceptual design based on geometry and and assumed system types	App. simulation based on specific building assemblies and engineered systems	Precise simulation based on specific manufacturer and detailed system components	Commissioning and recording of measured performance

A CDE can be in a form of project server, an extranet or a cloud-based system. One of the most significant things that since it is digital it allows easy access to it and it can be easily sub-divided into areas. It allows parties to communicate and collaborate easily and share the data in a well-structured CDE for collecting, managing and sharing the information on a project level.

2.3.1. Level 2 BIM Implementation

Regarding to the BS Standard PAS 1192-2 BIM Level 2 guideline, document and data management is demonstrated as the figure 2.6.

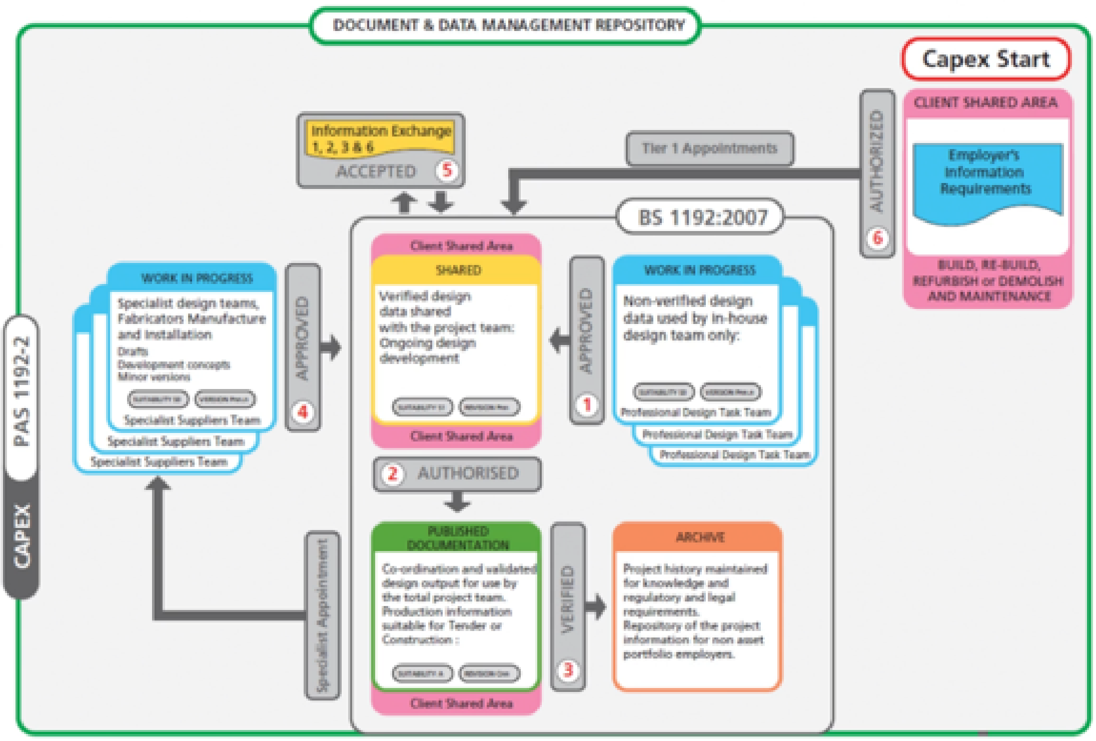

Figure 2.6. Level 2 BIM Document and Data Management Process (PAS 1192-2)

Within the single shared area, first the process starts with receiving the client's authorized Employer's Information Requirements (EIRs) which is a document includes the set outs of needs. Having EIRs lead to produce a strategy for the procurement and the BIM execution plan (BEP). However, without EIRs there will be a problem in issuing the right information in decision making process. BEP explains how the information modeling aspects of the project will be carried out and it is significant for all parties involve the project. Once the project team are appointed, work takes place within an area that was already defined in BS 1192, in 2007. And, Master Information Delivery Plan (MIDP) is produced. MIDP sets the protocols and the procedures to highlight what kind of information required, when it is needed, by whom and in which format the information will be prepared. Each project contributors work in their 'work in progress' areas where they develop the information. After the check and approval of the information, data will be ready to shared in an area for other parties to have an access. Now, the other contributors will be ready to use and develop their contributions. This leads the first creator keeps the power of changing the information that (s)he created in a scenario of re-user wants to change it. Next step is the approval by the client to observe the created information aligns with the needs. After, taking the Client's approval the information will be published for the appointment of the specialists. As the approval by the specialist taken, the information can be stored in an archive as references for future projects.

Effective use of a CDE will build an accurate and well-structured data set which is known as a 'Project Information Model (PIM)' as the project stages progress until the end of stage 6. In the above figure 2.7 PIM is shown with its six stages;

(i) Brief
(ii) Concept
(iii) Definition
(iv) Design
(v) Build and Commission
(vi) Handover and Closeout

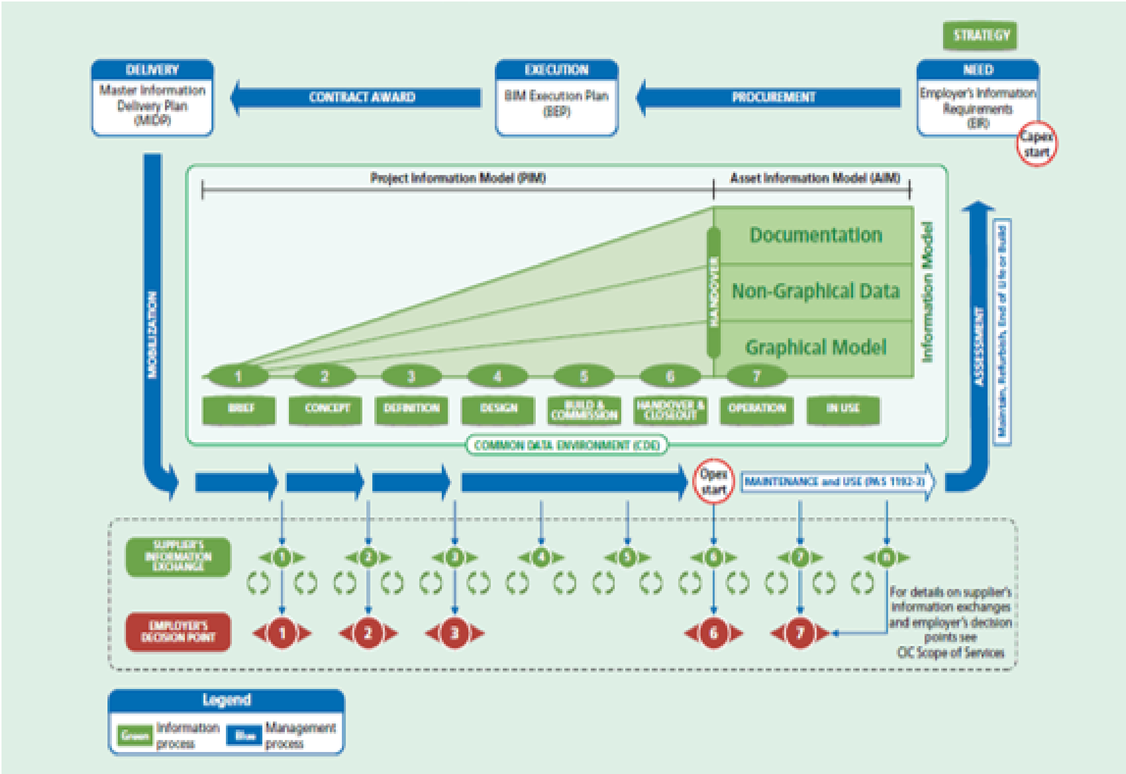

Figure 2.7. Level 2 BIM Information Delivery Process (PAS 1192-2)

After the handover stage, the data will be used in the asset management phase following the PIM called as the Asset Information Model (AIM) which has two phases;

(vii) Operation

(viii) In use

2.3.2. Level 3 BIM Implementation

As expressed in detail, Level 2 BIM implementation is all about the delivery phase. However, Level 3 covers the operational phase of a building. And, after the handover and close out stage in Level 2 BIM implementation asset management phase begins with Level 3. The AIM includes all the documentation, non-graphical data and the graphical model. And operational management covers the planned and unplanned events in an asset's life cycle. Therefore, whether any plan or unplanned event occurs the data set needs to be updated. As shown in figure 2.8 document and data management have additional steps onto Level 2 data management. The section indicated as PAS 1192-3 stands for the asset management phase of a building. It eases the understanding of the building digitally and allows to collect the information regarding to performance of the building in CDE. This leads to make right decisions in right time in the operational phase.

2.3.3. Related Concepts with BIM Implementations

2.3.3.1. Lean Construction. Lean Construction term stands agains to give the attention on the inefficiencies and produced waste by the construction industry. Through the shift from the traditional approach to BIM processes which covers the whole life of the buildings life cycle, substantial savings can be procured by rising productivity with BIM. This means that the amount of unnecessary materials or waste can be reduced in the construction phase of a project (Eadie *et al.*, 2013).

To observe reductions via lean construction, the process extends to the BIM models' level of detail highlighting the accuracy of the performed BIM model. Since a model prepared at the LOD 400 level has sufficient details for fabrication production, it will prevent any extra concrete and iron usage by being manufactured and assembled at the factory together with structural elements such as walls, floors, beams etc. which require production on site. Coates *et al.* (2010), stated that "BIM is a foundational tool for implementing an efficient process and invariably leads to lean-orientated, team based approach to design and construction" (Coates *et al.*, 2010). Olatunji (2011), supported the statement of Arayıcı by adding "the development of lean approaches to the management of projects, as the enhanced collaboration and information sharing can contribute to the lean management's goal of reducing waste (Olatunji, 2011). Collaboratively working on a single model, allows all the project parties to distinguish the clashes over the designs and solve the problems before arriving to the site activities. This explains how BIM model helps to reduce the wastes by minimizing the errors and the possible reworks on the construction site. That is why, lean approach can be a great tool to link with BIM processes to increase the benefits of BIM.

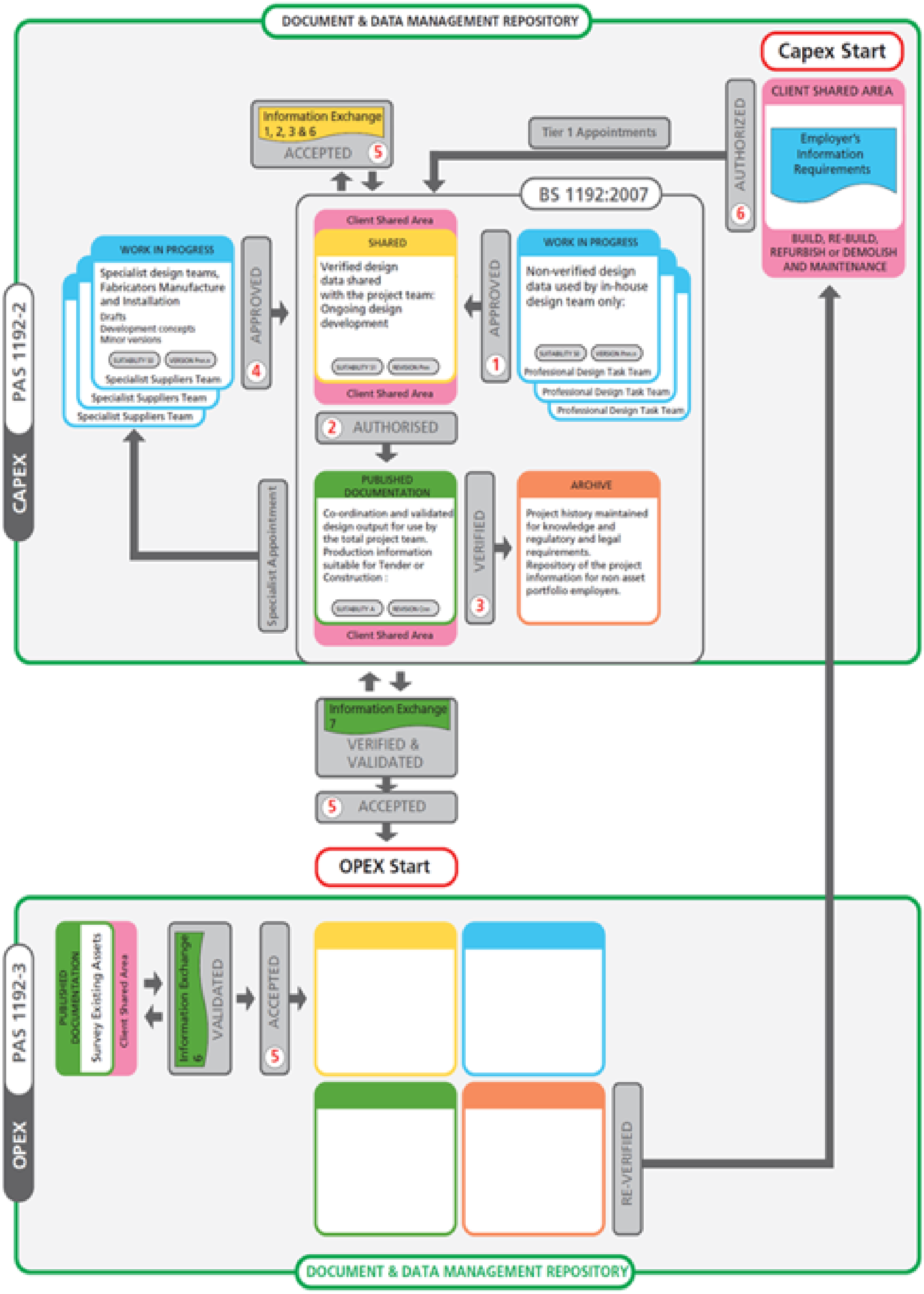

Figure 2.8. Level 3 BIM Implementation Process (PAS 1192-3)

2.3.3.2. Integrated Project Delivery and BIM. Integrated Project Delivery(IPD) is a collaborative alliance that helps to optimize the project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction for the participants including the architect, key technical consultants as well as a general contractor and key subcontractors.

IPD combines ideas from integrated approach and lean construction to solve several problems in contemporary construction such as low productivity and waste, time overruns, quality issues, and conflicts. It works a process where all disciplines in a construction project work as one firm, creating faster delivery times, lower costs, no litigation and a more enjoyable process for the entire team – including the owner.

As a result, BIM modeling in the construction industry is allowing far greater information collaboration between project participants using IPD and therefore IPD is considered as an important project management tool to increase productivity.

2.3.3.3. Green Buildings and BIM. Green Building concept with BIM refers to combination of the sustainable design concept and BIM. Sustainable design is stated for an environmental friendly buildings' designs concerning the energy consumption of the building. The purpose in green design is to minimize the energy consumption during the operational phase and maximize the harnessless to the environment. That is why, through utilizing BIM in design phase, decision making related to the costs and environmental impacts of the selected materials can be easier through running an energy analysis over the BIM model that includes useful information about the all materials (Krygiel *et al.*, 2008).

There are several rating systems to classify in what extend the design is sustainable. "LEED" and "BREEAM" are top two commonly known examples of the rating systems.

Building Research Establishment's Environmental Assessment Method (BREEAM) is developed in UK. It takes the following areas consideration for rating the building's performance. After awarding the credits in each area, buildings are rated as; Unclassified $(< 30\%), Pass(> 30\%), Good(> 45\%), VeryGood(> 55\%), orExcellent(> 70\%), andOutstanding$(>85%) to the project (NBS, 2019). These areas are;

- Management
- Health and Well-Being
- Energy
- Transport
- Water
- Material and Waste
- Land Use and Ecology
- Pollution

On the other hand, LEED is developed by the United States Green Building Council (USGBC). Similar to BREEAM rating system, LEED has 9 major categories as;

- Location and Transportation
- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Material and Resources
- Indoor Environmental Quality
- Regional Priority
- Integrative Process
- Innovation

In LEED, there exists 4 groups as shown below (USGBC, 2019);

- CERTIFIED(40-49 Points)
- SILVER(50-59 Points)
- GOLD(60-79 Points)
- PLATINUM(80+ Points)

2.3.3.4. Agile PM and BIM. BIM concept with Agile Project Management(PM), find a common ground on a construction project for managing more efficiently, reducing the number of reworks, therefore the fastest and earliest delivery to the owner as shown in the figure 2.9.

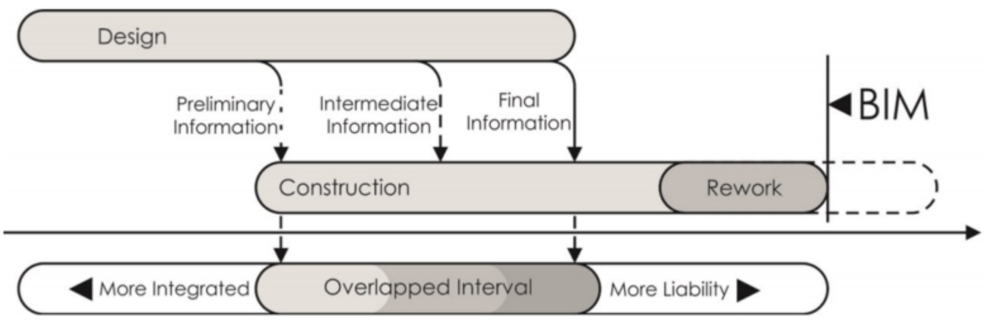

Figure 2.9. The role of BIM in the mechanism of activity overlapping (Tomek *et al.*, 2015)

As Agile PM concept aims to perform the activities of design and construction phase synchronously, through BIM's effective collaboration and communication environment project management activities can be handled by eliminating the reworks. As a result, time saving could be observed by deducting the rework time from the overlapping time period. Therefore, key emphasis is given to the project scheduling as more integration exists among parties yields to more time saving as well as cost in terms of project performance.

2.4. BIM APPLICATIONS

2.4.1. Application Areas of BIM

BIM is a comprehensive process that can be applied to every stage in a project's life cycle. In the Tables 2.2 and 2.3 below, the primary and the secondary uses of BIM for the AEC members on a project is demonstrated. Regarding to the life cycle phases the primary uses of BIM can be categorized as;

For Plan Phase; existing conditions modeling, cost estimation, phase planning, programming, site analysis,

For Design Phase; design authoring, structural analysis, lighting analysis, energy analysis,

For Construction Phase; 3D coordination, site utilization planning, 3D control and planning,

For Operational Phase; record model, maintenance scheduling and building system analysis.

Secondary uses of BIM can be categorized as;

For Design Phase; design reviews, mechanical analysis, other energy analysis, LEED evaluation, code validation,

For Construction Phase; construction system design, digital fabrication,

For Operational Phase; asset management, space management/tracking, disaster planning.

Primary uses of BIM for each phase are explained in details below,

Table 2.2. Primary BIM Uses in the Project's Life Cycle (Penn State, 2018)

Primary BIM Uses			
PLAN	**DESIGN**	**CONSTRUCTION**	**OPERATE**
Existing Conditions Modeling Cost Estimation Phase Planning Programming Site Analysis			
	Design Authoring Structural Analysis Lighting Analysis Energy Analysis		
		3D Coordination Site Utilization Planning 3D Control and Planning	
			Record Model Maintenance Scheduling Building system analysis

Table 2.3. Secondary BIM Uses in the Project's Life Cycle (Penn State, 2018)

Secondary BIM Uses		
DESIGN	**CONSTRUCTION**	**OPERATE**
Design Reviews Mechanical Analysis Other Eng. Analysis LEED Evaluation Code Validation		
	Construction System Design Digital Fabrication	
		Asset Management Space Management Disaster Planning

2.4.1.1. Planning Phase. Planning phase uses of BIM are detailed as;

- "Existing Conditions Modeling" stands for the creation of existing conditions 3D model by using photogramemetry, laser scanning, surveying techniques etc.

- "Cost Estimation" refers to improved quantity take-offs that cause a better estimating. Also through 3D BIM model, even a change occurs in the quantity the material list updates automatically. That is why budget overruns during the construction phase can be prevented with 3D BIM models.

- "Phase Planning" refers to the identification of schedule for a better understanding of the critical path of the project and so that the necessary steps can be planned structurally.

- "Programming" is a process that developed BIM model allows the project team to analyze space and understand the complexity of space standards and regulations. Critical decisions are made in this phase of design and bring the most value to the project when needs and options are discussed with the client and the best approach is analyzed (General Services Administration BIM Guide 02).

- "Site Analysis" stands for realizing an optimization based on the given Project area. The site data collected is used to first select the site and then position the building and infrastructure based on other criteria (Suermann P.C., 2005).

2.4.1.2. Designing Phase. Designing phase uses of BIM are detailed as;

- "Design Authoring" stands for the process of developing the parametric model for design exploration, communication and iteration purposes.The key is connecting the 3D model with enriched properties, quantities, costs and Schedule. Design authoring allows transparency for all stakeholders and add value to the collaboration among each other (Tardif M., 2008).

- “Structural Analysis” refers to the analyzing the model whether it meets the minimum required standards for structural design. This leads to optimizing the structural design elements of the model which helps to create effective, efficient and contractible structural system fast (Eastman *et al.*, 2010).

- “Lightning Analysis” refers to analyzing the natural and artificial lighting of the model. This helps to optimize the lighting system of the Project and improve the efficiency of the building.

- “Energy Analysis” stands for the energy simulation to conduct energy assessments for the model to observe whether an opportunity is available to decrease the life cycle cost of the building. This helps to build energy code verification for the buildings (Stumpf *et al.*, 2009).

2.4.1.3. Construction Phase. Construction phase uses of BIM are detailed as;

- “3D Coordination”, in another term it is known as the “Clash Detection”, stands for overcoming the geometric conflicts comparing the 3D models created by each design party. 3D Coordination provides visualization of the model and solves the problems on the model before starting the construction phase. That is why, it helps to decrease the construction time and the cost by increasing the productivity on site activities (Staub-French and Khanzode, 2007).

- “Site Utilization Planning” stands for a better site planning when both temporary and permanent facilities exist on the site. Since time information can be added to the model’s element because of a better scheduling the site management activities improve. For example; one can accurately evaluate site layout, select a feasible construction scheme, easily update and analyze the space usage during the construction phase so unforeseen conflicts can be easily prevented.(Heesom and Mahdjoubi, 2004)

- "3D Control and Planning" refers to a process that utilizes an information model to layout facility assemblies or automate control of equipment's movement and location. This helps to reduce the time spending for surveying on the construction site. (TEKLA International, 2008).

2.4.1.4. Operational Phase. Operational phase uses of BIM are detailed as;

- "Record Model" is an accurate representation of the latest version of what constructed. Record model refers to the adjusted version of the model created by the designers in the first place. But, during the construction some changes regarding to the structural, architectural or MEP designs may occur and after processing them into the model, record model can be achieved. Record model serves as an asset for the facility management of the project in the operational phase. (Woo *et al.*, 2010).

- "Maintenance Scheduling" stands for the creation of a well-structured maintenance program that can improve the performance of the building and reduces the corrective and emergency maintenance and operational costs of the building. (Campbell, 2007)

- "Building System Analysis" refers to a measuring process of the building's performance by comparing the specified design. This includes how the mechanical system operates and how much energy a building uses. Other aspects of this analysis include, but are not limited to, ventilated facade studies, internal and external CFD airflow, and solar analysis etc. These helps to identify the opportunities to modify the systems for a better performance. (Autodesk, 2007)

2.4.2. Design Tools for BIM Applications

2.4.2.1. Autodesk Revit. Autodesk Revit is one of the architectural BIM software which allows users to design with parametric modeling and drafting elements. In this way, Revit provides full bi-directional associativity. A change anywhere is a change everywhere, instantly, with no user interaction to manually update any view.

Revit is a single file database that can be shared among multiple users. Plans, sections, elevations, legends, and schedules are all interconnected, and if a user makes a change in one view, the other views are automatically updated. Thus, Revit drawings and schedules are always fully coordinated in terms of the building objects shown in drawings.

The base building is drawn using 3D objects to create walls, floors, roofs, structure, windows, doors and other objects as needed. Generally, if a component of the design is going to be seen in more than one view, it will be created using a 3D object. Users can create their own 3D and 2D objects for modeling and drafting purposes.

Small-scale views of building components may be created using a combination of 3D and 2D drafting objects, or by importing drafting work done in another CAD platform via DWG, DXF, DGN, SAT or SKP.

When a project database is shared, a central file is created which stores the master copy of the project database on a file server on the office's LAN. Each user works on a copy of the central file, stored on the user's workstation. Users then save to the central file to update the central file with their changes, and to receive changes from other users. Revit checks with the central file whenever a user starts working on an object in the database to see if another user is editing the object. This procedure prevents two people from making the same change simultaneously and prevents conflicts.

Multiple disciplines working together on the same project make their own project databases and link in the other consultants' databases for verification. Revit can perform interference checking, which detects if different components of the building are occupying the same physical space.

Revit uses .RVT files for storing BIM models. Parametric objects – whether 3D building objects (such as windows or doors) or 2D drafting objects – are called families and are saved in .RFA files, and imported into the RVT database as needed. Families do not require programming skills and there are many sources of pre-drawn RFA libraries.

Autodesk has developed three versions of Revit for the varying building design disciplines:

- Revit Architecture, for architects and building designers (formerly Revit Building)
- Revit Structure, for structural engineers
- Revit MEP, for mechanical, electrical and plumbing engineers (formerly Revit Systems)

2.4.2.2. Autodesk Naviswork. Naviswork is a 3D model review software which is preferred for improving the coordination in BIM model. Naviswork enables to make construction simulations and a comprehensive whole-project analysis by provided greater coordination conditions. Also Naviswork manage includes specialized tools for advanced simulation and validation. It is preferred to use in 4D and 5D simulation to control Project Schedule and cost. Naviswork animates and interacts the model objects for simulation. Creates schedules directly from the Project models and import schedules with cost items for the Project management activities. Naviswork is one of the key softwares in 4D and 5D design, because it captures the materials quantity automatically so that brings accuracy in the estimations. İt measures lines, areas, and counts from 2D sheets or 3D models. It creates synchronized project views that combine Revit and AutoCAD files, including geometry, images, and data. Also, Naviswork allows to export takeoff data to Excel for analysis.

2.4.2.3. Autodesk Dynamo. Dynamo is a computational software allowing to program the environment to create visual logic via parametric designs and enables to automate the tasks. Through using Dynamo during the BIM implementations design decisions can be done quickly and work-flows can be created easily because Dynamo is rich in functionality. Through dynamo DWG files can be imported as an object and converted to actual geometries and allows to import geometries based on the filtering option. Filtering the object can be realized on the following basis;

- Layer label
- Geometry type
- Diffuse color Etc.

Rather than these ways also based on selection imports can be done in Dynamo. Moreover, by using the multiple ways the desired import can be realized. For example, one can first do the selection based on the geometry type and then by filtering a separation based on the selected objects' diffuse color can be done and further filtering options can be applied as well. Dynamo helps to analyze the performance of the design quickly fort he architectures which is efficient in space management. If a geometric problem occurs software warns the user to change the design model. By defining the Project parameters and created basic concept, best design option can be obtained from the hundreds of possible iterations. And, modifications on the model can be realized quickly by creation work-flows to do the changes automatically. Also connecting Dynamo with Revit extends BIM model's flexibility. Revit allows project parties to create custom tools by its Application Program Interface however everyone can not Access to the scripts. With Dynamo Revit data can be used for interoperability, documentation and analysis purposes.

2.4.2.4. Tekla Structure. Tekla Structure is a structural design software that is used for design, detailing and information management for BIM models. One of the key benefits of using Tekla Structure, the constructibility of the models can be designed up to LOD 500. And the enriched information of the structural data is helpful fort he fabrication and construction phases on site activities. Moreover, high LOD serviceability minimizes the costs and reduces the RFI's by using only one software for all materials leads to result more profitable projects. Tekla Structure allows collaboration among the Project members and third-parties. And, the created model can be linked with architectural, MEP and plant design softwares via IFC so that any geometrical fails can be observed and whether any clashing problem occurs, can be redesigned by the design groups.

2.5. ADOPTION OF BIM

2.5.1. Global perspective of BIM Adoption

AEC industries increased the adoption of BIM for design improvements and Project management since 2010. In the McGraw-Hill's 2012 report, the adoption rate of BIM in the industry increased to 71 % from 28% within the last 5 years. Moreover, multiple studies are realized to observe the benefits, trends and challenges of BIM (Azhar, 2011; Bryde, 2013; McGraw-Hill, 2012). “In the UK, the National BIM Report found that only 39% of survey respondents in 2012 were both aware of, and actually using, BIM (National BIM Survey 2013). In Australia, a survey found that 49% of architects, and 75% of both engineers and contractors used BIM, and on average, that BIM is used on 36% (engineers) to 59% (architects) of projects (BEIIC 2010). New Zealand's only national BIM survey recently found that the proportion of BIM users increased from 34 % [2012] to 57 % [2013], with a year-on-year increase in overall BIM awareness in the construction industry, from 88 % [2012] to 98 % [2013] (Masterspec 2012; 2013)” (Stanley *et al.*, 2014). According to Shimonti Paul's studies in 2018, the recent BIM implementations and national decisions on the transition to BIM projects shown in figure 2.10 demonstrates the evolution of BIM in the World. Countries which are evolved in the adoption of BIM are introduced to observe the current situation of global BIM map.

Figure 2.10. Global BIM Evolution Map (Paul, 2018)

2.5.1.1. Asia. *Japan*: The building and construction agency of The Ministry of Land, Transport and Tourism is the responsible on behalf of the government to carry out the BIM process in Japan. In 2014 the agency released a guideline for the BIM implementations till the 2017 which was the only national BIM Protocol at that time. In the meanwhile, The Japan Institute of Architects issued two protocols; one, issued in 2012, is emphasizing the concept and the potential of BIM, the second, issued in 2015, highlighting the process for BIM applicaitons. After multiple publications of protocols, a BIM guide explains the implementation of BIM in construction phase with several examples. However, even multiple publications exist the adoption rate is low in Japan may results that they are not reaching an industry-wide development.

Singapore: In Singapore BIM seen as a key innovation in the AEC industries to ease the smart nation journey of future. That is why Building and Construction Authority and BuildingSMART Singapore supports the transition towards BIM implementation. That is why, in 2010 a draft "BIM Roadmap" is published and it is mandated members to submit the architectural and engineering documents via electronic BIM format. So that, at 2015 80% of the construction industry is altered to implement BIM in the projects. While the adoption of BIM was rising, Building and Construction Authority of Singapore come up with road-maps putting the emphasize on the construction productivity and to drive BIM collaboration in virtual design and construction to utilize BIM in the facility management and Smart City purposes of Singapore.

India: Whilst the AEC industries are the second largest industries in India, BIM implementations held in design phase. There are several supports by the government and the private sector to implement 4D and 5D BIM in the projects. However, the low awareness level of BIM is limiting the BIM applications.

United Arab Emirates: Dubai Municipality mandated the BIM use for architectural and MEP purposes on the building projects in 2013. Then, in 2015 the municipality widened the content by including the buildings above 20 floors, facilities which are sitting on an area grating than 200,000 square foot, special buildings such as; hospitals, governmental projects, universities and offices. So far, there is no any attempt accompanied to bring a standardization on BIM in UAE.

2.5.1.2. North South America. *United States of America*: USA is the earliest adopter of BIM, however being in the first place required to deal with the occurring problems alone. That is why the adoption of BIM is decreased slowly in the US. This lead the countries left behind to take lessons from the US' cases to prevent the same faced problems. So far there is no mandate from the government side. Many government departments published their own standards. For example, "The US General Services Administration formulated the National 3D-4D-BIM Program in 2003". This program established policy mandating BIM adoption for all Public Buildings Service projects. Wisconsin became the first state to mandate BIM on publicly-funded projects with a budget of over 5 million dollars. Recently, BIM gained its popularity as an important architectural tool by the architects in US. Also, government supporting the implementation of BIM in infrastructure projects especially fort he construction phase benefits of BIM.

Brazil: The Strategic Committee fort he Implementation of BIM (CE-BIM) and a Technical Support Group (CAT-BIM) were established in 2017 to follow the BIM road-map for mandating the BIM in 2021. The committee deals with the regulations and standardization related to the technological infrastructure, training the members of AEC and BIM platform. Regarding to the previous investigations on the BIM usage in the country it is observed that the adoption rate in the industry is not bad and BIM is preferred to used mostly in the cost control activities on site.

2.5.1.3. Europe. *France*: Firstly, BIM standards are developed for infrastructure projects in France in 2014. Then, in 2015, 20 million Euro is allocated for the digitalization process and government decided to develop new housing units in enormous scale by 2017 through implementing BIM. In 2017, France mandated BIM as a part of strategy for digitizing the AEC industry. The objective was including the enhancement of the quality of the data and reducing the life cycle cost of the project.

Denmark: One of the key reasons to explain how BIM become popular in Denmark that leads Denmark to become one of the early adopters of BIM can be underlined by the support of the government. Denmark government established a "Digital Construction Initiative" to develop common standards and guidelines for digital construction projects in 2007 (Steffensen, 2012). Semi-government bodies played a key role on generating the standards to increase the BIM usage in Denmark as well. Transition to BIM is demanded because BIM processes allows to cut the costs on the construction phase and increases the quality of work served.

Germany: Like Denmark, the government's support key role in the adoption of BIM in Germany. In 2015, government introduced a "Digital Building Platform" to set a nation-based BIM strategy. It is expected to set BIM mandatory in German starting from 2020 in the infrastructure projects.

Netherlands: In a global perspective, one of the highest adoption of BIM is realized in Netherlands. A number of open protocols (or standards) for processes, data formats and/or semantics are in use that support the extent to which BIM systems can exchange, interpret and share data. VISI is a Dutch standard that forms the basis of communication and information exchange between building parties. COINS (Constructive Objects and the INtegration of processes and Systems) refers to a Dutch integrated, complementary standard for exchanging digital information and with support for Systems Engineering. CB-NL is a Dutch standard that connects object libraries for objects and spaces in the built environment.

Spain: In the early times of global BIM adoption, Spain started to require the BIM implementation in EU funded projects, means that the BIM applications are not mandatory in Spain by 201. In 2015, Ministry of Development created a road-map called "BIM Commission" to establish the BIM methodology for the implementations. Now as 2019, it is mandatory to use BIM in public construction projects and infrastructure projects.

Austria: Austria is one of the productive country when it comes to develop series of standards regarding to BIM implementation starting from 2015. Lastly, they introduced the BIM Level 3 standard by Austrian Standards. However, the shortage of skilled personnel and the contractors able to work through BIM processes keeps the adoption rate low.

Norway: Norway is one of the early adopters of BIM. Public sector BIM standards or requirements are already in place for Norway and Norway has been a partner in the development of openBIM standards.

Italy: BIM implementation become mandatory in Italy in the early times of 2019 with a limitation that it will be applied in the projects valued 100,000,000 or above. For full implementation of BIM, 2022 is foreseen by the ministry.

2.5.1.4. Australia. Australia is one of the Commonwealth of Nations Coalition members and since UK leads the way in BIM, PAS 1192-2 standard gained the popularity for BIM adoption. BIM is preferably used mostly in the infrastructure projects. However, fragmented nature of the AEC industries and the shortage of skilled personnel hinders the adoption of BIM. In addition to this, due to the disorderliness of the governmental departments which are following their own processes and strategies causes companies to struggle in understanding the each departments process and information requirements.

2.5.2. BIM Adoption in Turkey

Regarding to an investigation hold on the end of the year 2018, general tendency in BIM adoption and the future expectations of the Turkish AEC members are published. According to the latest survey, BIM adoption and BIM awareness among the Turkish members are represented in the figure 2.11 and the BIM users breakdown regarding to the disciplines shown in the figure 2.12 below.

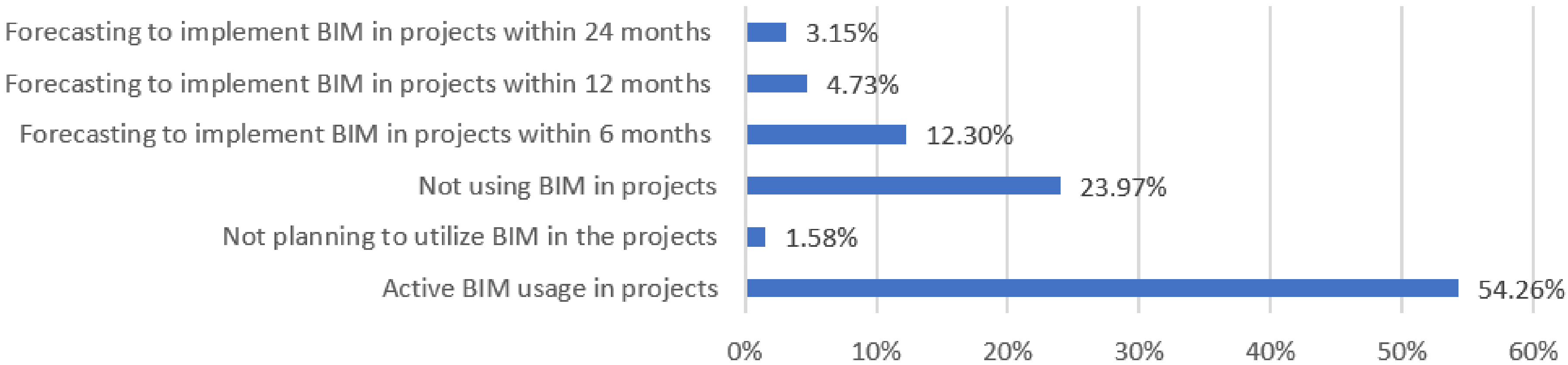

Figure 2.11. BIM Maturity in Turkey (Bimgenius, 2018)

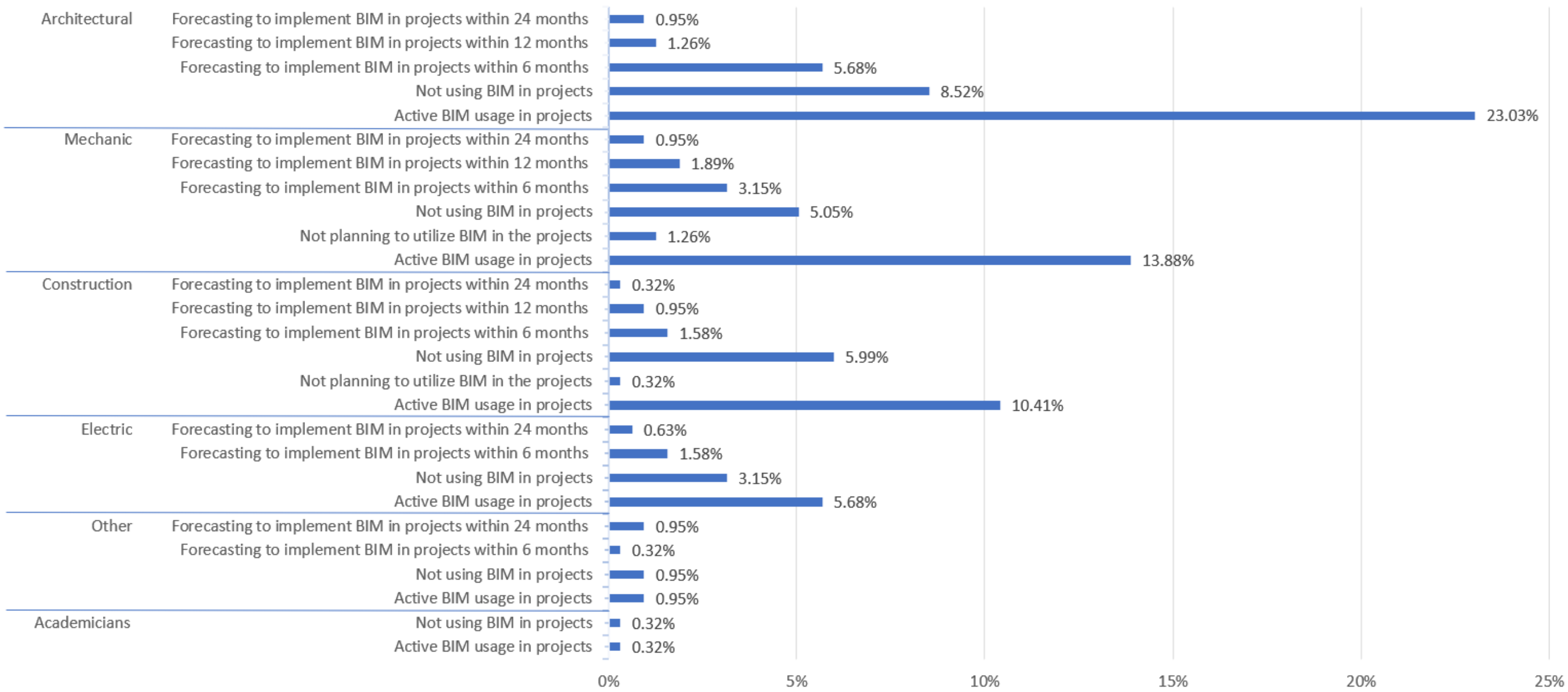

Figure 2.12. Breakdown Chart of BIM users in Turkey (Bimgenius, 2018)

Regarding to the results, low third-part usage leads to question the maturity of the BIM implementations in Turkey. And according to the results figure 2.13 demonstrates the BIM implementation level in the AEC industries.

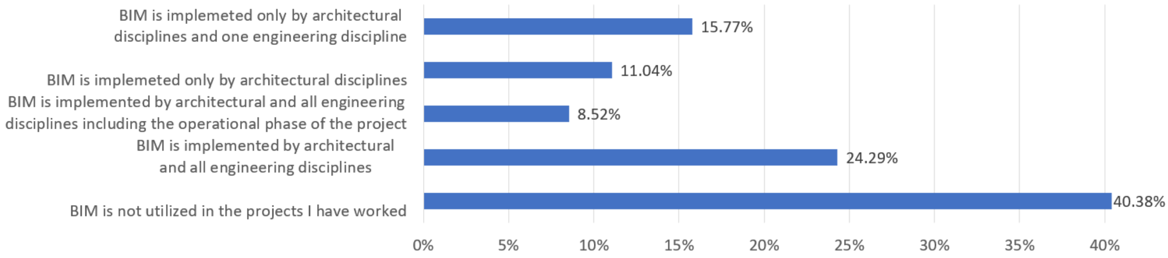

Figure 2.13. BIM İmplementations Based on the Functionality in Turkey (Bimgenius, 2018)

And one of the surprising results is more than 50% of the respondents in the BIM-Geniıs' investigation stated that they are not using parametric design tools opposing to the around 30% of Autodesk Dynamo user respondents.

As known as the parametric design is one of the key characteristic of BIM implementations, low utilization of the proper softwares can be explained with lack experience. As shown in the figure 2.14 most of the users have experience between 1 and 3 years and considerable amount of inexperienced users exists in the market.

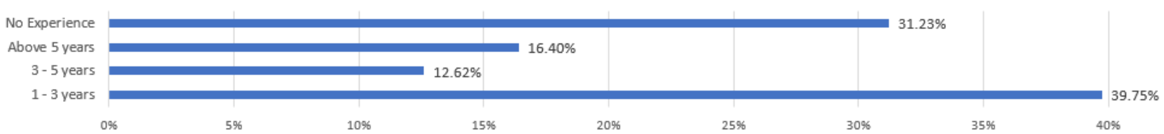

Figure 2.14. Experience Years of Turkish Members on BIM Implementations (Bimgenius, 2018)

This may occurred because of the problems in organizing lack BIM trainings in the industry level. Also, respondents expressed their willingness to get BIM trainings in the topics as illustrated in the figure 2.15.

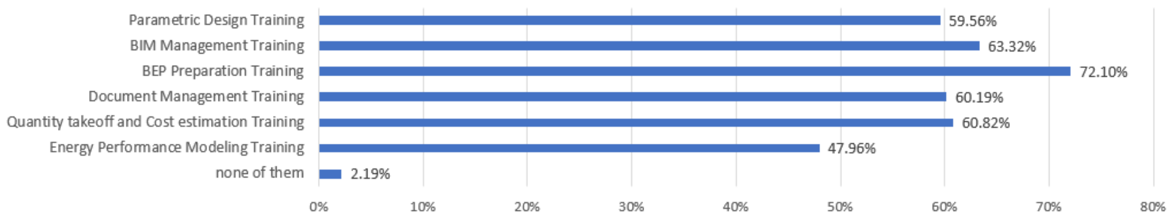

Figure 2.15. Necessary BIM Trainings (Bimgenius, 2018)

2.6. GLOBAL BIM STANDARDS

2.6.1. Introduction

BIM awareness is rising day by day and countries have already determined their strategies for the digital transition. Lots of protocols and procedures are established and published in country level as guidelines and standards. Standards allows, - to prevent the creation of unnecessary information, - to make easier the confusing processes and procedures, - to structure the information properly - to improve the co-ordination of information which can be add around 20-25% onto the cost. However, internalization of these protocols did not realized yet, except one country that taking the lead come a long way to publish a global standard. The ancestor for the establishment of the standard is the UK. That is why UK's BIM history is separated from the countries above to demonstrate how the evolution for transition is progressed step by step by each standard publishing. And, it is known that many countries are evolving in the shadow of UK's progress.

2.6.2. UK's Standards-Publicly Available Specification No. 1192 (PAS 1192)

2.6.2.1. BS 1192. This is a document set out the code of practice for collaborative production of building project information. This is the initiating attempt for bringing a standardization for the collaboration in AEC industries. That is why, BS 1192 counts as the part 1 of the PAS 1192. PAS 1192 is published in 2007 by British Standards Institution to bring a standardization for BIM implementation in UK. PAS 1192 has

5 parts to describe different aspects of the BIM implementing levels.

2.6.2.2. PAS 1192-2. PAS 1192 Part 2 is developed to support BIM adoption in the UK, in 2013. It provides a consistent industry-wide framework for collaborative working and information management in BIM Level 2 environment. PAS 1192 Part 2 evolved from the BS 1192, published in 2007. That is why it is considered as the part 1 of the PAS 1192-2. This standard focuses on information that is originated or managed in a BIM environment.

2.6.2.3. PAS 1192-3. PAS 1192 Part 3 published in 2013 and it is another PAS document which covers the topic of operational phase of a building's life cycle. PAS 1192-3 is a guideline for the asset management.

2.6.2.4. PAS 1192-4. PAS 1192 Part 4 stands for the Construction Operations Building information Exchange (COBie). PAS 1192-4 is structured to guide the exchange of the information created. It is originally produced as COBie UK 2012 but then it is turned into a BS in 2015. COBie is helpful to take the information as output to make key decisions at any stages.

2.6.2.5. PAS 1192-5. PAS 1192-5 puts the emphasize on the cyber security and digital security during the BIM implementation since CDE is a digital based environment. That is why protecting the created information is one of the significant topics in the digitalization generally. PAS 1192-5 published in 2015 is useful guide to determine the requirements for security within an organization to prevent the cyber attacks may ocur during all phases of the building's life cycle.

2.6.2.6. PAS 1192-6. PAS 1192-6 is published by BSI in 2018 to instruct collaborative sharing of Health and Safety information created throughout the Project and asset life cycle. PAS 1192-6 sets out a framework (risk information cycle) for the application of Health and Safety information-use through BIM processes and applications. All

Health and Safety risk information can be included within an information model, this PAS requires the contextualization and filtering of hazards and risks to prioritize the elevated risks and aspects that are safety critical The principles and requirements of this PAS can be applied equally to non-BIM projects.This PAS standard supports the development of structured HS information for all construction projects progressively from the outset.

2.6.3. International ISO 19650 Standard

During the publishing of these standards and protocols, notable people trying to generate an international standard to dominate the AEC industries since other countries (Middle East and Australia) were following UK standards and principles. Because of this reason, in the first quarter of 2019 UK published the world's first global standard called ISO 19650 which is exactly the same of BIM Level 2's internationalized version. This standard is pretty much aligns with the PAS 1192-2 principles and standards. It has 2 internationalized parts; ISO 19650-1 and ISO 19650-2 as shown in the figure 2.16 below. Since ISO 19650 is adopted as a national standard and CEN (the European standards body) also confirmed that they would adopt the ISO 19650 series as European standards, for the UK, this means that BS 1192 and PAS 1192-2 will be withdrawn and replaced by BS EN ISO 19650-1 and BS EN ISO 19650-2. This is because there cannot be two competing standards at a national level.

ISO 19650 series aim to manage the information among the teams in a simplified approach for diminishing the waste by increasing the accuracy of cost and time in the globe. ISO 19650 series are helpful for the multinational organizations struggling to accommodate the requirements from their customers, partners and suppliers by establishing an unified approach across each of their regions and offices, creating immediate eficiencies and increasing the mobility of their internal resources. With ISO 19650-1 and ISO 19650-2, it is expected to see new members in the ISO 19650 series since the recent PAS standards had focused to the management of information during the operational phase of assets, and the adoption of a security-minded approach to the management of information relating to sensitive assets.

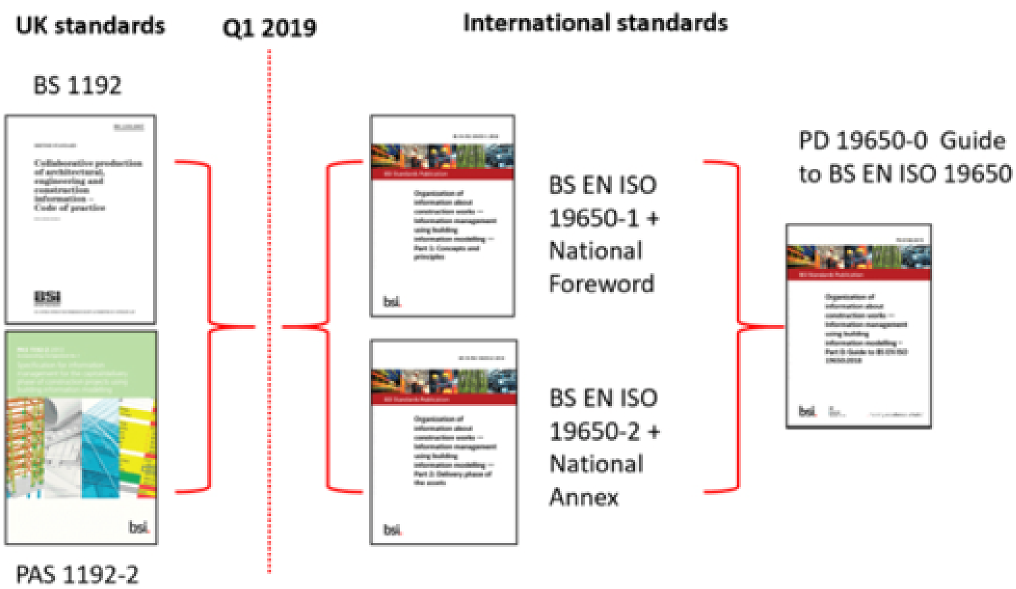

Figure 2.16. Creation of International BIM Standard-ISO 19650 (NBS, 2019)

That is why, new ISO 19650-3 and ISO 19650-5 series can pop up based on the PAS 1192-3 and PAS 1192-5.

For the AEC organizations who are already aligned their BIM process in the UK way, can easily follow the ISO 19650 series. However, ISO19650-2 includes national annexes to meet the regional needs. This issue is controversial because if it is a standardized document, adding national annexes contradicts with the idea because it allows flexibility for each region to use standards that are already in place. But in doing so, I believe we failed as a working group to create a truly common approach. This is because organizations who work in different regions will still need to comply with local standards, which adds unnecessary overheads, such as continuously educating teams and maintaining multiple configurations in the common data environments, for example.

3. RESEARCH METHODOLOGY

BIM in most simple terms is the utilization of a database infrastructure to encapsulate built facilities with specific viewpoints of stakeholders.(Krygiel, *et al.*, 2008) Object based design and integrated infrastructure of BIM's nature playes a key role in the creation and use of coordinated, consistent, computable information about a building project in design process. The main aim of this thesis is to observe how the members of AEC industries in Turkey are interconnected with BIM and to examine their experiences in order to distinguish the critical success factors of BIM for further studies. In order to find the critical success factors for Turkish members, firstly, a framework which is highlighting the 6 components of BIM implementations as drivers, inputs, enablers, barriers, benefits and impacts is created. And, an extensive literature review about related studies' experience, methods, and findings is realized in order to find the related factors for each component of the framework.And then regarding to the obtained data from literature case study method is conducted as a final step.

In this research, 25 case studies are evaluated with 15 respondents through interviews to obtain detailed information from the respondents. The advantage of this methods allows purely conversational way to find the motivations underlying the respondent's decision. Since the aim of this research is to evaluate the critical success factors in Turkish AEC industries the focus groups were the members of the AEC industries mostly using BIM in the design phase. Afterwards case study research is conducted with the respondents to evaluate the CSFs regarding to their experiences. That is why, it was important to make the case studies with respondents whom have different experience levels in the industry.

3.1. Design of the Framework

One of the significant aspects of this study is the design of the framework which should cover all the details of the BIM implementations. Taking all of the considerations in to find out which components can fully identify the successful implementations, a framework created by Ozorhon (2013) taken as a basis. This framework, shown in figure 3.1, provides to analize the CSFs in all dimensions and provides linkages among them.

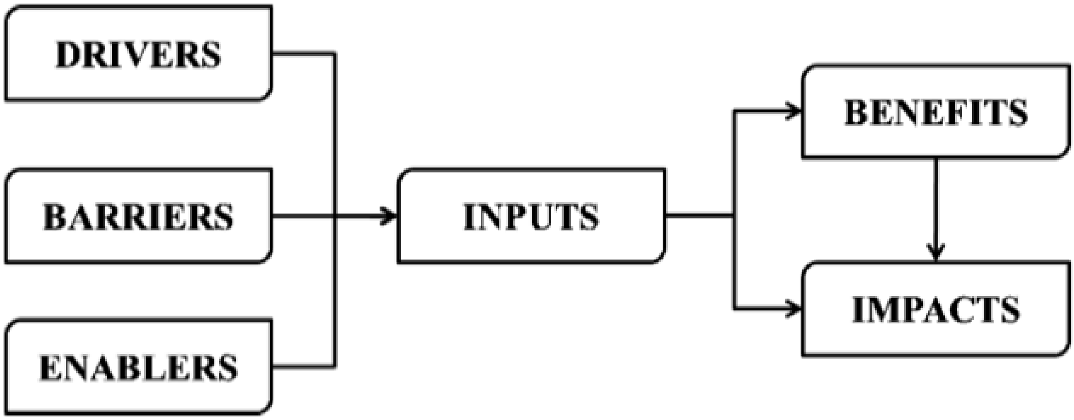

Figure 3.1. Framework Model for BIM Implementations (Ozorhon, 2013)

As seen in the figüre 3.1, it demonstrates the six components; drivers, enablers, inputs, barriers, benefits and impacts of the BIM application. And, the model emphasizes that each component is related and linked to each other for a successful BIM implementation.

In this created framework, drivers can be defined as the motivations behind the willingness to shift from the traditional approach to more digitalized environment of BIM. Enablers can be defined as the facilitators or the accelerators for the adoption of BIM. Barriers represents the hindering factors and challenges that have a negative impact on the adoption of BIM applications. These components plays a crucial role on the decision to follow the BIM flow as shown in the figure 3.1 that they are the first components to be thought. Inputs cover the tools and requirements in order to implement a successful BIM applications. Benefits represents the Project level gains can be defined as also the short term gains that can be observed through the BIM applications. Impacts are also refers to the gainings in the company level which can be defined as the medium or long term gainings that a firm can benefit in the long run by adopting BIM.

3.2. CSFs of BIM Implementation

Previous studies willing to find answers to the questions such as; "how beneficial is implementing BIM?", "what are the enablers for BIM implementations?", "what are the driving factors to use BIM?", "what are the risks to shift BIM?" or "what are the possible challenges and barriers for the adoption of BIM?" are taken as relevant studies to validate the framwork's components as well as the CSFs. Regarding to the aim, 45 research papers are examined to highlight the so far studied literature CSFs in this topic. Examined 45 research papers' summary tables 3.1, 3.2 and 3.3 are shown below. Tables include the details of the discussed cases, prefered BIM functions in the cases and details of research methods and evaluation methods in the papers.

Following the creation of the desired framework, in order to identify the key factors under each components as mentioned above, total of 181 factors are found in the literature review. Some of the literature review notes are given as;

Yan and Damien (2008), investigated the benefits and the barriers of BIM in UK's AEC industry by applying a questionnaire survey that compares the traditional CAD implementations vs BIM with around 70 individuals. Their method starts with reviewing the literature and find an answer why some companies this technology while others do not (Yan and Damien, 2008). Similar study is also realized by Kassem *et al.* (2012), Ghaffarianhoseini *et al.* (2017), Eadie *et al.* (2013), Chileshe *et al.* (2012), Chien *et al.* (2014), Abbasnejad *et al.* (2016) and Bryde *et al.* (2013) to highlight the barriers, risks, challenges and the drivers for change in the construction industry. Cao *et al.* (2017), also searching for an answer to highlight the motivations underlying for BIM implementations through examples from China. Sun *et al.* (2017), focuses on finding the limiting factors of the BIM usage in the construction industry and classifying the negaive fcators. So far, most of the research studies are implemented regarding to the questionnaire survey method. Arayıcı *et al.* (2012) and Barlish *et al.* (2012) gives an example of BIM implementation through applying all the necessary steps in the firm level and evaluate the results of transforming from traditional approach to BIM regarding to case study reseaech method. There are few studies chosen the case study research method to investigate the barriers, drivers, enablers, benefits, inputs and impacts of the BIM applications and evaluate the CSFs like Shang *et al.* (2014) and Ozorhon (2013).

So far highlighted benefits are creativity, sustainablility, improved quality, reduced human resources, reduced costs and time. On the other hand, the barriers are listed as; current technology is enough, refuse to learn, unsuitable for projects, waste time and human resource, cost copyright and training costs.(Yan and Demian, 2008)

Sun, *et al.* (2017), studied barriers which are categorized in 5 groups; technology, cost, management, personnel and Legal. "Technology" group includes the following barriers; functionality of BIM tools, accessibility of BIM tools, requirements of computable digital design data, need for sophisticated data management, lack of data interoperability. "Cost" group includes the following barriers; time and training, specialized software and hardware upgrades. "Management" group includes the following barriers; fragmented nature of the industry, no well-developed practical strategis and standards, lack of managers' and owners' awareness and support, changes in workflows and lack cooperation among the partners. "Personnel" group includes the following barriers; need of educated personnel about BIM, resistance to change and not familiar members with BIM capabilities. "Legal" group includes the following barriers; safety and reliability of building information, responsibility between stakeholders, missing insurance framework for BIM applications, contractual environmental and lack of protocols, ownership of BIM data and its copyright. Also, Kassem *et al.* (2012), highlighted the similar reasons for the BIM implementation as barriers.

Regarding to Arayıcı's case study results, observed gains are listed as following; increasing the quality, speed and decreasing the cost of the services, automatic low-level corrections when changes are made to the design through the use of parametric relationship between objects, generating accurate and consistent 2D drawings throughout the design, visualizations to allow checking against design intent, discovering design errors before construction, information sharing, greater flexibility to satisfy customers, better financial control, simultaneous work by multiple disciplines (Arayıcı *et al.*, 2012).

Table 3.1. Details of Reviewed Literature Sources (1/3)

Source	Country	Project Type	BIM Function	Data collection	Data Analysis
1	USA, UK	-	-	Questionnaire	-
2	-	-	-	Literature Review	-
3	New Zealand	-	5D	Questionnaire, Case Study	-
4	UK	-	4D	Questionnaire	-
5	-	-	-	Literature Review	-
6	UK	Housing	5D	Case Study	-
7	China	-	-	Questionnaire	Factor Analysis
8	-	-	4D, 5D, 7D	Literature Review	-
9	Turkey	-	3D, 4D, 5D, 7D	Questionnaire	ANOVA
10	UK	-	-	Questionnaire	-
11	Australia	-	-	Questionnaire	RII
12	-	-	-	Case Study	-
13	-	-	-	Questionnaire	-
14	-	Federal Building	-	Questionnaire	-
15	-	-	-	Literature Review	-

Table 3.2. Details of Reviewed Literature Sources (2/3)

Source	Country	Project Type	BIM Function	Data collection	Data Analysis
16	UK	-	-	Case Study	-
17	China	-	-	Questionnaire	ANOVA
18	Lithuania	Highrise, Industrial	4D	Case Study	-
19	Mixed	-	-	Literature Review	-
20	-	-	-	Literature Review	-
21	-	-	-	Literature Review	-
22	UK	-	3D	Case Study	-
23	Turkey	-	3D, 4D, 5D, 7D	Questionnaire	ANOVA
24	-	-	5D	-	-
25	US	Medical	3D, 4D	Case Study	-
26	-	-	-	-	-
27	Finland	-	-	-	-
28	UK	-	-	Questionnaire	-
29	-	-	-	Literature Review	-
30	-	-	-	-	-

Table 3.3. Details of Reviewed Literature Sources (3/3)

Source	Country	Project Type	BIM Function	Data collection	Data Analysis
31	-	-	-	-	-
32	-	-	-	-	-
33	-	-	7D	Literature Review	-
34	-	-	6D	Literature Review	-
35	China	-	-	-	-
36	-	-	-	Literature Review	-
37	-	-	4D	Literature Review	-
38	UK	-	-	Case Study	-
39	-	-	-	Literature Review	-
40	-	-	-	Literature Review	-
41	India	-	-	Questionnaire	Z-test
42	Mixed	-	-	Literature Review	-
43	-	-	3D	-	-
44	-	-	4D	Case Study	-
45	-	-	7D	Literature Review, Case Study	-

According to Eadie *et al.* (2013), drivers listed as government pressure, competitive pressure, improving the capacity to provide whole life value to client, streamlining design activities and improving design quality, communication for operations, cost and time savings and monitoring, accurate construction sequencing and clash detection, automation of schedule/register generation, facilitating increased pre-fabrication and facilities management activities, improving built output quality (Eadie *et al.*, 2013).

Lack of understanding, education and training cost, start-up costs and changing the way of business realized are the top ranked barriers hindering the BIM adoption. On the other hand, critical BIM enablers can be listed as the size of the Project, reducing risk, quality and accuracy requirement, cost reduction and time constraints (Chileshe *et al.*, 2012).

Some of the top benefits such as scheduling, sequencing coordination, decreasing the rework, visualization, rising productivity, communication,safety etc. And within this study 12 using case study methods emphasized that change orders and scheduling are top positive two benefits (Barlish *et al.*, 2012).

Risks categorized in 5 groups; technical, management, environment, financial and legal which are listed as inadequate experience, lack of software compatibility, model management difficulties, inefficient interoperability, management of change difficulties, workflow transition difficulties, lack of skilled personnel,, increase of the short term workload and rising short term costs, lack of BIM standards and liabilities and additional expenditures (Chien *et al.*, 2017).

BIM has an impact on the quality, cost, on time delivery of the construction project and safety. It decreases the cost via minimized errors due to design accuracy causing to decrease units and unit material costs (Suermann *et al.*, 2009).

Abbasnejad, *et al.*(2016), highlights the BIM enablers while adopting the BIM implementations in a construction firm. This is also a scenario of change management within a firm since company transformation is taking the priority in this study. That is why, the enablers regarding to the strategic initiatives, cultural readiness, lerning capacity, IT leveragability and knowledge-sharing capability, network relationships, change management practice and process management practice are highlighted in his study. Strategic initiative enablers cover the support from the top management, user's input, strategic vision and the plan, stakeholder's analysis and cost-benefit-risk analysis. Change management enablers include the rewards and recognition, user training and education, supportive supervisor and management readiness for change. Cultural readiness enablers cover the existence of change agents, risk aversion, early user involvement and open communication and information sharing environment. Learning orientation enablers include the colleagues' supporting, system expertise, learning-by-doing or from past experiences, Knowledge capacility enablers contain the development of knowledge management system and the use of communication Technologies. Network relationship enablers cover inter-organizational linkage and cross-functional cooperation within the firm. Process management enablers include benchmarking and BIM maturity assessment tools (Abbasnejad *et al.*, 2016).

And as seen in the literature review some of the factors were mentioned in multiple researches and some factors are evaluated under different components by the researchers. That is why, according to the first modification the number of key indicators are decreased to 153 to prevent the overlapping parameters among the factors. And the resultant factors are re-examined to group the factors extensively because of the high number of factors under the components. In addition to this, some of the factors are interrelated which was supportive to make grouping over the factors. This was the second adjustment phase in the framework components. And, at the end of this adjustment the number of the key factors decreased to 43.

The finalized key factors for the "drivers" are identified as; to improve corporate performance, to improve project performance, to improve building's energy performance, to improve collaboration and coordination, client requirement, governmental push, for design improvements, to improve construction productivity, to improve HSE activities and to reduce life-cycle cost of the building. Factors under the "enablers" are determined as; corporate and academic level collaboration, project level collaboration, managerial and technical abilities, supportive organizational culture, external grants, incentives and promotions, global standardization, IPD Type Contracts, planning of BIM Execution Process. The determined factors under the "barriers" are listed as; availability of knowledge based on experience, unclear benefits, lack of best practices, high costs, technology related problems, change process problems, legal and protocol problems, fragmented nature of the industry, interoperability problems of different parties, project specific problems, lack of government support. Identified factors under the "inputs" are found out as; human resources, financial resources, technological infrastructure, softwares and hardwares, custom 3D library, internal knowledge, external knowledge and consultancy, project information, project BIM Execution Plan, company's BIM Policy, BIM Guideline, training and education. Specified factors under the "benefits" are listed as; project financial benefits, right and accurate construction activities, right and accurate technical office works, improve staff performance, knowledge management benefits, claim management benefits, reduction of facility management costs, client satisfaction, improve communication and collaboration, improve energy savings. And lastly, for the factors determined under the "impacts" are listed as; company's productivity improvement, corporate management improvement, expanding company's scope of services, enable new businesses, improve corporate financial performance, generate corporate knowledge.

3.2.1. Descriptions of CSFs

3.2.1.1. Drivers. As stated in the framework designing, "drivers" represents the motivations for implementing BIM. Regarding to the resultant factors, there are 10 specified drivers for BIM implementations. And it is stated that these key factors are created by grouping the reviewed factors having interrelation among each other. Descriptions of all resultant factors are determined below as;

(i) "To improve corporate performance" key factor is resulted by the combination of the factors; social image of the company, not to stay behind the industry (competitiveness), to gain experience on BIM and marketing performance. These 4 mentinoed factors are found as the motivations to implement BIM within the literature study. Due to the company level motivation referings in a broaden approach, they are representing the corporate performance in the same pot.

(ii) "To improve project performance" key factor is resulted by the combination of the factors; facility management (to provide whole life value), earlier risk identification, increase efficiency, better financial control, increase in quality, increase in speed and decrease in cost. Project performance measurement is determined in terms of cost, Schedule, time and quality which is called "iron triangle" by the academics. That is why any factor referring to the components of the iron and the remaining factors supporting the main components can be linked together easily. As a result, all of these factors are gathered under Project performance key factor.

(iii) "To improve building's energy performance" key factor is resulted by the combination of the factors; sustainability, green building purposes and reduce waste (lean design). This key factor stands for the motivation to decrease the buildings' harmful effects on the environment.

(iv) "To improve collaboration and coordination" key factor is resulted by the combination of the factors; improve collaboration and communication, integrated Project delivery, better document coordination and interdisciplinary data Exchange.

(v) "Client requirement" key factor stands for the contractual push by the client to realize BIM implementations in a Project.

(vi) "Governmental push" key factor stands for the motivation provided by the government to support the BIM implementations in a nation.

(vii) "For design improvement" key factor is resulted by the combination of the factors; creativity, solvng design problems (clash detection), code checking, greater analysis capability, allowing to put information to the objects, simultaneous updates after each change in a single model, consistent and parametrically linked drawings and ease of use. All of the grouped factors to come up with the key factor serves to the design related activities. That's why this key factor stands for the design motivations to implement design through BIM.

(viii) "To improve construction productivity" key factor is resulted by the combination of the factors; site management, better scheduling, facilitating prefabrication and understanding the constructibility. İncreasing all of the site related Works performance was the common denominator to link them. That is why rather than representing each of them seperately as components, they are highlighted as the motivations to rise the productivity on site activities.

(ix) "To improve HSE activities" key factor stands for the health and safety purposes to implement BIM.

(x) "To reduce life cycle cost of the building" key factor refers to optimazing the operational cost of the building.

3.2.1.2. Enablers. "Enablers" are emphasizing the facilitators or the accolertor factors which provides to overcome the hindering challanges of implementing BIM. Regarding to the study, 8 components are listed under this factor.

(i) "Corporate Academic Level Collaboration" stands to put an emphasis on compounding the theoretical and technical knowledge of BIM with the AEC firms to overcome the encountered challanges in BIM applications.

(ii) "Project Level Collaboration" key factor is resulted by grouping the factors; communication (knowledge sharing with firm) and client involvement. This factor stands for transfering the experience based knowledge about BIM implementations in a Project level within the project parties to accomplish an objective.

(iii) "Managerial and Technical Abilities" key factor is resulted by combining the factors; experience level within firm, company's ability to use BIM, multidisciplinary personnel and choosing the correct software. This factor refers company's own abilities to implement BIM to accomplish an objective.

(iv) "Supportive Organizational Culture" key factor is resulted by combining the factors; transformational change management approach, internal support, support of Project leaders, commitment and supportive organizational culture. As seen by the grouped factors, all of them refers to the organizational attitude to support the change for BIM applications.

(v) "External Grants, Incentives Promotions" key factor emphasizes the industry level commitment for market transformation with the assurance of future demand by the government.

(vi) "Global Standardisation" means the existence of global protocols and standards that ease the adoption of BIM.

(vii) "IPD Type Contracts" stands as an approach to prevent the affect of the fragmented nature of the AEC industry in a contractual way with multi-party agreements among key participants In a multi-party agreement, primary project participants execute a single contract specifying their respective roles, rights, obligations, and liabilities. In effect, the multi-party agreement creates a temporary organization to realize the project. Because a single agreement is used, each party understands its role in relationship to the other participants.

(viii) "Planning of BIM Execution Process" refers to plan how company will realize BIM adoption and implement it.

3.2.1.3. Barriers. Barriers represents the hindering factors and challenges that have a negative impact on BIM applications. In this study, 11 barriers are determined for BIM implementations.

(i) "Unavailability of Knowledge Based on Experience" refers to the lack of knowledge and skilled personnel within the industry.

(ii) "Unclear Benefits" refers that BIM implementations has no tangible benefits to shift from the traditional way to accomplish the target.

(iii) "Lack of Best Practices" factor puts emphasis on the shortage of case study evidences for benchmarking which can occurs due to lack of industry awareness, lack of demand and rapidly developing innovation.

(iv) "High Costs" represents the transformation cost of a non-BIM company to become a BIM friendly company. This includes the cost of purchasing new softwares and high-end hardwares. Also, the cost of time and human resource refers to this factor.

(v) "Technology Related Problems" key factor is determined by combining the factors; lack of data interoperability (incompatible softwares), safety and reliability problems of the information, user friendlinessless, lack of software adaptation and license compliance and vendor's license policies. This key factor referrs to the insufficient knowledge and complicated technical issues of the potential BIM adopters on

(vi) "Change Process Problems" key factor is created by the combination of the following factors; training process (lack of training), resistance to change, belief that current tech is enough, change in business model (company culture), lack of will and fear of failure. This barrier stands to put an emphasis on the challenges occurred by shifting from a traditional approach (non-BIM oriented) to a BIM oriented company.

(vii) "Legal Protocol Problems" factor refers to the lack of standards (protocols), legal issues, ownership and level of responsibility uncertainty among the parties.

(viii) "Fragmented Nature of the Industry" refers to the general nature of the aec industries.

(ix) "Interoperability Problems of Different Parties" refers to the challenges related to low collaboration among parties (interoperability of parties).

(x) "Project Specific Problems" stands for the specific problems hinders to shift BIM implementation in a project level. This key factor contains the combination of following factors; BIM is not suitable for the project, lack of integrated models, delivery method is not suitable (contract types) and unique project requirements.

(xi) "Lack of Government Support" means the lack governmental support in industry level.

3.2.1.4. Inputs. Inputs correspond to the necessary resources (tools and requirements) to realize a succesful BIM implementation. Rearding to this study 12 factors are determined;

(i) "Human Resources" key factor is determined by the combination of qualified staff, strong team leader and interrelation of people. This factor emphasizes the role of the personnel on BIM implementations.

(ii) "Financial Resources" key factor stands for the investmet power of the organization for adoption and implementation of BIM.

(iii) "Technological Infrastructure" key factor covers the technological developments enhancing the implementations of BIM.

(iv) "Softwares Hardwares" key factor is determined with the combination of the factors; hardwares, project management control system softwares. This key factor stands for the significance of the modeling and managing programs affect on the BIM implementations.

(v) "Custom 3D Library" key factor refers to the Project specific object models for BIM implementations.

(vi) "Internal Knowledge" factor refers to the know-how within the company to implement BIM process.

(vii) "External Knowledge Consultancy" factor stands for the need of taking consultancy services to implement BIM process in the company.

(viii) "Project Information" refers to availability of receiving the correct and valid Project data, drawings etc. İn order to implement BIM process.

(ix) "Project BIM Execution Plan" factor stands to underline the necessity of the guideline to explain how BIM can be implemented in a Project level.

(x) "Company's BIM Policy" factor means the organization's strategy to plan how BIM process is going to be implemented in the company.

(xi) "BIM Guideline" factor referrs to the BIM implementation rules for succeding during the process.

(xii) "Training Education" key factor stands as a tool to enhance the level of knowledge within the company by training the personnel for BIM process rather than outsourcing the knowledge this factor underlines to invest on organization's own personnel.

3.2.1.5. Benefits. Benefits represent the Project level gains which can also be defined as the short-term gains that can be observed as the outputs of implementing BIM. In this study, 10 benefit factors are determined;

(i) "Project Financial Benefits" key factor refers to the cost reductions that can be occured because of two reasons; decreasing the time and the cost.

(ii) "Right and Accurate Construction Activities" key factor is created by the combination of the factors; reduce human resource (better recruitment), improve quality, easy (pre)fabrication (for building components), safety management, reduce reworks, virtual environments and animations (visualization), reducing risk and better site planning. This key factor stands for the improvements gained by the BIM implementations on-site activities. "Right and Accurate Technical Office Works" key factor refers to the technical improvements occured by the adoption of BIM in Office activities. This key factor includes factors; better cost estimation (quantitiy take off), clash detection (coordination), as built renders and minimize errors provided by implementing BIM.

(iii) "Improve Staff Performance" key factor stands for the gainings in human resource which highlight factors like the better decisions (improve decision making process), better (effective) procurement process, better awareness of the design for whole team and understanding the project scope by the personnel with BIM implementations.

(iv) "Knowledge Management Benefits" key factor put the emphasis on the positive affect on the knowledge management with BIM process. This key factor is determined by the combination of the integration of the documents (improved documents), easy to apply changes, easy to keep track and enriches data factors allow personnel to share and edit the new data easily with BIM in an integrated environment.

(v) "Claim Management Benefits" key factor stands for the enhancement in management process of the Project. This key factor is determined with the combination of the BIM implementation gaining factors of reduce number of RFI change orders, easy resolution of RFIs, effective project management and fewer claims.

(vi) "Reduction of Facility Management Costs" key factor means the potential gainings on the operational phase of a Project life cycle of the facility by implementing BIM since it integrates with the whole life cycle

(vii) "Client Satisfaction" key factor means the clent satisfaction through the BIM process and all kind of benefits that BIM provided based on a Project level.

(viii) "Improve Communication Collaboration" stands for implementing BIM leads to a creation of an environment allowing integration of multiple disciplines and provides an effective commnication among the Project parties.

(ix) "Improve Energy Savings" refers to the gainings that can be observed through 6D BIM implementations

<u>3.2.1.6. Impacts.</u> Impacts refer to the gainings in the company level which can also be defined as the medium or long term gainings that a firm can benefit in the long run by adopting BIM. In this study, 6 impact factors are determined;

(i) "Company's Productivity Improvement" key factor is related with the experience level of BIM in a company level which stands for the increase in productivity (performance) and improved business value.

(ii) "Corporate Management Improvement" key factor represents the long-run enhancements in the marketing, ease of administration, information management, improvement of organizational structure and capability by getting used to BIM process.

(iii) "Expanding Company's Scope of Services" stands for highlighting that new services can be given through BIM

(iv) "Enable New Businesses" refers to the creation of new Works with the existing clients or starting to a new business with new clients by implementing BIM.

(v) "Improve Corporate Financial Performance" key factor refers to the increased ROI (finance) by adopting BIM.

(vi) "Generate Corporate Knowledge" means that starting to implement BIM in Project level will create useful database in the long term for creating an archive full of experienceses.

The summary table of the resultant factors in each component is demonstrated in the Figures 3.2, 3.3 and 3.4 show the factors and their sources in detail.

CSF of BIM in the Turkish Construction Industry			Literature Sources																																												
#	**Drivers of BIM**	**#**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
1	Improving Corporate Performance	12					x		x			x							x					x			x	x				x									x	x	x	x			
2	Improving Project Performance	34		x	x		x	x	x			x	x					x	x	x	x	x		x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3	Improving Building's Energy Performance	26	x	x								x				x		x	x	x	x	x		x	x			x	x	x		x	x	x	x	x		x	x	x		x	x		x		x
4	Improving Collaboration & Coordination	33		x	x	x	x	x				x						x	x	x	x	x	x	x	x	x	x	x		x	x		x	x	x	x	x	x		x	x	x	x	x	x	x	x
5	Client Requirement	11				x			x		x	x	x						x		x	x			x		x																x				
6	Governmental Push	12				x	x		x		x	x							x			x							x			x					x						x	x			
7	Design Improvement	38	x	x	x		x	x	x			x		x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8	Improving Construction Productivity	27				x		x				x		x						x	x	x	x		x		x	x		x		x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
9	Improving HSE Activities	5										x								x																			x						x	x	
10	Reducing Life Cycle Cost of The Building	17		x			x												x		x			x	x					x				x	x		x		x		x	x	x	x	x		x
#	**Inputs of BIM**	**#**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
1	Human Resources	25				x					x		x		x		x		x	x	x	x	x	x	x			x	x			x				x	x	x	x	x	x		x	x	x	x	
2	Financial Resources	18	x	x	x	x	x				x		x	x		x	x		x			x			x															x	x	x	x	x			
3	Technological Infrastructure	39	x	x		x	x	x		x	x	x	x		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	
4	Softwares & Hardwares	40	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x	
5	Custom 3D Library	12			x			x							x				x				x	x			x		x			x			X				x					x			
6	Internal Knowledge	15				x		x			x				x		x		x		x	x		x	x											x	x				x	x		x			
7	External Knowledge & Consultancy	10									x						x		x	x	x	x			x															x	x		x				
8	Project Information	12			x			x			x			x		x	x			x		x							x												x	x			x		
9	Project BIM Execution Plan	15				x		x						x	x			x	x	x		x		x										x		X		x	x	x			x				
10	Company's BIM Policy	15					x	x			x	x					x		x	x					x		x				x			x		X		x		x			x				
11	BIM Guideline	19		x						x	x	x	x		x	x			x			x								x	x	x	x	x			X			x	x		x	x			
12	Training & Education	29	x	x	x	x	x	x		x	x		x	x			x	x	x		x	x		x	x		x	x			x	x				x	x	x		x	x	x	x	x			

Figure 3.2. Summary Table of Factors' Sources (1/3)

CSF of BIM in the Turkish Construction Industry			Literature Sources																																												
#	**Barriers of BIM**	**#**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
1	Unavailability of Knowledge Based on Experience	25		x		x	x		x				x		x				x	x	x	x	x	x	x		x	x	x	x	x				x		x			x	x		x	x			x
2	Unclear Benefits	9				x													x			x	x		x		x			x		x					x										
3	Lack of Best Practices	21	x			x	x				x		x						x			x	x	x			x	x	x	x				x	x		x	x			x		x	x			x
4	High Costs	28	x	x	x	x	x						x		x				x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x		x				x		x	x			x
5	Technology Related Problems	30		x	x	x	x		x	x			x		x				x	x	x	x	x			x	x	x	x	x	x			x	x		x	x		x	x	x	x	x	x		x
6	Change Process Problems	31	x	x	x	x			x	x			x		x		x		x	x	x	x	x			x		x	x	x	x	x		x	x		x	x		x	x	x	x	x		x	x
7	Legal & Protocol Problems	24		x	x	x	x			x	x		x		x				x	x	x	x	x					x	x			x			x		x			x	x		x	x		x	x
8	Fragmented Nature of the Industry	11		x	x								x								x	x	x		x										x						x	x	x				
9	Interoperability Problems of Different Parties	17				x		x	x	x			x		x				x	x	x	x			x												x			x		x	x	x	x		
10	Project Specific Problems	25	x	x	x	x	x	x	x				x		x					x	x	x	x		x	x			x	x					x		x	x		x	x	x		x			x
11	Lack of Government Support	4																					x		x												x							x			
#	**Enablers for BIM**	**#**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
1	Corporate & Academic Level Collaboration	15				x		x			x						x		x	x	x	x			x						x	x				x				x	x		x				
2	Project Level Collaboration	30				x		x		x	x		x				x		x	x	x	x	x	x	x		x	x		x	x	x		x	x	x	x	x	x	x	x		x	x		x	x
3	Managerial and Technical Abilities	16									x		x				x		x	x		x		x	x				x	x	x				x		x				x		x	x			
4	Supportive Organizational Culture	31		x		x	x	x	x	x	x		x		x		x		x	x	x	x	x	x	x				x			x		x	x	x	x	x	x	x	x		x	x		x	x
5	External Grants, Incentives & Promotions	22		x			x		x		x	x	x	x	x				x		x	x		x					x			x	x	x	x		x			x	x		x	x			
6	Global Standardisation	10																	x				x		x							x	x		x		x				x		x	x			
7	IPD Type Contracts	11				x													x	x	x														x		x				x	x	x	x		x	
8	Planning of BIM Execution Process	11				x											x		x			x	x											x	x					x	x		x	x			

Figure 3.3. Summary Table of Factors' Sources (2/3)

#	CSF of BIM in the Turkish Construction Industry	Literature Sources																																													
#	**Benefits of BIM**	**#**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
1	Project Financial Benefits	30	x	x		x	x	x		x				x	x	x		x	x	x	x			x	x		x	x				x	x	x	x	x	x	x			x	x	x	x	x		x
2	Right and Accurate Construction Activities	37	x	x	x	x	x	x		x				x	x	x	x	x	x	x	x			x	x		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3	Right and Accurate Technical Office Works	34		x	x		x	x		x				x	x	x		x	x	x	x		x	x	x	x	x	x		x		x	x	x	x	x	x		x	x	x	x	x	x	x	x	x
4	Improve Staff Performance	24	x	x			x	x						x					x		x	x	x	x	x	x						x		x	x	x	x				x	x	x	x	x	x	x
5	Knowledge Management Benefits	26	x	x			x	x											x	x	x	x	x	x	x	x	x	x						x	x	x	x		x		x	x	x	x	x	x	x
6	Claim Management Benefits	23		x	x		x							x	x	x			x		x			x			x	x		x	x		x	x	x		x	x				x	x	x	x		x
7	Reduction of Facility Management Costs	20					x			x				x					x	x	x	x	x				x						x	x	x	x	x					x	x	x	x	x	x
8	Client Satisfaction	5				x	x	x													x																						x				
9	Improve Communication & Collaboration	29	x	x		x	x	x						x				x	x	x	x	x		x	x		x	x		x	x		x	x	x	x	x	x			x	x	x	x	x		x
10	Improve Energy Savings	14					x														x							x			x	x		x	x	x		x	x			x	x		x		x
#	**Impacts of BIM**	**#**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
1	Company's Productivity Improvement	27		x		x	x	x						x		x			x		x		x	x	x		x	x		x	x	x		x	x	x	x	x	x			x	x		x	x	x
2	Corporate Management Improvement	11						x													x			x	x		x			x					x	x	x							x			x
3	Expanding Company's Scope of Services	6																						x			x						x	x							x		x				
4	Enable New Businesses	12					x		x									x			x			x	x		x		x				x	x		x							x				
5	Improve Corporate Financial Performance	11					x	x													x			x	x		x					x	x	x									x	X			
6	Generate Corporate Knowledge	6	x					x	x															x											x											x	

Figure 3.4. Summary Table of Factors' Sources (3/3)

3.3. General Information About Research Methods

3.3.1. Qualitative and Quantitative Research Methods

Qualitative research is a non-numerical method to evaluate the evidences provided by the respondents. It is a market research tool focusing the data througout the conversational communication. In this method respondents are selected randomly to find the answers of "what" and also "why". Findings thorugh this method will also provide "how" the decision making is done by the respondents to explain "why". Also this method is prefered because it is easy to be understood due to its communicative and descriptive charachteristics. There exists several qualitative research methods as;

- One-on-One Interviews
- Focus Groups
- Ethnographic Research
- Case Studies
- Record Keeping
- Process of Observation

On the other hand, quantitative research method is a numerical approach that transforms the obtain data to numerical values demonstarting as tables and graphs to evaluate the numbers for statistical results. Statistics is the common used branch of mathematics in qualitatative research. A comparison of both methods are shown in the Table 3.4.

3.3.2. Case Study Research Method

Case study method is defined in different types in the literature. According to Merriam Webster Dictionary (2003), the definition of a case study is made as follows:

"Case study is an intensive analysis of an individual unit (as a person or community) stressing developmental factors in relation to environment."

According to Yin (2009);

"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."

Table 3.4. Comparison of Qualitative and Quantitative Research Methods (FHI, 2005)

	Quantitative	**Qualitative**
General Framework	Seek to confirm hypotheses about phenomena Instruments use more rigid style of eliciting and categorizing responses to questions Use highly structured methods such as questionnaires, surveys and structural observation	Seek to explore phenomena Instruments use more flexible, iterative style of eliciting and categorizing responses to questions Use semi-structured methods such as in-depth interviews, focus group and participant observation
Analytical Objectives	To quantify varition To predict casual relationships To describe characteristics of a population	To describe variation To describe and explain relationships To describe individual experiences To describe group norms
Question Format	Closed-ended	Open-ended
Data Format	Numrical	Textual
Flexibility in Study Design	Study design is stable from beginning to end Participant responses do not influence or determine how and which questions researchers ask next Study design is object to statistical assumptions and conditions	Some aspects of the study are flexible Participant responses affect how and which questions researchers ask next Study design is iterative

“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 relies 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.” And Yin stated that there are three types of case studies 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.

Various definitions are asserted to define the case study. The essence of a case study is to search the tendency of the underyling factors among the similar type of cases to figure out an analytic result. In this context, the case study is used as a comprehensive research strategy. Regarding to the implementation of the case study, one of the most significant point is making the questions clear to investigate a particular issue depthly. According to Yin (2003), research questions have an influence on controlling the actual events and can degree the focus on past contemporary events. Table 3.5 shows these conditions indicating the relations among the different research strategies by Yin (2003).

In the below table it is demonstrated that “who“, “what”, “where“, “how many” and “how much“ questions are related with the survey and archival analysis strategies. These two strategy methods can be beneficial in describing the influential effect of a case about a certain event. On the other hand how and why questions are linked with the strategies; experiment, history and case study.

Table 3.5. Relevant situations for different research methods (Yin, 2003).

Strategy	**Research Question**	**Control of Events**	**Focus on Contemporary Events**
Experiment	How, Why	Yes	Yes
Survey	Who, What, Where, How Many, How Much	No	Yes
Archive Analysis	Who, What, Where, How Many, How Much	No No	Yes / No Yes / No
History	How, Why	No	No
Case Study	How, Why	No	Yes

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 how and why questions' answers are the central investigation in this research, case study method is the proper research strategy for 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 case study is the perfect match to understand the importance of BIM and to evaluate the importance level of the reviewed critical success factors for for the Turkish market within this research.

3.4. Research Method

From the defined various research method case study research method is chosen for this study. Since there is no control of events in this research, case study is the perfect match to understand the importance of BIM implementations and to evaluate the importance level of the CSFs for the Turkish market within this research. Also, while selecting the research method it is noticed that case study method is rare when it is compared with the other survey methods. Investigating the BIM applications through cases within the Turkish AEC industries provide real life experiences and the evaluation of CSFs can emphasize the key indicators and the accelerators of the BIM adoptions and implementations in the current situation in the design phase.

3.4.1. 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 3.6, 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.

3.4.2. 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.

Table 3.6. Complementarity of case studies and statistical methods (Flyvbjerg, 2011).

Case Studies	**Statistical Methods**
Strenghts	
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 causes and outcomes	Establishment of probabilistic level of confidence
Fostering new hypotheses and new research questions	
Weaknesses	
Selection bias may overstate or understate relationships	Conceptual stretching by grouping together dissimilar cases to get larger samples
Weak understanding of occurrence in population of phenomena under study	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

(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 3.7 (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 3.7. 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 Establish chain of evidence Have key informants review draft case study report	data collection data collection composition
Internal Validity	Do pattern matching Do explanation building Address rival explanations Use logic models	data analysis data analysis data analysis data analysis
External Validity	Use theory in single case studies Use replication logic in multiple case studies	research design research design
Reliability	Use cases study protocol Develop case study database	data collection data collection

3.4.3. Sources of Data

There are two main information resources in case studies: primary information and secondary information. Primary one consists of any documents about the subject like reports, forms and letters. Archives such as project drawings and name lists are also examples of primary information. On the other hand, interviews made with project personnel or clients are in class of secondary information that also provides direct observations about the subject. Yin (2009) defines sources that the investigator makes use of:

(i) Interview is the first data source that can be used in case study research method. It is accepted as a qualitative form of data. The researcher has to organize and then analyze the collected data. Open interviews, semi structured interviews and structured interviews are the three types of this source. Case questions are the advantage of interviews and lead to causal actions and references. The disadvantage of interviews is that the data may be biased due to badly formed questions and it may also occur that the interviewer may get the data he/she wants to hear.

(ii) Documentation can be diagrams, reports, documents, contracts and memos etc. Since this source is rarely created for the sake of a case study, the data can give the researcher a better overview of the situation in the case. However, the relevant reports and references can be hard to find among many other documents.

(iii) Archives are precise and quantitative and do not have to be within the organization. They can be provided from other resources. They have similar advantages and disadvantages as the documentation. Besides, they may have limited access due to privacy reasons.

(iv) Direct observation is based on that the researcher is someone out of the case organization and can observe extrinsically what happens within the case using. The researcher's judgment is decisive in choosing what is needed to continue the study. However, this may lead to that the collected data may be biased because of the subjective judgment. Besides, participant observations have similar properties as direct observations. They are insightful into interpersonal behaviors however they may be biased due to the researcher's manipulation of events.

(v) Physical artifacts may be a technological device, a tool and an instrument etc. Such evidences may be collected or observed as part of a visit. They have less potential relevance in case studies but when they are relevant, the artifacts can be important components in the overall case. They have two typical disadvantages: availability and selectivity.

3.4.4. Design of the Case Study Interview Form

In this research, case study interview form is constructed in 3 parts; “Part 1”, “Part 2“ and “Part 3”.

Part 1 stands for gathering the data of the respondents’ carrer in the industry. That is why in this part questions were focusing on getting to know the respondents’ professions, positions and their total experience years in the industry.

In Part 2, the aim is to gather the company level data such as the establishment year of the company, fields of the operation of the company, expertise areas of the company, number of hired employees in the compnay, the adoption year of BIM within the company, number of finalized projects by utilizing BIM and investigating for which functions BIM is utilized in the company.

Part 3 focuses on the investigation of the cases and the evaluation of the CSFs. Identification of the project type and duration, total gross construction area, number of BIM team members and softwares involved in the cases investigated in this part of the form. Also, questions supporting to investigate whether a cost or time saving is occurred because of implementing BIM process are asked to the respondents.

An example of the form can be seen in the APPENDIX A.1 and A.2.

3.4.5. Evaluations of the CSFs

As mentioned, the last part of the case study interview form is placed to review the factors for the 6 components of the framework to find the critical factors for each. It is desired by the respondents to rate the each factor of the components between 1 to 5 interval, regarding to their significance during the projects’ BIM implementation in the design phase. Rating system is created as converging to “5“ represents the high level of importance. The rating system’s definition is demonstrated in the Table 3.8.

Table 3.8. Rating System

Ratings	**Meanings of the Ratings**
1	Insignificant
2	Less Significant
3	Moderate Significant
4	Significant
5	Very Significant

4. FINDINGS

In this chapter, first of all the general findings covering the results of the interview form including the Part 1, Part 2 and particllay from the Part 3 except the evaluation of the CSFs are demonstrated. Afterwards, CSF's evaluation results are presented regarding to the each framework component. Based on the respondents' rankings, the factors are evaluated on the basis of each Project and the each company representer. During the evaluation the average of the each factor component is used for the comparison purpose to highlight the siginficant factors for a succesfull BIM implementation.

4.1. General Findings

4.1.1. Findings of Part 1

This investigation is realized with 25 respondents currently dealing with the BIM implementations within well known 15 companies in Turkish AEC Industries. According to the results, distribution of the respondents' professions is shown in the figüre 4.1, distribution of the respondents' experience years in the industry is shown in the figure 4.2 and the distribution of the respondents in the companies also demonstrated in figure 4.3 below.

As shown in the figüre 4.3 the experience year of all the respondents has a range between 2 to above 30 years. According to the results, almost 50% of the respondents have at least 10 years experience in the industry with various titles. Distribution of their positions is also demonstrated in the figüre 4.4 below. And, it is noticed that if respondents' levels are clustured into 3 groups as the executive level, founder level and members of the BIM team, the participation rates from these levels are observed as 20%, 12% and 68% respectively.

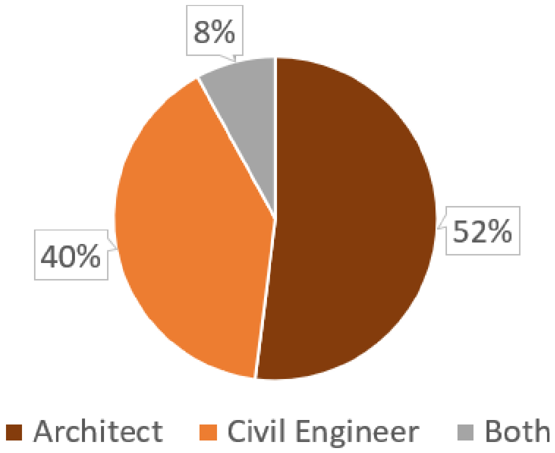

Figure 4.1. Distribution of the Respondents' Professions

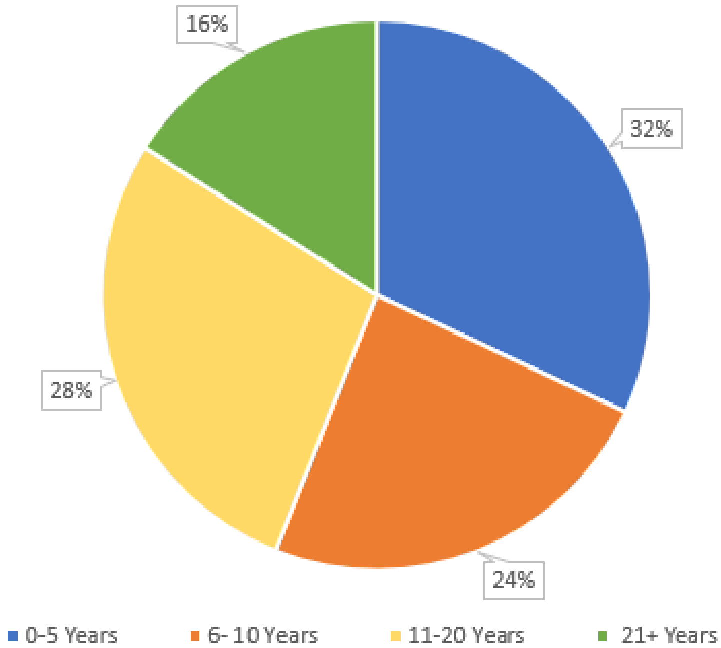

Figure 4.2. Distribution of Respondents' Experience Years in Ranges

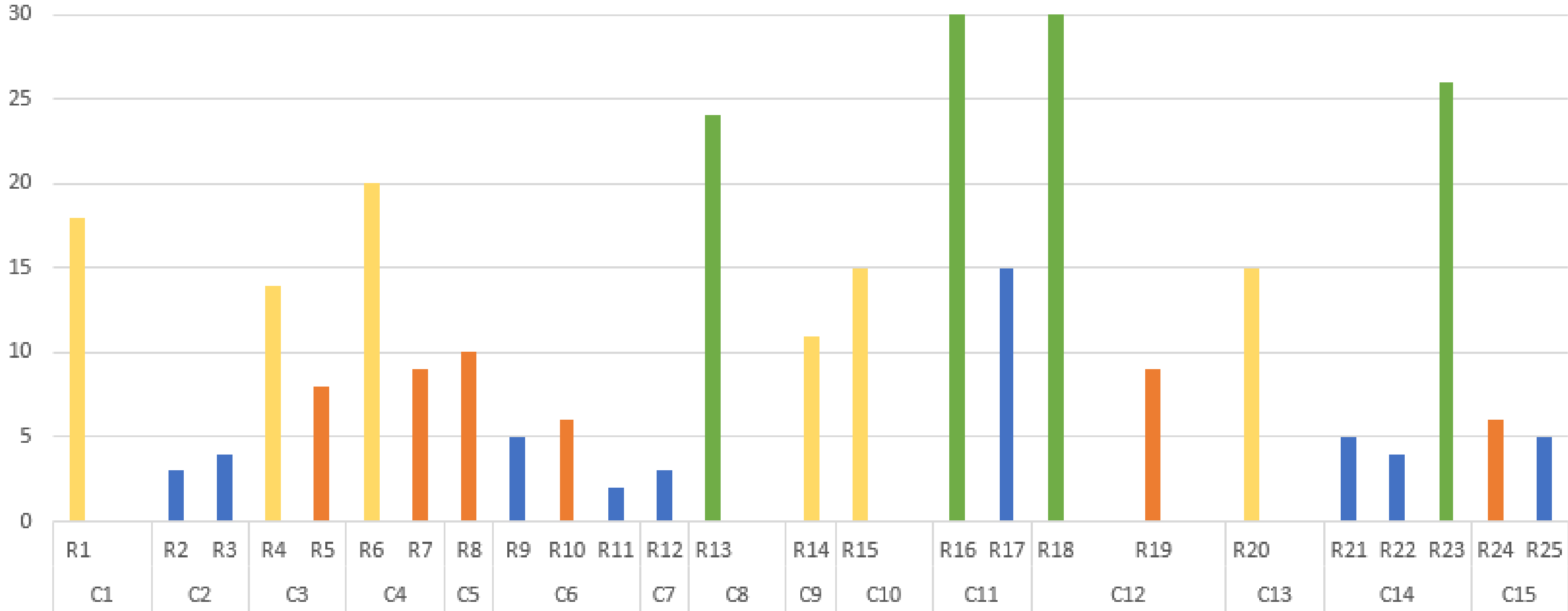

Figure 4.3. Respondents Distribution in the Companies

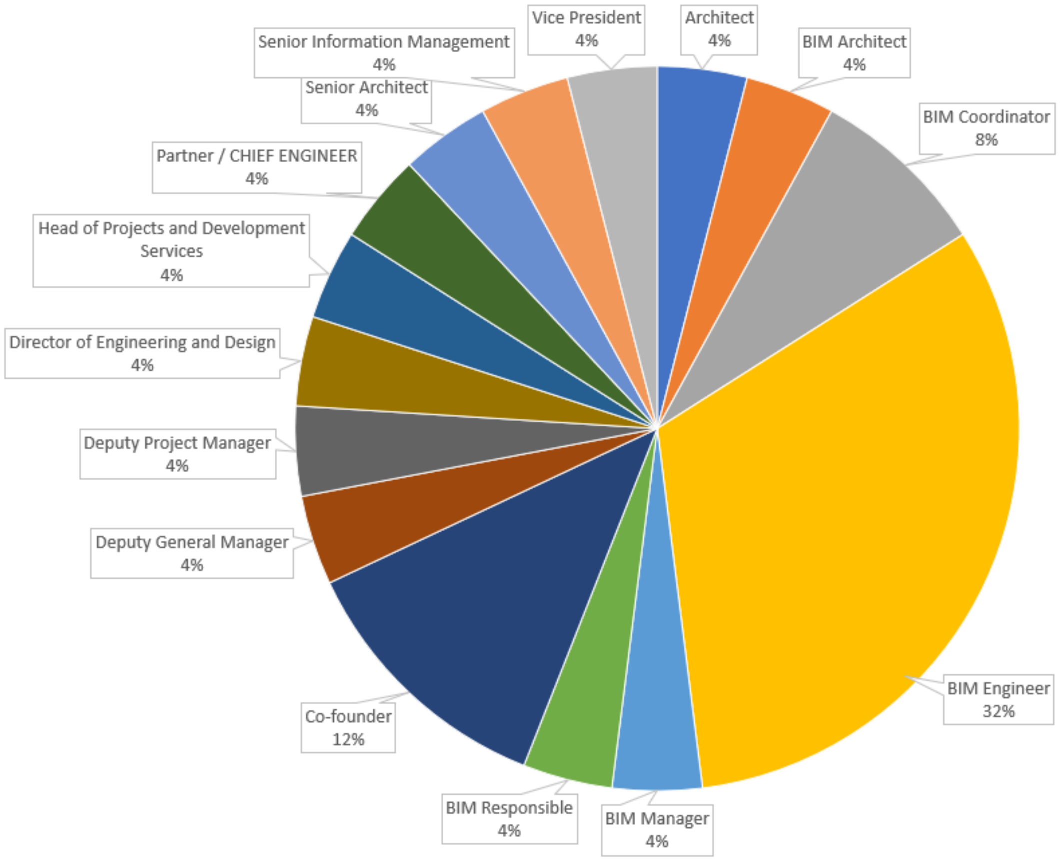

Figure 4.4. Distribution of Respondents' Positions in the Companies

4.1.2. Findings of Part 2

In this part, 15 companies general information results are shared. First of all a timeline is created to see the establisment years of each company easily. This timeline figüre 4.5 is demonstrates that 8 of the companies is established before 1990 which is just before the commencement of designing through object based and the remaining 7 companies established starting from 1997.

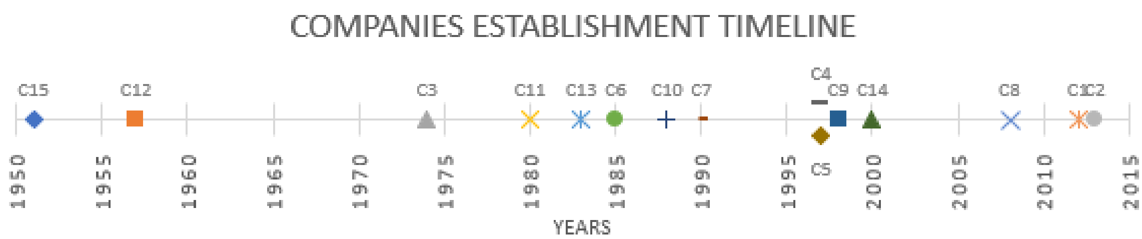

Figure 4.5. Companies Establishment Years

Companies's field of operations are investigated in 5 groups; Architecture, Engineering, Construction, Consultancy and Project Management and the results are presented in the figüre 4.6. 87% of the interviewed companies are providing Architectural operations. It is followed by the Engineering operations by 80%. Operations related to the Consultancy and Project Management are given by 60% of the companies. Lastly, only 47% of the interviewed companies providing operations in Construction. Also the expertise areas of the companies are demonstrated in figure 4.7.

Figüre 4.8 shows the distribution of the employee's range hired by the companies. Figure 4.8 shows that 0-250 range dominates the general scenario by having a ratio 67% which corresponds that 2 over 3 respondents works in a company that has upto 250 employees. Also, companies distribution with notaions shared in the figüre 4.8 to transparent which companies are aligned in the proper ranges.

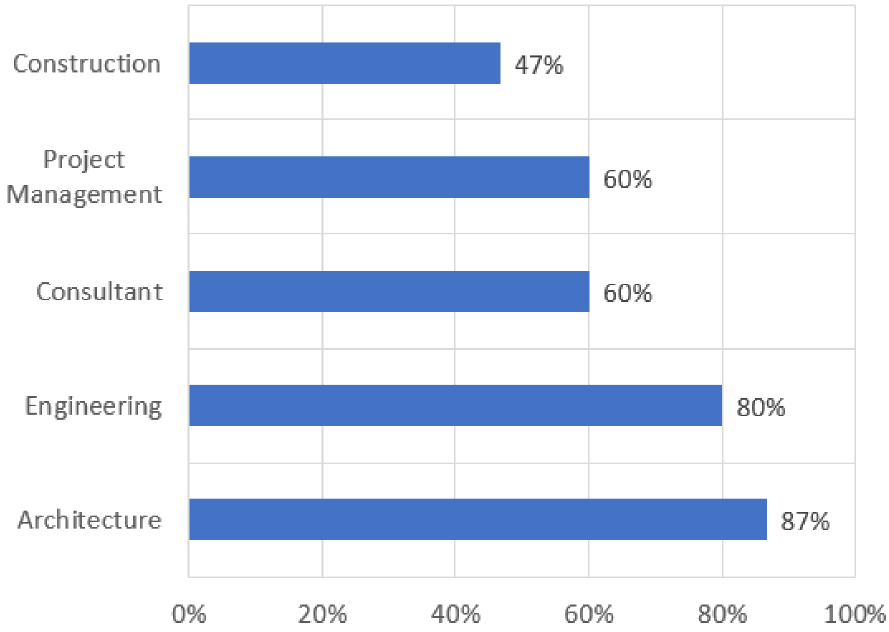

Figure 4.6. Distribution of Operations Among the Companies

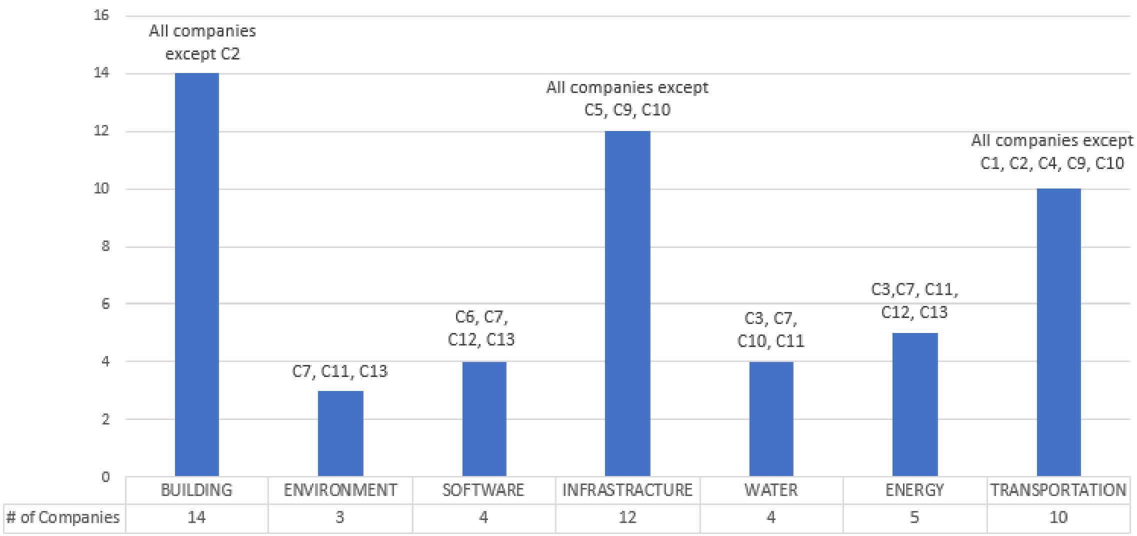

Figure 4.7. Distribution of Companies' Expertise Areas

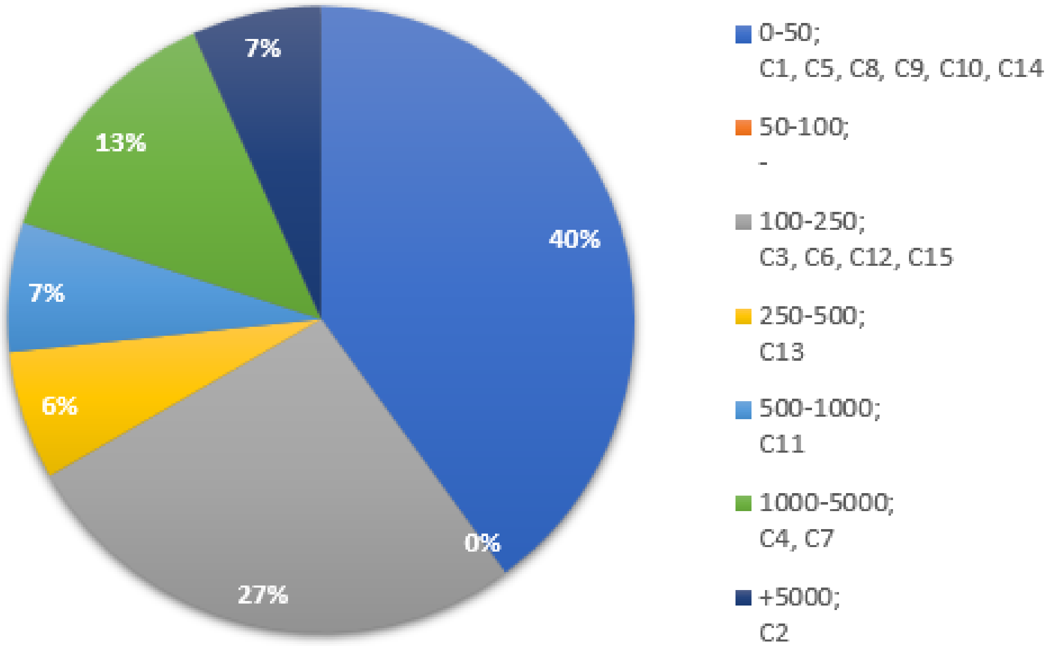

Figure 4.8. Distribution of Employees Range in Companies

Since companies familiarity with the BIM is one of the key parts of the investigation, the adoption within the organization and the respondents knowledge on BIM functions are also investigated. Regarding to respondents' answers, BIM adoptions among the companies are also shared in the following figüre 4.9 chronologically. This figüre 4.9 shows that only 1 company has experience above 10 years and most of the companies's familiarity with BIM process waves around 7 years. And the functions that are utilized with the BIM shared in the figüre 4.10. Results show that every company provides 4D level of BIM implementation in their organizations. 87% of the companies interviewed also realizes 5D level of BIM implementations. 6D and 7D level of BIM implementations are rare in the investigated cluster so that they are realized by 33% and 27% of the companies. The distribution of the BIM functions' utilization showed in figüre 4.10.

When the establishment years of the companies and the BIM adoption years are compared, it is noticed that company C1 is founded as a BIM based design company and the companies C2 and C8 are the quick adopters. The rest of the companies can be so-called "latercomers" except C12. Since the establishment year of the company C12 is in late 1960s, it is first adopter among the 15 companies. Latecomers may failed to adopt BIM early possibly because of the transition problems.

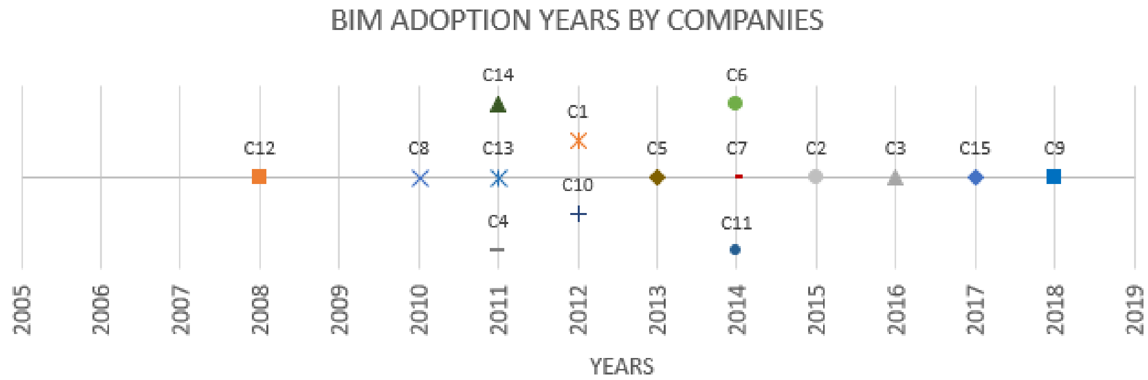

Figure 4.9. BIM Adoption Timeline by Companies

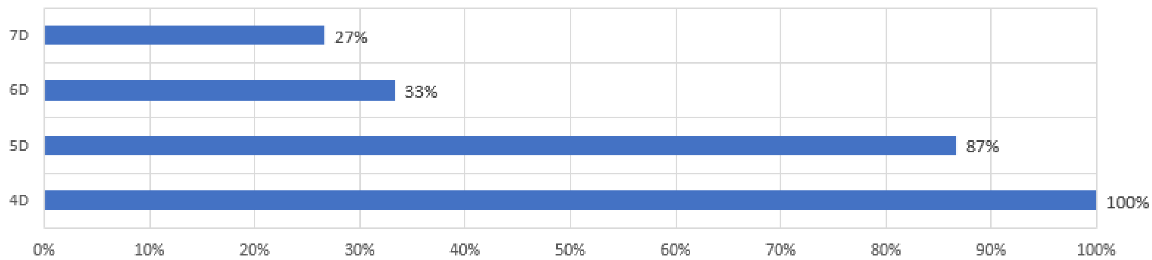

Figure 4.10. Distribution of BIM Functions' Utilization Among the Companies

4.1.3. Findings of Part 3

In this part, except the CSFs' evaluations findings as general information of the interviewed cases are shared. According to the gathered results, the commencement years of the cases demonstrated chronologically in the figüre 4.11 indicating that first BIM project is realized in 2009 by company C12 through project P17. Also, distribution of the projects' types are shown in the figüre 4.12.

Tables 4.1 and 4.2 demonstrates the details obtained regarding to the projects as a summary table. Most of the respondents hesitated to tell their v-contractual budget. That is why, analysis related to finacial comparisons could be realized.

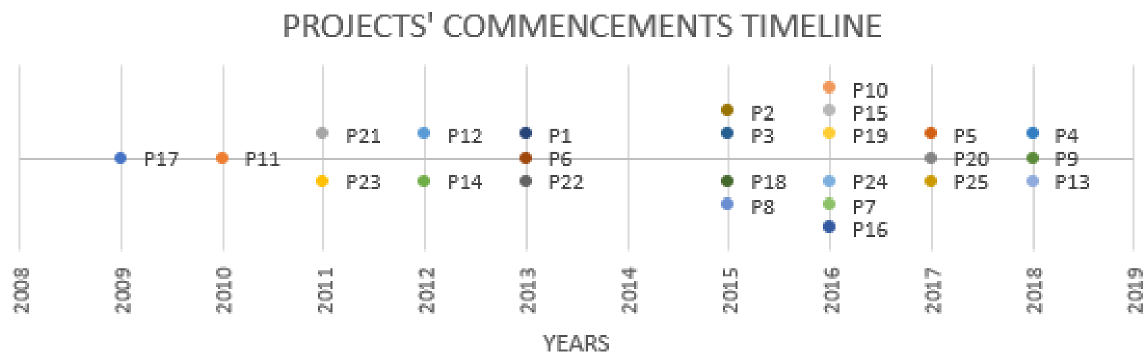

Figure 4.11. Timeline of the Case Projects' Commencement Years

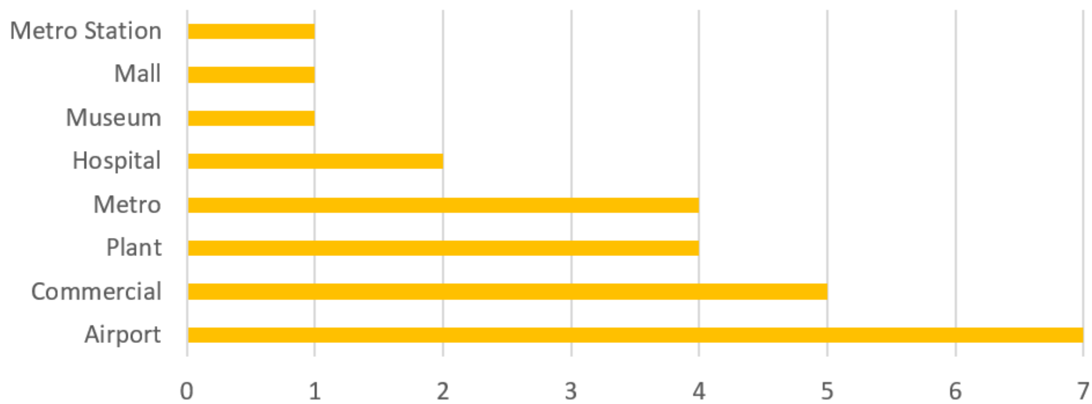

Figure 4.12. Distribution of the Project Types

Table 4.1. Interviewed Case Projects (1/2)

Company Code	Respondent Code	Project Code	Project Type	Interviewed Party	TCA (M2)	Budget	Duration (Months)	Size Of BIM Team	BIM Application
C1	R1	P1	Airport	Designer	12 M	-	24	30	7D
C1	R1	P2	Commercial	Designer	75 K	-	14	30	7D
C2	R2 R3	P3	Airport	Contractor	76 M	35 B TL	42	15	7D
C3	R4 R5	P4	Plant	Designer	60K	-	6	5	5D
C4	R6 R7	P5	Airport	Designer	25 K	-	24	2	5D
C5	R8	P6	Commercial	Designer	400 K	-	36	7	5D
C6	R9	P7	Metro	Designer	13.4 km + 12 station	-	36	15	5D
C6	R10	P8	Metro	Designer	22.5 km+18 station	-	54	15	5D
C6	R11	89	Commercial	Designer	15K	-	24	15	5D
C7	R12	P10	Commercial	Designer	6.5 K	-	24	7	6D
C8	R13	P11	Airport	ST Designer	2 K	2 M $	12	3	5D
C8	R13	P12	Plant	ST Designer	350 K	1 M TL	12	6	5D

Table 4.2. Interviewed Case Projects (2/2)

Company Code	Respondent Code	Project Code	Project Type	Interviewed Party	TCA (M2)	Budget	Duration (Months)	Size Of BIM Team	BIM Application
C9	R14	P13	Commercial	PM	6 K	3 M $	6	8	7D
C10	R15	P14	Airport	ST Designer	30 K	400 K TL	6	4	5D
C10	R15	P15	Hospital	ST Designer	130 K	500 K TL	18	2	5D
C11	R16 R17	P16	Metro	Designer	14.3km+13 Station	-	36	10	4D
C12	R18	P17	Airport	Designer	1 M	-	24	10	6D
C12	R18	P18	Mall	Designer	200 K	-	32	3	6D
C12	R19	P19	Hospital	Designer	12 K	-	14	3	6D
C12	R19	P20	Commercial	Designer	1.6 K	-	18	3	6D
C13	R20	P21 P22	Plant Plant	Designer Designer	600 1400 K	- -	4 24	8 3	5D 5D
C14	R21	P23	Metro	Designer	90 K	-	12	2	7D
C14	R22 R23	P24	Airport	Designer	700 K	- -	12	32	7D
C15	R24 R25	P25	Metro	Contractor	11 km+8 station 7 km+ 6 station	-	12	5	4D

4.2. General Case Study Results of the CSFs' Evaluation

4.2.1. Drivers of BIM Implementations

"Drivers" stand for the motivation behind the transition to BIM. Factors for successful implementations under this component are evaluated by the respondents. The results are given in the Table 4.3 and the average of each factor is used for the comparison purpose to highlight the significant factors for a successful BIM implementation.

It is found out that the AEC industries found the motivation for the transition to BIM implementations in factors which have affects on the "Project Level". Based on the results, "Improving the Collaboration and Coordination" is taking the first place among the other factors. And with a little difference "Improving Corporate Performance" took the second place.

Apart from these drivers, respondents put emphasize on the desire to improve the designs and project performance. However, since these factors ranked as the top drivers, factors like to "Improving Project Performance" and "Design Improvement" have minimum rankings as 1. Company C14 ranked the "Improving Project Performance" factor as 1. In project P23, the respondents R21 and R22 said that it was their first BIM project and the aim was dare for the transition and understand the concepts and the challenges to finish a project by implementing BIM. As a result, "Improving Project Performance" factor follows "Improving Corporate Performance" factor on the list.

Also, respondent R15 from company C10 which is a structural design firm indicated that during the project P14 design improvement had no importance when it is compared with their second project P15. That is why, these two projects ranked the "Design Improvement" factor as 2 and 1 respectively in the evaluation. Therefore, their evaluation leads the "Design Improvement" factor to take the fourth place in the list.

Table 4.3. Case Study Results For Drivers

No	**CSFs**	**Influence Level**	**Min. Ranking**	**Max. Ranking**	**Avg. Result**
1	Improving Collaboration and Coordination	Project Level	3.00	5.00	4.64
2	Improving Corporate Performance	Firm Level	1.00	5.00	4.56
3	Improving Project Performance	Project Level	2.00	5.00	4.48
4	Design Improvement	Project Level	1.00	5.00	4.44
5	Client Requirement	Project Level	1.00	5.00	4.00
6	Improving Construction Productivity	Project Level	1.00	5.00	3.80
7	Reducing Life Cycle Cost of The Building	ProjectLevel	1.00	5.00	3.04
8	Improving Building's Energy Performance	Project Level	1.00	5.00	2.80
9	Improving HSE Activities	Project Level	1.00	5.00	2.20
10	Governmental Push	Industry Level	1.00	5.00	1.56

Lastly, “Client requirement” found out as one of the significant factors among the other components. On the other hand, remaining factors are ranked in between being less and moderate significant regarding to the evaluating system as shown in table 3.8.

Most of the companies are using BIM for 4D 5D modeling which means that the general of the companies are more focused on the performance related activities. That is why the motivation comes high in the related factors. Remaining factors like health and safety, energy performance and lifecycle cost are related with 6D and 7D BIM implementation activities that why their importance is low in the evaluated cases.

Lastly, as seen through the general result from the table 4.3 “Governmental Push” took the last place. It is ranked 1.56 by taking three 5 points means that over the investigated 25 case projects government support is realized in just 3 projects which are P10, P24 and P25. Moreover, P24 is located in abroad and respondent R23 told that its obligated to utilize BIM by the government in this huge scale of infrastructure projects. So, that is why C7 and C15’s projects are realized in Turkey. And regarding to the rest of the respondents, they all mentioned that there was no support from the governmental side for the transition to implement BIM.

4.2.2. Enablers of BIM Implementations

“Enablers” stand as the facilitators or the accolertors which provides to overcome the hindering challanges of implementing BIM in an easy way. Factors for successfull implementations under this component are evaluated by the respondents and the results are given in the Table 4.4. And, the average of each factor is used for the comparison purpose to highlight the significant factors for a successful BIM implementation.

Table 4.4. Case Study Results For Enablers

No	**CSFs**	**Influence Level**	**Min. Ranking**	**Max. Ranking**	**Avg. Result**
1	Supportive Organizational Culture	Firm Level	3.00	5.00	4.56
2	Project Level Collaboration	Project Level	3.00	5.00	4.52
3	Managerial and Technical Abilities	Firm Level	3.00	5.00	4.32
4	Global Standardization	Industry Level	1.00	5.00	4.00
5	Planning of BIM Execution Process	Project Level	1.00	5.00	3.92
6	Corporate and Academic Level Collaboration	Industry Level	1.00	5.00	2.64
7	IPD Type Contracts	Project Level	1.00	5.00	2.43
8	External Grants, Incentives and Promotions	Industry Level	1.00	5.00	2.08

Regarding to the results, organization's attitude takes the leadership for a successful BIM implementation. And, with a very little difference achievement of "Project Level Communication and Collaboration" eases to have a successful BIM process since this factor took the second place on ranking. It can be said that factors which have an influence on firm level are the most significant factors because the third significant factor is the "Managerial and Technical Abilities". This factor corresponds to the experience level in the company and highlights the effect on making right decisions through experienced employees.

Separately from these factors, "Global standardization" and "Planning BIM Execution Process" are listed as fourth and fifth significant factors respectively. When these factors minimum and maximum values are checked, it is seen that these factors have ranked as 1 by the respondents. Regarding to the "Global Standardization" factor companies C10 and C12 evaluated this factor as insignificant in their projects P14 and P17 respectively. As mentioned previously, company C10 is a structural design company and the respondent told that they had nothing to do with the BIM protocols or the standards in the project P14. From company C12, respondent R23 said that P17 is the first BIM project that a Turkish company participated in and this factor was not a prior facilitator in that time.

Similar to "Global Standardization" factor, evaluation of the "Planning of BIM Execution Process" factor is ranked as insignificant by the similar companies C10 and C12. Also company C14 ranked this factor as "1" by explaining that P23 was their first BIM project and they were not aware of planning an execution plan.

All remaining factors which are mostly having an effect on "Industry Level" are considered as "Less Significant" factors in the case of Turkey. Interestingly, even if they have low ranking values 3 companies; C1, C7 and C11 indicated that they were cooperating with academicians in their projects and they have found the "Corporate and Academic Level Collaboration" factor as a significant facilitator in their BIM processes.

Also except the companies C6, C7 and C9, mostly every respondent said that they have not faced such a promotion. That is why “External Grants, Incentives and Promotions“ factor listed as least significant CSF among all.

Regarding to “IPD Type Contracts” factor; respondents from companies C2, C7 and C13 stated that they are targeting to finish the projects as a whole body. Because of making easy their implementations, these company respondets ranked this factor as high as possible.

4.2.3. Inputs of BIM Implementations

“Inputs” cover the necessary resources like tools or requirements to implement a successful BIM. Factors for successful implementations under this component are evaluated by the respondents and the results are given in the Table 4.5. And, the average of each factor is used for the comparison purpose to highlight the significant factors for a successful BIM implementation.

“Human Resources“ takes the first place in the listing. Afterwards, “Training and Education” and “softwares and hardwares” factors come in the second and third place, respectively. Having a “Project BIM Execution Plan” comes as fourth significant factor. And lastly the fifth important factor is the “Internal Knowledge”. When the last two factors minimum values are observed it is seen that they are ranked as “1“. For the “Project BIM Execution Plan” factor, companies C10 and C14 stated that this factor was insignificant for the projects P14, P15, and P23. For the “Internal knowledge” factor, companies C12 and C14 ranked “1” in the projects P17 and P23.

Also, when the results of Table 4.5, all CSFs have moderate significant level. That is why, factors ranked above “3.5“ have the potential to become a CSFs for some projects even their minimum and maximum rankings are in between 1 and 5. When all of these 4 factors which have a ranking above “3.5” are investigated, it is seen that companies C10, C12 and C14 gave the minimum rankings.

Table 4.5. Case Study Results For Inputs

No	CSFs	Influence Level	Min. Ranking	Max. Ranking	Avg. Result
1	Human Resources	Project Level	3.00	5.00	4.60
2	Training and Education	Firm Level	2.00	5.00	4.48
3	Softwares and Hardwares	Firm Level	3.00	5.00	4.36
4	Project BIM Execution Plan	Project Level	1.00	5.00	4.04
5	Internal Knowledge	Firm Level	1.00	5.00	3.96
6	Technological Infrastructure	Industry Level	1.00	5.00	3.92
7	Project Information	Project Level	1.00	5.00	3.91
8	Financial Resources	Project Level	1.00	5.00	3.88
9	Company's BIM Policy	Firm Level	1.00	5.00	3.68
10	Custom 3D Library	Industry Level	1.00	5.00	3.36
11	BIM Guideline	Industry Level	1.00	5.00	3.20
12	External Knowledge and Consultancy	Project Level	1.00	5.00	3.12

The least insignificant factor is the external knowledge and consultancy. Respondents R15, R18 and R19, R20 from the companies C10, C12 and C13 evaluated the projects P14 and P15, P18, P19 and P20, P21 and P22 with the minimum ranking. Respondent R20 from the company C13 told that rather than taking consultancy we hired an employee who was a good fit to take the leadership to guide us and follow the necessary procedures for a successful implementation. Respondent R15 told that, he got experienced in BIM while working in US in a complex health center project. That is why, he proceed to use his own knowledge without considering to take any consultancy. R18 and R19 stated that in their first BIM project they took the consultancy but afterwards they become aware that spending for consultancy is costly. As a result of this, they preferred to invest to their employees.

4.2.4. Barriers of BIM Implementations

"Barriers" cover the hindering factors those undermine the successful BIM implementation process. Critical factors for BIM implementations under this component are evaluated by the respondents and the results are given in the Table 4.6. And, the average of each factor is used for the comparison purpose to highlight the significant factors for a successful BIM implementation.

"Fragmented Nature of the Industry" found as the main barrier in the BIM implementations by the respondents among the CSFs. Company C7 and C13 ranked this factor as insignificant. Company C7 is a well known international design firm and has ranked "Internal Knowledge" as a significant factor shows that they are capable of handling their work on in the Turkish AEC industries. Also, C13 has separate companies that they generally implement their projects with their other own companies. So that they can act as a whole body without seeing this factor as a barrier. The "Interoperability Problems of Different Parties" factor is the second highest ranked barrier by the respondents. Also, only company C7 ranked this factor as the least significant factor among the others. "Unavailable Knowledge Based on Experience" factor took the third place in the list.

Table 4.6. Case Study Results For Barriers

No	**CSFs**	**Influence Level**	**Min. Ranking**	**Max. Ranking**	**Avg. Result**
1	Fragmented Nature of the Industry	Industry Level	1.00	5.00	3.25
2	Interoperability Problems of Different Parties	Project Level	1.00	5	3.13
3	Unavailability of Knowledge Based on Experience	Firm Level	1.00	5	3.00
4	Change Process Problems	Industry Level	1.00	5.00	2.84
5	Project Specific Problems	Project Level	1.00	5.00	2.68
6	Unclear Benefits	Project Level	1.00	5.00	2.38
7	Legal and Protocol Problems	Industry Level	1.00	5.00	2.32
8	Lack of Best Practices	Industry Level	1.00	5.00	2.17
9	Technology Related Problems	Industry Level	1.00	5.00	2.12
10	High Costs	Project Level	1.00	4.00	2.04
11	Lack of Government Support	Industry Level	1.00	4.00	1.46

Overall results also indicates the gap among companies BIM implementation maturities. Each factor has a minimum and maximum range between being "insignificant" and "significant" but none of the factors could reach maximum value than "3.25" in the average results. Only 3 factors are found as "Moderate Significant" and the all remaining 8 factors are resulted as "Less Significant". And, the least significant one is the "Lack of Government Support" factor.

4.2.5. Benefits of BIM Implementations

"Benefits" cover the Project level gainings in the short term by utilizing a succesfull BIM implemention process. Factors for BIM implementations under this component are evaluated by the respondents and the results are given in the Table 4.7. And, the average of each factor is used for the comparison purpose to highlight the siginficant factors for a succesfull BIM implementation.

Through implementing BIM processes, the top firm level benefit is observed as the "Right and Accurate Construction Activities" factor as an outcome of the well-designed 3D BIM model during the design phase. This factor is evaluated by the respondents via gathering feed-backs from the contractors during the construction phase. The second critical benefit is the "Improve Staff Performance" factor. Third significant benefit is listed as the "Right and Accurate Technical Office Works" factor that covers the better designed models with minimized errors allowing better estimations. With a little difference, "Knowledge Management Benefits" took the fourth place in the list. Fifth significant factor is the "Claim Management" benefit. Last, significant benefitis the "Client Satisfaction" which is evaluated regarding to their affirmative feed-backs to the project parties.

Table 4.7. Case Study Results For Benefits

No	CSFs	Influence Level	Min. Ranking	Max. Ranking	Avg. Result
1	Right and Accurate Construction Activities	Project Level	3.00	5.00	4.72
2	Improve Staff Performance	Project Level	3.00	5.00	4.68
3	Right and Accurate Technical Office Works	Project Level	3.00	5.00	4.60
4	Knowledge Management Benefits	Project Level	1.00	5.00	4.52
5	Claim Management Benefits	Project Level	3.00	5.00	4.43
6	Client Satisfaction	Project Level	1.00	5.00	4.20
7	Project Financial Benefits	Project Level	1.00	5.00	3.88
8	Improve Communication and Collaboration	Project Level	2.00	5.00	3.80
9	Reduction of Facility Management Costs	Project Level	1.00	5.00	3.36
10	Improve Energy Savings	Project Level	1.00	5.00	2.92

Among these CSFs findings, just “Client Satisfaction“ and “Knowledge Management Benefits” factors have minimum rankings. For the “Client Satisfaction“ factor only the respondent R15 from the company C15 ranked this factor as insignificant in project P14 because the architect was working in 2D and that lead the company to deliver the ruined outputs while taking 2D outputs from Revit. So because of the technical problem client could not be satisfied. For the “Knowledge Management Benefits” factor in P14 the respondent ranked this factor as insignificant. Also respondent R21 from the project P23 ranked this factor as “Less Significant“. This project P23 was their first BIM project and told before the only matter was the transition for the company C14. That is why they were not aware of this factor.

“Project Financial Benefits” listed gradually low among the CSFs because most of the companies are still in the investment phase for BIM in Turkey. BIM based design companies like C1 and C8 ranked this factor higher.

“Improve Communication and Collaboration“ also evaluated as more “Moderate Significant” benefit because 20% of the respondents evaluated this factor as “Less Significant“.

“Reduction of Facility Management Cost” and “Improve Energy Savings” factors are evaluated as the two insignificant benefits by the respondents. This result is observed because of the companies have a tendency to use BIM for 4D and 5D purposes. Only 4 companies were utilized 7D function of BIM.

4.2.6. Impacts of BIM Implementations

“Impacts” cover the firm level gainings in the long term by utilizing a succesfull BIM implemention process. Factors for BIM implementations under this component are evaluated by the respondents and the results are given in the Table 4.8. And, the average of each factor is used for the comparison purpose to highlight the siginficant factors for a succesfull BIM implementation.

Table 4.8. Case Study Results For Impacts

No	CSFs	Influence Level	Min. Ranking	Max. Ranking	Avg. Result
1	Generate Corporate Knowledge	Firm Level	3.00	5.00	4.60
2	Enable New Businesses	Firm Level	1.00	5.00	4.56
3	Company's Productivity Improvement	Firm Level	1.00	5.00	4.44
4	Corporate Management Improvement	Firm Level	2.00	5.00	4.32
5	Expanding Company's Scope of Services	Firm Level	2.00	5.00	4.32
6	Improve Corporate Financial Performance	Firm Level	2.00	5.00	4.00

According to the resultant evaluation of "Impacts" CSFs, all of them are found as significant. "Generate Corporate Knowledge" and "Enable New Businesses" factors are the two leading CSFs by the respondents. R23 told that after realizing projects P23 and P24 they made a new contract for a financial institutional project thanks to shifting to BIM implementations. But, on the other hand, respondent R13 from company C8 told that after project P12 we did not take a new project similar to this reference project. That's why R13 evaluated this factor as "insignificant".

"Company's Productivity Improvement" factor is listed as the third significant factor. Respondent R18 which is the vice president of the company C12 told that project P17 was our first BIM project and as company we decided the transition to BIM at one night and forced architectures to design in Revit. That was the beginning of our BIM journey and employees were struggled a lot. That is why at the time of P17's implementation it was hard to speak about the productivity.

The fourth place is shared between "Corporate Management Improvement" and "Expanding Company's Scope of Services" factors. Respondent R1 from company C1, gave the minimum value for the "Corporate Management Improvement" because they were found as a BIM-oriented design company. Respondent R16 by company C11 evaluated the "Expanding Company's Scope of Services" factor as "Less Significant" claiming that they are still giving the same services.

The last, sixth significant factor is the "Improve Corporate Financial Performance" because at the current time everybody is trying to learn and rise their awareness regarding to BIM process. That is why non of the respondents are focused on monetary gainings but there are few companies noted that made money.

5. DISCUSSION

In this chapter, the general case study results of CSFs are compared with the literature findings to observe the similarities and differences based on the CSFs ranking. Also, through using the data collected during the evaluation of the cases, project specific CSFs could be identified. And since the projects' implementation times are gathered the evolution of the CSFs can be tracked to comment on the trending CSFs. This investigation provides the recent industry conditions. Also, investigation based on the BIM functions utilization provides detail information about the chosen CSFs.

5.1. Case Study Results Comparison with Literature Findings

5.1.1. Comparison of Drivers

According to the comparison figure 5.1 "Improve Coordination and Collaboration", " Improving Project Performance" and "Design Improvement" factors are found as "Significant" factors in both studies."Reducing Life Cycle Cost of The Building" factor keeps the same significance level in both studies. Moreover, "Improving HSE Activities" factors keep their evaluation as being "Insignificant" for both results. Notable differences in the rankings are occured in "Improving Corporate Performance" and "Client Requirment" factors as being ranked higher in the case studies and for the "Improving Building's Energy Performance" and "Governmental Push" factors ranked higher in literature review.

"Improving Corporate Performance" is found as the sixth important factor in the literature whilst the second important factor for the respondents. D. Cao *et al.*(2017), said that "organizations with high BIM capability, they may need to conduct BIM implementation to exhibit their BIM capability, and so to avoid their established image for embracing advanced technologies being contaminated. On the other hand, organizations with low BIM capability, they may need to conduct BIM implementation to improve or re-establish their social image for utilising the advanced BIM technology and narrow the image gap". This dilemma can be the underlying factor in Turkey case, BIM applications are seen important for the companies image that can step the company forward in the rivalry and for the marketing purposes. Also, the study carried by Eadie *et al.* (2013), find that one of the drivers for BIM implementations is "sales promotion to client".

Table 5.1. Comparison of the Drivers' Case Study Results vs Literature Results

General Case Study Results	**Ranking**	**Literature Review Results**
Improving Collaboration and Coordination	1	Design Improvement
Improving Corporate Performance	2	Improving Project Performance
Improving Project Performance	3	Improving Collaboration and Coordination
Design Improvement	4	Improving Construction Productivity
Client Requirement	5	Improving Building's Energy Performance
Improving Construction Productivity	6	Reducing Life Cycle Cost of The Building
Reducing Life Cycle Cost Productivity	7	Improving Corporate Performance
Improving Building's Energy Performance	8	Governmental Push
Improving HSE Activities	9	Client Requirement
Governmental Push	10	Improving HSE Activities

“Client requirement” is found important in the case of Turkey. However, in the literature it is not important regarding to the results.In addition to this factor “Governmental Push” factor also showed a similar increase in its significance level. In 2017, Jin *et al.*, stated that in the developing countries BIM implementation accelerates by clients and government mandate. Even if the adoption of BIM implementations is increasing slowly, this occurs because of the client mandates since government is not taking a step in promoting BIM implementations. Also, respondents whom finished projects abroad indicated that there are obligations stated by law to implement BIM for certain project type. Also, companies working globally possibly faced with the governmental effect. Also, the BIM’s maturity is rising globally day by day and each nation creates their standards for BIM implementations except Turkey. Since, the literature sources covers the cases and investigaions mostly out of Turkey, “Governmental Push” is ranked greater than the general case study results in literature review.

“Improving Building’s Energy Performance” found significant in the literature. Still this factor ranked fully by some respondents it is noticed that it has a min-max ranking between 1 and 5. Means that this factor’s importance level can vary regarding to the project type or the utilization of different function level of BIM implementation. Regarding to the survey results, number of 7D BIM implementations among the companies involved in the case studies are really low. Also, most of the literature sources emphasizing the BIM utilization for green designs(i.e Eadie *et al.*, Coates *et al.*, etc) whilst the Turkish companies are implementing BIM for 4D and 5D.

5.1.2. Comparison of Enablers

According to the comparison Table 5.2, “Supportive Organizational Culture”, “Project Level Collaboration” and “Managerial and Technical Abilities” factors are found as “Significant” factors in both studies. “Corporate and Academic Level Collaboration” and “IPD Type Contracts” factors keep the same significance level in both studies.Notable differences in the rankings are occured in “Global Standardisation” and “Planning of BIM Execution Process” factors as being ranked higher in the case studies and for the “External Grants, Incentives Promotions” factor ranked higher in literature review.

Table 5.2. Comparison of the Enablers' Case Study Results vs Literature Results

General Case Study Results	**Ranking**	**Literature Review Results**
Supportive Organizational Culture	1	Supportive Organizational Culture
Project Level Collaboration	2	Project Level Collaboration
Managerial and Technical Abilities	3	External Grants,Incentives and Promotions
Global Standardization	4	Managerial and Technical Abilities
Planning of BIM Execution Process	5	Corporate and Academic Level Collaboration
Corporate and Academic Level Collaboration	6	IPD Type Contracts
IPD Type Contracts	7	Planning of BIM Execution Process
External Grants,Incentives and Promotions	8	Global Standardization

Ozorhon *et al.*, stated the lack of Turkish Government's support to widen the adoption of BIM in the industry by not providing any financial support or publishing road-maps to rise the awareness in the industry. That is why, respondents ranked "External Grants, Incentives and Promotions" as the lowest enabler factor. And, since local protocols and procedures are missing, respondents told that Global Standards helped in their transition process.As a result of this "Global Standardization" ranked greater than literature in the case study results. "Planning of BIM Execution Process" is one of the least mentioned factor in the literature.

5.1.3. Comparison of Inputs

Table 5.3. Comparison of the Inputs' Case Study Results vs Literature Results

General Case Study Results	**Ranking**	**Literature Review Results**
Human Resources	1	Softwares and Hardwares
Training and Education	2	Technological Infrastructure
Softwares and Hardwares	3	Training and Education
Project BIM Execution Plan	4	Human Resources
Internal Knowledge	5	BIM Guideline
Technological Infrastructure	6	Financial Resources
Project Information	7	Internal Knowledge
Financial Resources	8	Project BIM Execution Plan
Company's BIM Policy	9	Company's BIM Policy
Custom 3D Library	10	Custom 3D Library
BIM Guideline	11	Project Information
External Knowledge and Consultancy	12	External Knowledge and Consultancy

Regarding to the comparison Table 5.3 results; "Human Resources", "Training and Education", "Softwares and Hardwares", "Internal Knowledge", "Financial Results", "Company's BIM policy", "External Knowledge and Consultancy" and "Custom 3D Library" results found consistent in the both studies except "Project BIM Execution Plan", "technological infrstructure", "Project Information" and "BIM Guideline".

Respondents' answer showed that Global standards importance level in their implementations. That is why "BIM Guidelines" ranked in the case study as one of the lowest factor means that Guidlines existing is not vital for the respondents. "Project Information" factor has a greater significance level in the respondents' evaluation. Since design methods are enriched to create the accurate model project information is ranked as "Significant" by the respondents."Project BIM Execution Plan" found one of the most significant factor among the respondents. When the companies adoption years of BIM is examined, it is found that the average adoption year is around 2014. And since more than 60% of the cases implemented after 2015 mostly in 2016, having an execution plan for further projects found significant by the respondents. On the other hand, "Technological Infrastructure" found less significant when it is compared with the literature findings. This gap can be explained by other nations' having closer bonds to technological developments so that this factor is found significant globally. Respondents indicated that they are not really interested in the technological developments such as the methods to design with point clouds, or rising the visualization of the model with VR and AR since Revit allows walkthroughs in the model.

5.1.4. Comparison of Barriers

As seen in the comparison Table 5.4 above "Lack of Government Support", "Project Specific Problems" , "Change Process Problems","Legal Protocol Problems" and "Lack of Best Practices" showed consistency in both lists. However, the remaining factors; "Fragmented Nature of the Industry", "Interoperability Problems of Different Parties", "Unclear Benefits", "Technology Related Problems" and "High Costs" are different in the studies.

Regarding to the respondents results, "Fragmented nature of the Industry" is the most crucial problem in the BIM implementation process since producing right BIM models could not be provided neither internally nor from 3rd parties because of the lack of knowledge or experience. That is why the involvement of multiple parties is considered as the main barrier among the respondents.

Table 5.4. Comparison of the Barriers' Case Study Results vs Literature Results

General Case Study Results	**Ranking**	**Literature Review Results**
Fragmented Nature of the Industry	1	Change Process Problems
Interoperability Problems of Different Parties	2	Technology Related Problems
Unavailability of Knowledge Based on Experience	3	High Costs
Change Process Problems	4	Unavailability of Knowledge Based on Experience
Project Specific Problems	5	Project Specific Problems
Unclear Benefits	6	Legal and Protocol Problems
Legal and Protocol Problems	7	Lack of Best Practices
Lack of Best Practices	8	Interoperability Problems of Different Parties
Technology Related Problems	9	Fragmented Nature of the Industry
High Costs	10	Unclear Benefits
Lack of Government Support	11	Lack of Government Support

Also, "Interoperability Problems with the Different Parties" is the second barrier among the other factors. In Turkey, interoperability problems are crucial because most of the AEC companies are working as local design groups with foreign design and consultancy firms so that different parties and different softwares can rise interoperability problems to communicate over a single model.

“Unclear benefits” factor was found as insignificant already but when it is compared with the literature results, it is noticed that there is a potential of being important for some cases since it had a min-max range of 1 to 5 in the evaluation. Respondents comment this factor crucial in their first implementation because their main focus was making this digital transition possible and learning how they can benefit by BIM process.

“Technology related Problems” stands for the licensing, data interoperability and reliability of the model ranked low by the respondents however in the literature by Kassem *et al.*, Arayıcı *et al.*, Chien *et al.*, etc. found data interoperability as crucial since in large scale projects multiple companies worked in the creation of the single BIM model had problems related softwares.

On the contrary of the general barriers, high costs have not seen as a barrier because respondents told that they were believing the industry will transit to BIM eventually, so that they did not cut the expenses regarding to implement BIM process in the company. But in the literature this factor was emphasized a lot. However since these cases are done by the companies investing to rise their skills in BIM, high cost did have an influence on the companies.

5.1.5. Comparison of Benefits

Regarding to the comparison Table 5.5, the enourmous different between the literature and case studies is occured in the “Client Satisfaction” factor. Regarding to respondents’ feedbacks, they indicated that they received positive returns by the contractors and the owner related to the designed 3D BIM models. That is why, they pay attention to receiving feedbacks in a way to evaluate their success. However, in the literature the frequency of the “Client Satisfaction” factor was really low.

Table 5.5. Comparison of the Benefits' Case Study Results vs Literature Results

General Case Study Results	**Ranking**	**Literature Review Results**
Right and Accurate Construction Activities	1	Right and Accurate Construction Activities
Improve Staff Performance	2	Right and Accurate Technical Office Works
Right and Accurate Technical Office Works	3	Project Financial Benefits
Knowledge Management Benefits	4	Improve Communication and Collaboration
Claim Management Benefits	5	Knowledge Management Benefits
Client Satisfaction	6	Improve Staff Performance
Project Financial Benefits	7	Claim Management Benefits
Improve Communication and Collaboraton	8	Reduction of Facility Management Cost
Reduction of Facility Management Cost	9	Improve Energy Savings
Improve Energy Savings	10	Client Satisfaction

"Improving Stuff Performance" is significantly ranked higher when it is compared with the literature review. Respondents keen on rising the awareness of BIM and want employee to understand the project by designing through BIM. When the adoption and application years are taken into account it can be said that most of the employees in the companies are in the learning phase. That is why increasing the capabilities in BIM process is important in the market. On the same hand, " Project Financial Benefits" factor is accepted by the respondents but since the priority is on rising the abilities and practice through BIM projects monetary benefits are thrown into the background.

However, respondents said that at some level after investing for the transition of BIM they would like to observe effective financial benefits.In the literature also financial benefits were associated within the cost reductions in the operational and maintenance phase of the building's life cycle. And, since most of the companies have not achieved 7D BIM level application, they are not putting their attention on financial gains yet. That is why it is ranked low in the case studies.

"Improving Communication and Collaboration" stands for the reduction of RFIs becasue of the effective communication environment of BIM. But, this is not the case all the time since it is depended to the project's complex level. However, respondents claimed that was not the case all the time. On the other hand, the literature findings pursues that the number of meetings are diminishing. Actually, some of the respondents agreed with the literature results but claimed that they are not in the case that implementing perfect BIM processes.

5.1.6. Comparison of Impacts

Table 5.6. Comparison of the Impacts' Case Study Results vs Literature Results

General Case Study Results	**Ranking**	**Literature Review Results**
Generate Corporate Knowledge	1	Company's Productivity Improvement
Enable New Businesses	2	Enable New Businesses
Company's Productivity Improvement	3	Corporate Management Improvement
Corporate Management Improvement	4	Improve Corporate Financial Performance
Expanding Company's Scope of Services	5	Expanding Company's Scope of Services
Improve Corporate Financial Performance	6	Generate Corporate Knowledge

Regarding to the comparison Table 5.6, as indicated by the respondent that they are in the learning phase, “Generating Corporate Knowledge” is the critical impact on the contrary of the literature finding. That is why respondents believe in there is still time for the “Improving Corporate Financial Performance” factor.

5.2. Comparison CSFs Based on Project Type

Distribution of the cases’ project types, 25 in total, showed in figure 4.12 can be divided in to 5 main project types; airport, metro, plant, commercial and other. Other projects covers the hospitals, mall, metro station and museum design projects. In this part, regarding to project types, respondents results are evaluated to check the consistency of the general case results and identifiy the CSFs for the specific type of the projects.

Summary Table of the factors’ comparison results and their average values for each project type are shown in Tables 5.7, 5.8 and 5.9 below. Each project types evaluation also criticized in details in the proper subsections.

Table 5.7. Comparison Based on Project Characteristics (1/3)

No		GENERAL CASE STUDY RESULTS	AIRPORT PROJECTS	COMMERCIAL PROJECTS	METRO PROJECTS	PLANT PROJECTS	OTHER PROJECTS	GROUP 1: 4D and 5D	GROUP 2: 6D and 7D	BEFORE 2014	AFTER 2014
No	DRIVERS										
1	Improving Collaboration and Coordination	4.64	4.75	4.60	4.50	5.00	5.00	4.43	4.91	4.89	4.50
2	Improving Corporate Performance	4.48	4.25	4.20	4.75	5.00	5.00	4.86	4.27	4.56	4.63
3	Improving Project Performance	4.60	4.50	4.60	4.25	5.00	5.00	4.57	4.36	4.33	4.56
4	Design Improvement	4.44	4.50	4.80	4.50	4.50	5.00	4.00	5.00	4.67	4.31
5	Client Requirement	4.00	3.50	3.60	5.00	3.00	5.00	4.07	3.91	3.33	4.38
6	Improving Construction Productivity	3.80	4.35	3.67	2.00	4.75	4.00	3.80	3.80	4.43	3.25
7	Reducing Life Cycle Cost of The Building	3.04	4.00	3.40	2.50	3.50	3.33	2.86	3.27	3.11	3.00
8	Improving Building's Energy Performance	2.80	4.25	3.40	1.25	2.75	5.00	1.93	3.91	2.11	3.19
9	Improving HSE Activities	1.56	2.33	1.00	1.00	3.75	4.00	2.20	2.20	2.14	2.25
10	Governmental Push	2.20	2.50	1.00	2.00	1.00	2.33	1.43	1.73	1.00	1.88
No	ENABLERS										
1	Supportive Organizational Culture	4.56	4.25	4.20	4.75	4.75	5.00	4.43	4.73	4.56	4.56
2	Project Level Collaboration	4.52	4.50	4.80	4.50	4.25	5.00	4.36	4.73	4.44	4.56
3	Managerial and Technical Abilities	4.32	3.75	4.60	4.75	4.50	5.00	4.43	4.18	4.11	4.44
4	Global Standardisation	4.00	3.50	4.20	4.50	5.00	5.00	4.14	4.00	3.56	4.38
5	Planning of BIM Execution Process	3.92	5.00	4.60	4.25	4.75	5.00	3.62	4.27	3.22	4.33
6	Corporate and Academic Level Collaboration	2.64	3.75	2.80	3.50	2.75	2.33	2.57	2.73	1.89	3.06
7	IPD Type Contracts	2.43	3.00	2.25	3.33	3.50	2.33	2.82	2.00	1.88	2.77
8	External Grants, Incentives and Promotions	2.08	2.00	2.60	3.00	1.75	2.33	2.21	1.91	1.00	2.69

Table 5.8. Comparison Based on Project Characteristics (2/3)

		GENERAL CASE STUDY RESULTS	AIRPORT PROJECTS	COMMERCIAL PROJECTS	METRO PROJECTS	PLANT PROJECTS	OTHER PROJECTS	GROUP 1: 4D and 5D	GROUP 2: 6D and 7D	BEFORE 2014	AFTER 2014
No	INPUTS										
1	Human Resources	4.60	4.50	4.60	5.00	4.50	4.33	4.71	4.45	4.78	4.50
2	Training and Education	4.48	4.50	4.80	3.50	4.75	5.00	4.14	4.91	4.78	4.31
3	Softwares and Hardwares	4.36	4.00	4.20	4.75	4.50	5.00	4.43	4.27	4.33	4.38
4	Project BIM Execution Plan	4.04	4.25	4.60	4.50	4.75	5.00	3.79	4.36	3.56	4.31
5	Internal Knowledge	3.96	4.50	4.40	3.25	4.50	5.00	3.79	4.18	3.67	4.13
6	Technological Infrastructure	3.92	4.50	4.40	4.50	4.00	4.33	3.86	4.00	3.67	4.06
7	Project Information	3.91	4.00	4.50	2.50	4.75	5.00	3.91	3.91	3.67	4.08
8	Financial Resources	3.88	4.00	4.00	5.00	4.25	4.33	4.00	3.70	3.67	4.00
9	Company's BIM Policy	3.68	4.50	4.60	3.75	4.75	3.67	3.64	3.73	3.33	3.88
10	Custom 3D Library	3.36	3.25	3.40	3.25	4.00	5.00	3.21	3.55	3.11	3.50
11	BIM Guideline	3.20	2.00	3.60	3.75	4.75	5.00	3.36	3.00	2.56	3.56
12	External Knowledge and Consultancy	3.12	3.25	3.60	4.50	2.00	2.33	3.00	3.27	3.00	3.19
No	BARRIERS										
1	Fragmented Nature of the Industry	3.25	3.67	4.33	3.00	2.50	1.00	3.00	3.67	3.50	3.00
2	Interoperability Problems of Different Parties	3.13	3.33	2.67	2.00	3.75	1.00	3.00	3.33	3.75	2.50
3	Unavailability of Knowledge Based on Experience	3.00	2.25	3.40	3.75	3.00	2.33	3.29	2.64	3.00	3.00
4	Change Process Problems	2.84	2.25	3.40	3.50	3.25	2.33	3.14	2.45	2.67	2.94
5	Project Specific Problems	2.68	2.50	2.00	3.00	5.00	1.67	3.43	1.73	3.00	2.50
6	Unclear Benefits	2.38	2.33	2.60	3.75	2.50	1.00	2.62	2.09	1.89	2.67
7	Legal and Protocol Problems	2.32	1.25	2.20	3.25	3.75	1.00	3.14	1.27	2.89	2.00
8	Lack of Best Practices	2.17	1.00	2.40	2.75	1.75	1.00	2.31	2.00	2.44	2.00
9	Technology Related Problems	2.12	2.25	2.60	2.25	1.75	1.00	2.43	1.73	2.11	2.13
10	High Costs	2.04	1.00	1.80	3.50	2.00	1.00	2.62	1.36	1.67	2.27
11	Lack of Government Support	1.46	1.00	1.40	2.00	1.75	1.67	1.69	1.18	1.00	1.73

Table 5.9. Comparison Based on Project Characteristics (3/3)

		GENERAL CASE STUDY RESULTS	AIRPORT PROJECTS	COMMERCIAL PROJECTS	METRO PROJECTS	PLANT PROJECTS	OTHER PROJECTS	GROUP 1: 4D and 5D	GROUP 2: 6D and 7D	BEFORE 2014	AFTER 2014
No	BENEFITS										
1	Right and Accurate Construction Activities	4.72	4.33	5.00	4.00	4.75	5.00	4.50	5.00	5.00	4.55
2	Improve Staff Performance	4.68	4.50	4.60	5.00	4.75	5.00	4.71	4.64	4.78	4.63
3	Right and Accurate Technical Office Works	4.56	4.25	4.80	4.50	4.75	5.00	4.36	4.82	4.89	4.38
4	Knowledge Management Benefits	4.52	4.75	5.00	5.00	4.75	5.00	4.43	4.64	3.89	4.88
5	Claim Management Benefits	4.43	4.33	4.67	4.00	4.25	5.00	4.20	5.00	4.67	4.25
6	Client Satisfaction	4.20	4.25	4.20	3.75	4.50	5.00	3.93	4.55	4.11	4.25
7	Project Financial Benefits	3.88	4.33	4.40	4.25	3.50	3.67	3.92	3.82	3.44	4.13
8	Improve Communication and Collaboration	3.80	4.50	3.40	3.25	4.50	3.67	3.57	4.09	4.22	3.56
9	Reduction of Facility Management Costs	3.36	4.33	3.50	3.00	2.75	5.00	3.00	4.00	2.83	3.75
10	Improve Energy Savings	2.92	4.25	3.50	1.75	3.00	5.00	2.15	3.82	2.00	3.38
No	IMPACTS										
1	Generate Corporate Knowledge	4.60	4.75	4.40	3.75	4.75	5.00	4.36	4.91	5.00	4.38
2	Enable New Businesses	4.56	4.75	5.00	5.00	4.00	5.00	4.43	4.73	4.00	4.88
3	Company's Productivity Improvement	4.44	4.75	4.80	4.50	4.50	4.33	4.50	4.36	4.22	4.56
4	Corporate Management Improvement	4.32	4.00	4.00	4.50	4.50	5.00	4.50	4.09	4.11	4.44
5	Expanding Company's Scope of Services	4.32	4.50	4.80	4.00	4.25	4.33	4.14	4.55	4.56	4.19
6	Improve Corporate Financial Performance	4.00	4.67	4.20	3.25	3.50	5.00	3.69	4.36	3.67	4.20

5.2.1. CSFs for Airport Projects

In this part, 7 airport projects are investigated to identify the CSFs role on airport projects to observe whether a change occurs when it is compared with the general case study findings. The figüre 5.1 shows the years of the projects taken.

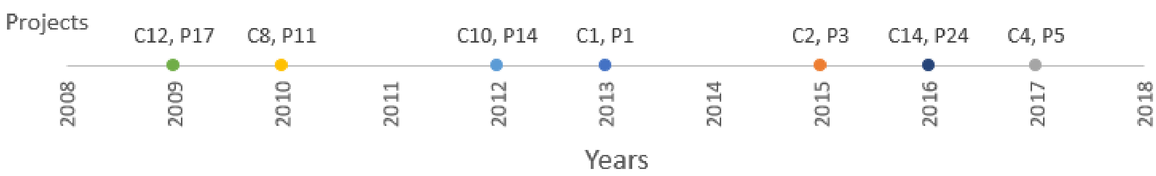

Figure 5.1. Timeline of the Airport Projects' Commencement Years

For the further comparison evaluations with the general case study results, firstly airport project P17 which is also the first BIM project of Turkey seen in the 4.11 implemented by company C12 is eliminated from the evaluation. This eliminated is done because of the lack knowledge and experience at that time may lead a negative deviation in the overall comparison. Moreover, the projects P11 and P14 which their work definition covers only the structural works realized by the companies C8 and C10 are eliminated as well because of ranking most of the factors as insignificant as a 3rd party design company.

Regarding to this approach all the CSFs are evaluated and compared with the case study results.

First of all, notable changes about the driver factors between the general case results and the airport projects are found as; "Reducing Life Cycle Cost of the Building", "Improving Building's Energy Performance" and "Governmental Performance" have greater importance level in the airport projects. In general, Infrastructure projects' owner is the government and scale of the infrastructure projects are generally greater than other projects. Greater scales means greater investment and the greater operational and maintanance cost. Because of this reason sustainability is one of the key factor in the airport projects. Therefore, according to the respondents' evaluations, these three driver factors significance level is risen in airport projects. And parallel to this logic, an increase occured in the benefit factors; " Improving Energy Saving" and "Reduction of Facility Management Costs". For the "Input" factor, "BIM Guideline's" significance level decreased but the "Company's BIM Policy" increased. This shows that "Firm Level" factor has a greater impact rather than an "Industrial Level" factor. This statement is also supported by the observation of an increase in the "Internal Knowledge" factor as well. Also, the enabler "Planning of BIM Execution Process" factor supports this idea. In the airport projects, "Fragmented Nature of the Industry" found the most critical factor. Greater scale of projects requires lots of project parties and in that kind of an environment coordination and collaboration activities most probably be negatively affected.

5.2.2. CSFs for Commercial Projects

General case study results of drivers' factors show similarity with the result of specifically investigated commercial project cases except "Design Improvement" factor. This factor is the leading motivation for the BIM applications in commercial projects."Internal Knowledge", "Project Information", "Company's BIM Policy", "BIM Guideline" and "External Knowledge and Consultancy" factors significance level increases in the commercial projects. Also for the commercial projects, first barrier is the "Fragmented Nature of the Industry" and the second barrier is the "Unavailability of the Knowledge Based on Experience". That is why, "Planning of BIM Execution Process" factor's importance is increased in the commercial projects. And through implementing BIM in commercial projects, it is noticed that the significance level of "Project Financial Benefits", "Right and Accurate Construction Activities", "Right and Accurate Technical Office Works", "Knowledge Management Benefits" and "Claim Management Benefits" factors are positively decomposed from the general case study results.

5.2.3. CSFs for Metro Projects

Among the projects evaluated, there are 5 metro projects. However, since the job description of the project P23 covers only the design of 1 metro station, considering that the proposed metro projects' size will not be suitable for comparison. That is why project P23 will be neglected in this category.

Metro projects' driver comparison stated that, “Client Requirement” and “Governmental Push” factors' significant is increased in the metro projects. Since this type of projects are infrastructure projects, at the end the client is also the government. On the other hand, notable decreases in the following driver factors' significance is observed; “Improving Building's Energy Performance”, “Improving Construction Productivity” and “Improving HSE Activities”. “Financial Resources” and “External Knowledge and Consultancy” input factors' significance levels are increased, while the “Project Information” factor's is decreasing in the metro projects. This can be explained due to the inadequate soil investigations depending on the soil layers characteristics potential revisions on alignment' design hinders the importance level of project information. It is also noticed that according to the respondents' results, a pessimist environment exists for implementing BIM processes in the metro projects because “Unavailablility of Knowledge Based on Experience”, “Unclear Benefits”, “High Costs” and “Legal and Protocol Problems” factors' significance level is higher than the barrier's general case study results. This situation also lead to a fall in the “Claim Management Benefits” “Improve Energy Savings” and “Reduction of Facility Management Costs” factors significance level. Also, decreases in saving factors shows a company level effect which decreases the “Improve Corporate Financial Performance” input factor.

5.2.4. CSFs for Plant Projects

“Client Requirement” factor's significance level is decreased for the plant projects regarding to the comparison with the general case study results. Notable increases in the significance level of “Project Specific Problem” and “Legal and Protocol Problems” factors is observed in the “barriers” comparison. Therefore, respondents put the emphasize on the “Planning of BIM Execution Process” factor and that causes an increase in the significance level. All of the factors of “Benefits” and “Impacts” components showed consistency with the general case study results.

5.2.5. CSFs for Other Projects

Other projects consists of complex projects such as hospitals, metro station, mall and museum projects in this study. When the projects and companies examined it is noticed that the structural company C10 has a hospital project P15 under this category. However since they represents the third party thoughts in general their results can be hindering to understand the project specific scenarios that is why P15 is left out of the evaluation in the further steps.

All of the factors under the “Drivers”, “Inputs” and “Enablers” components showed consistency. Surprisingly, it is noticed that during the “barriers” comparison that all of them significance level is decreased notably. “Reduction of Facility Management Costs” and “Improve Communication and Collaboration” factors’ significance level is greater then the general case results. This leads to an expected increase in the significant level of “Corporate Management Improvement” and “Improve Corporate Financial Performance” in the “impacts”.

5.3. Function-based Comparison of CSFs

According to the respondents’ answers related to the utilization of BIM functions, it is found that each company is already utilized 4D BIM implementations and most of them also implementing 5D BIM Modeling. Also, the utilization rate of the 6D and 7D BIM implementations fluctuates around 30%. Regarding to these findings, two groups are created based on the BIM functions utilization;

- Group 1: Includes the respondents utilized 4D and 5D BIM implementations
- Group 2: Includes the respondents utilized 6D and 7D BIM implementations

Factors in the “Drivers”, “Enablers” and “Impacts” components showed consistency with the general case study results. Comparison of the “Input” factors showed that “Training and Education”, “Internal Knowledge” and “Project BIM Execution Plan” factors’ significance level is greater for the 6D and 7D BIM implementations. However, “Fragmented Nature of the Industry” is higher than the general case study results. In addition to this, “Legal and Protocol Problems” and “Project Specific Problems” factors’ significance level is increased notably for the 4D and 5D BIM implementations. Surprisingly in the “benefits” components, the “Claim Management Benefits” factor’s significance is evaluated greater in the 6D and 7D BIM implementations. Even if the 4D and 5D BIM implementations are related with the project performance activities, 6D and 7D BIM implementations can be useful in the decision of materials purchasing regarding to the sustainability requirements which causes a greater benefits in the operational phase. Moreover, the higher significance of the “Reduction of Facility Management Costs” factor supports why project management is better wih 6D and 7D implementations.

5.4. Comparing CSFs of Similar Time Implementations

In this section projects are classified regarding to their implementation time. This is an important section because through this investigation CSFs’ alterations in BIM implementations depending on time interval could be observed. Division of similar time implementations are distinguished into two groups as; projects implemented before 2014 and after 2014.

According to this approach, “drivers” comparison showed that “Improving Building’s Energy Performance”, “Client Requirement” and “Governmental Push” factors significance is flowering. This shows that the awareness of BIM is developed in the industries.As a result, in the “inputs” comparison it is found that values of the “Financial Resources”, “Technological Infrstructure”, “Internal Knowledge”, “Project BIM Execution Plan” and “BIM Guideline” factors are increased in the projects implemented after 2014. It is seen that over the time, “Legal and Protocol Problems”, “Fragmented Nature of Industry” and “Interoperability Problems of Different Parties” barrier factors criticality is decreased. This can be clarified by rising significance of “Planning of BIM Execution Process” factor. After 2014, according to the respondents’ rankings important benefit is determined as “Knowledge Management Benefits” that showed the effect on “Enable New Business” factor by increasing its significance level.

6. CONCLUSION

Throughout this study the aim was investigating the BIM implementations in the design phase for Turkish companies. To this end, extensive literature research is done to decide the CSFs for each component of BIM to cover all of its aspects. And then, the case study method is applied with respondents from different companies to evaluate which factors were crucial in their projects. In the evaluations after the discussion chapterö the goal is to conclude the general CSFs for the framework that will be a basis for each type of project. Through the outcomes, it is desired to share key factors to which industry members pay attention in their BIM implementations.

6.1. Conclusion Based on Research Findings

As explained in the methodology, BIM components are investigated thorugh the case studies by Turkish companies to evaluate the significance of the factors. And regarding to gathered information related with the respondents, companies and projects extensive discussions are made in order to conclude the general CSFs for each components of BIM implementation process.

Regarding to this approach; firstly, general results are shared in Chapter 4 representing the general case study results. After that, secondly, the discussion part held to search the CSFs' alteration regarding to the projects type, BIM functions and implementation time. And, finaly based on the comparisons of each alteration, general case study results are compiled.

The major drivers were observed as; "Improving Collaboration and Coordination", "Improving Corporate Performance", "Improving Project Performance" and "Design Improvement" factors.

The major inputs were observed as; “Human Resources”, “Training and Education”, “Softwares and Hardwares”, “Project BIM Execution Plan” and “Technological Infrastructure” factors.

The major enablers were observed as; “Supportive Organizational Culture”, “Project Level Collaboration”, “Managerial and Technical Abilities”, “Global Standardisation” and “Planning of BIM Execution Process” factors.

The major barriers were observed as; “Fragmented Nature of the Industry”, “Interoperability Problems of Different Parties”, “Change Process Problems” and “Project Specific Problems” factors.

The major benefits were observed as; “Improve Staff Performance”, “Claim Management Benefits”, “Knowledge Management Benefits”, “Right and Accurate Technical Office Works”, “Right and Accurate Construction Activities” and “Client Satisfaction” factors.

The major impacts were observed as; “Generate Corporate Knowledge”, “Enable New Businesses”, “Company’s Productivity Improvement”, “Corporate Management Improvement” and “Expanding Company’s Scope of Services” factors.

Final results are shown in the figure 6.1 which highlights the top common factors in the Turkish AEC industries for the BIM implementations in design phase.

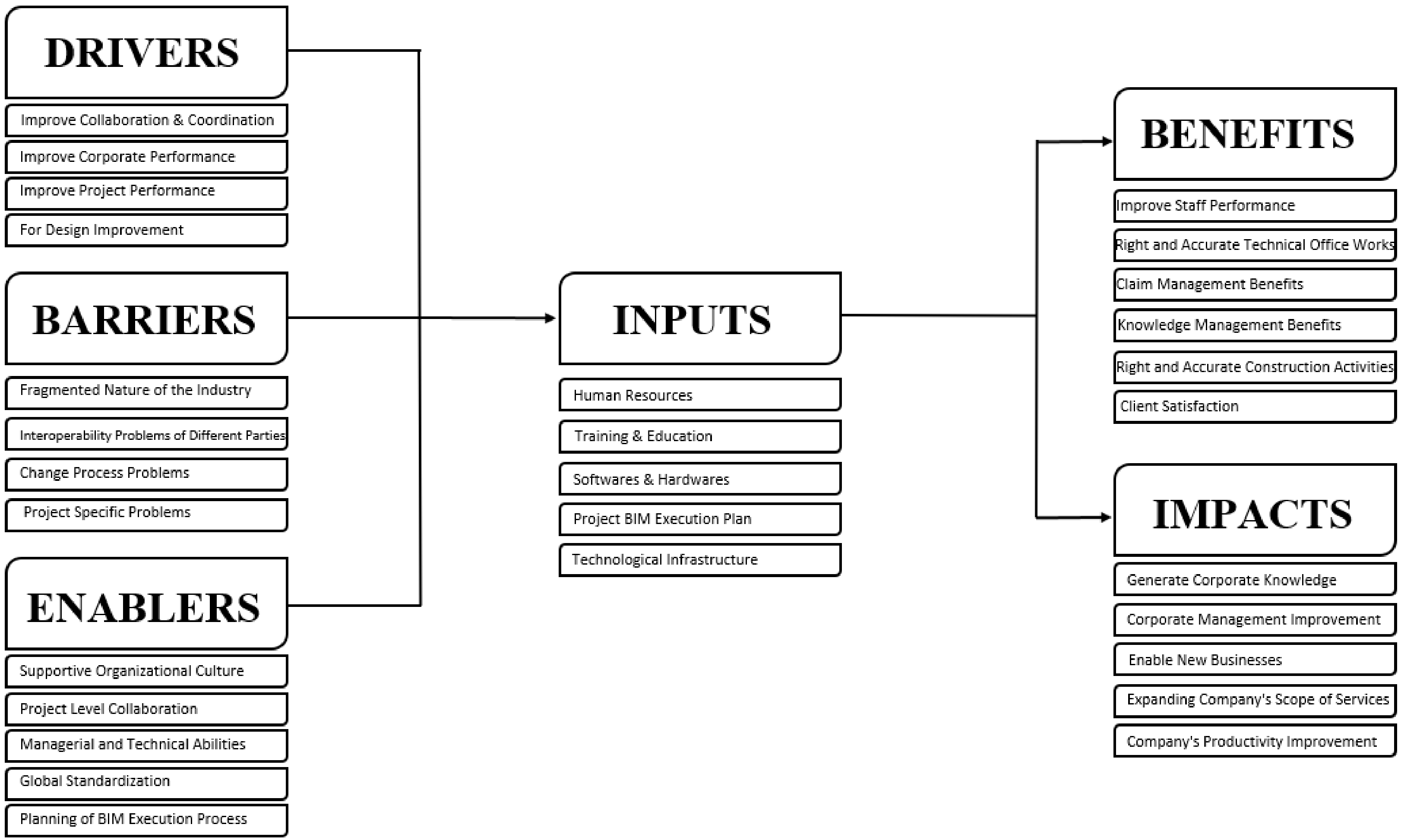

Figure 6.1. Common CSFs for BIM Implementations

6.2. Recommendations

As case studies conducted with different type of companies and expressions collected from different industry members created a great population with diversity. Since these companies were chosen because of implementing BIM in their projects, findings of this research can lead the other industry members for the transition to utilize BIM processes. Factors provided within this study can ease the change process of companies, employees and owners of the projects. These highlighted factors can affect their decision making process in the transition time because new adopters are able to determine where to focus in their BIM applications.

Also, when the influence level of this factors are examined further recommendations can be done in industry level, firm level and project level to support successful BIM implementations in these 3 levels.

6.2.1. Industry Level Recommendations

According to the resultant framework, when the factors under each component is distinguished regarding to their influence level, only three factors are found in the "enablers" and "barriers" components at the industry level.

On the other hand, although one of the factors seems to be good as an "enabler", it should be perceived negatively as it derives from international standards due to the absence of national standards. The fragmented nature of the industry and resistance to change problems of the industry members cover the remaining two factors in the "barriers" component.

When all these factors are considered together, in order to ensure the development of BIM applications at the industry level; primarily, industry members need to be encouraged to overcome their resistance to change by getting inform about BIM across the country. At the same time, strategic national BIM Implementation guidelines or standards have to be prepared in order to increase the permanence of the changes and to see the long-term effects. The guidelines or standards prepared in this way will prevent damages caused by the fragmented nature of the industry. They address how improvements can be made among project parties who have difficulties conducting the project together. The UK illustrates this as a good example becasue Turkish AEC members struggle in technical applications due to lack of experience. Recently, the UK published numerous standards in various BIM topics whilst a first study is yet to be completed in Turkey. Because of this, the BIM practices in Turkey are underdeveloped, and government support is crucial to rectify this.

6.2.2. Firm Level Recommendations

Results show that corporate performance is the most important firm level driver for industry members because it feeds the company's passion not to fall behind the other companies in the industry. For this reason, successful BIM applications at the company level can be realized through;

- determining the after-change work descriptions of the employees before the change, to avoid the problems in a sudden change,
- determining the current capabilities of the employees
- matching the work descriptions and required capabilities to see if any lack of skill exists in the company
- supporting the employees by training and education, and hiring experienced employees as leaders to fill the skill gap
- enforcing the technological requirements and obtaining the necessary softwares and hardwares

When companies meet the requirements of the transition properly, they can take advantage by generating corporate knowledge and improving corporate management, acquiring new business with existing clients or new ones. Moreover, companies' scope of services and their productivity will be affected positively as well.

6.2.3. Project Level Recommendations

According to the resultant framework, it is found that at the project level results put the emphasis on "Collaboration and Coordination" as a driver and an enabler factor. But, results show that the hindering factor besides the project specific problems is the interoperability problems between the different parties at the project level.

As a result of this, companies which would like to realize successful BIM implementations at the project level, should overcome the challenge of interoperability problems among the parties. These interoperability problems may arise because of technical reasons or communication problems among the parties.

That is why it is imperative to have a BIM Execution Plan before starting each project. And, in light of the EIRs project parties should determine how and with which tools they will carry out designing.The design comprises a single model with multiple parties and is produced by humans in a digital environment. Therefore, managers should not forget to invest in their employees as humans are key to the process. Their motivation has a huge potential to affect the efficacy of design activities, staff performance and client satisfaction. That is why, it is necessary to act together as a whole entity, avoid incentive structures with competing interests, and promote project level collaboration.

As discussed in detail based on the different project characteristics, for airport projects energy saving and sustainability related drivers need to be taken into account additionally for successful BIM implementations in design and materials decision. For plant and other projects, safety related parameter is important. That is why, project level manuals and related educations could be provided to employee. In metro projects to overcome the project specific problems, financial factors and getting consultancy have greater effect on achieving the success.

6.3. Future Research

When the BIM applications before and after 2014 are examined in detail, it is seen that most of the factors improved their significance level. That is why each factor indicated in this study keeps their potential to become one of the common CSFs for each type of BIM project in the future.

While the current most preferred BIM functions are 4D and 5D, most of the industry members became aware of the benefits provided by the 6D and 7D BIM implementations since 2014. That is why, topics covering the facility management and energy management are matter to further studies regarding to BIM implementations. Different parameters that may arise in these level of BIM implementations have the potential to reveal weaknesses of so-called successful projects. The concepts related to BIM implementations should not be forgotten especially the Green Building design concept that encourages the sustainable design. As a result, as 6D BIM implementations become widespread, rating criteria could differ for these kinds of implementations as seen in LEED and BREEAM ranking systems.

Moreover, Agile PM could be the new hot topic for designers to spend their time. As they become more integrated with the main contractor party to finalize the construction phase as early as possible, the future rewards could be higher due to being more competitive in the industry , even if a situation where no IPD type contract is implemented.

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APPENDIX A: SAMPLE INTERVIEW FORM

BOĞAZİÇİ UNIVERSITY
INSTITUTE OF GRADUATE STUDIES IN SCIENCE AND ENGINEERING
CIVIL ENGINEERING DEPARTMENT
CONSTRUCTION MANAGEMENT MASTER THESIS QUESTIONNAIRE

Thesis : Investigation of the BIM Implementation Process in the Design Phase: Case of Turkish Companies
Student : Sercan GÜRÜNLÜ
Professor : Assoc. Prof. Beliz ÖZORHON ORAKÇAL

GENERAL INFORMATION (Respondent)

1) Name / Surname / Age :
2) What is your profession? :
3) How many years have you been working in the industry? :
4) What is your position in the company? :

GENERAL INFORMATION (Company)

4) Name of the company :
5) Establishment Year of the Company Globally / In Turkey) :
6) Please, mark the fields of operations of the company : ☐ ENGINEERING ☐ ARCHITECTURE ☐ CONSTRUCTION ☐ CONSULTANT ☐ PROJECT MANAGEMENT
7) Please, mark the company's expertise areas : ☐ BUILDING ☐ ENVIRONMENT ☐ SOFTWARE ☐ TRANSPORTATION ☐ INFRASTRUCTURE ☐ WATER ☐ ENERGY
8) What is the recent annual turnover of the company (in M$) : ☐ 0-2 ☐ 2-10 ☐ 10-50 ☐ 50-250 ☐ 250-1000 ☐ +1000
9) How many employees are hired in the company? : ☐ 0-50 ☐ 51-100 ☐ 100-250 ☐ 250-500 ☐ 500-1000 ☐ 1000-5000 ☐ 5000-10000 ☐ +10000
10) How many countries does your company operates? : ☐ 1 ☐ 2-5 ☐ 6-20 ☐ +20
11) What is the total number of the projects that your company involved in Turkey? :
12) When did your company adopt BIM? :
13) Which project did you choose for benchmarking first?
14) Which functions of BIM are you using in the company?
15) What is the number of finalized projects of your company by utilizing BIM (in general/in Turkey) :

GENERAL INFORMATION (Project)

16) Name of the Project :
17) What was the type of the project : ☐ Residential/Commercial ☐ Hospital ☐ Metro ☐ Airport ☐ Bridge ☐ Road ☐ Others:
18) What was the project's ownership status? : ☐ Sole ☐ Joint Venture ☐ Consortium ☐ Other:
19) What was your company's role in the project? :
20) What was the total construction area of the project (in m2)? :
21) What was the contract type of the project? : ☐ IPD Type ☐ Lump Sum ☐ Unit Price ☐ Cost + Fix fee ☐ Others: ☐ Cost + % of Cost ☐ Turnkey ☐ BOT ☐ G. Maximum Price
22) Please, mark the specific softwares / tools that you had used for the project :

Design
- Architectural: ☐ Revit ☐ 3D Studio Max ☐ Dynamo ☐ ArchiCAD ☐ V-Ray ☐ CorelCAD ☐ Bentley ☐ Naviswork ☐ Others:
- Engineering: ☐ SAP2000 ☐ ETAPS ☐ AutoCAD ☐ GIS ☐ Plaxis ☐ Geodin ☐ Micro Station ☐ Tekla BIMsight ☐ Others:
- Managerial: ☐ BIM360 Glue ☐ Naviswork ☐ Synchro ☐ Maximo ☐ Prolog ☐ ARCHIBUS ☐ Primavera ☐ Eco domus ☐ Aconex ☐ Others:
- Document Control: ☐ BIM360 Docs ☐ BIM Track ☐ Others:

23) What was the contractural budget of the project?
24) What was the total amount of cost saving in the project? :
25) How long was the project duration? :
26) What was the total time saving in the project? :
27) How much did your company invest for the project to utilize BIM (in % of the contract value)? :
28) How many employees were in the company's BIM team? :

Figure A.1. Case Study Interview Form (1/2)

29) DRIVERS - Please indicate the importance level of the relevant critical success factor in your project (1 Lowest - 5 Highest)

	Description	1	2	3	4	5
To Improve Corporate Performance	Company image, competitiveness, gain experience					
To Improve Project Performance	Efficiency, quality, speed, cost, risk reduction					
To Improve Building's Energy Performance	Sustainability, LEED, lean implementation					
To Improve Collaboration & Coordination	IPD, collaboration, coordination,					
Client Requirement	Contractual obligation					
Governmental Push	Law enforcement					
For Design Improvement	Clash detection, visualization, simple revision process					
To Improve Construction Productivity	Site logistics, optimized schedules, prefabrication					
To Improve HSE Activities	Safety measurements					
To Reduce Life Cycle Cost of The Building	Maintenance & usage costs					

30) INPUTS - Please indicate the importance level of the relevant critical success factor in your project (1 Lowest - 5 Highest)

	Description	1	2	3	4	5
Human Resources	Qualified staff & leader					
Financial Resources	Investment					
Technological Infrastructure	Technological developments enhancing the scope of BIM					
Softwares & Hardwares	Modeling & managing programs, computers					
Custom 3D Library	Open family libraries					
Internal Knowledge	Company know-how					
External Knowledge & Consultancy	Outsource know-how, consultancy					
Project Information	Drawings, specifications, project data					
Project BIM Execution Plan	BIM implementation roadway					
Company's BIM Policy	BIM implementation approach					
BIM Guideline	BIM implementation rules					
Training & Education	Internal & external staff trainings					

31) BARRIERS - Please indicate the importance level of the relevant critical success factor in your project (1 Lowest - 5 Highest)

	Description	1	2	3	4	5
Availability of Knowledge Based on Experience	Lack of experience, awareness					
Unclear Benefits	Lack of tangible benefits					
Lack of Best Practices	Lack of cases, benchmarks, universal use					
High Costs	Time, HR, software & hardware investment					
Technology Related Problems	Licensing, data interoperability, reliability					
Change Process Problems	Resistance to change, company culture, fear of failure					
Legal & Protocol Problems	Lack of legal protocols, ownership, responsibilities					
Fragmented Nature of the Industry	Number of parties getting involved to the process					
Interoperability Problems of Different Parties	Low collaboration, interoperability					
Project Specific Problems	Delivery method, contract type, unique requirements					
Lack of Government Support	Lack of incentives, initiatives					

32) ENABLERS - Please indicate the importance level of the relevant critical success factor in your project (1 Lowest - 5 Highest)

	Description	1	2	3	4	5
Corporate & Academic Level Collaboration	Academic partnership, research teams					
Project Level Collaboration	Communication, involvement of parties					
Managerial and Technical Abilities	Experience level, right decisions					
Supportive Organizational Culture	Commitment, internal support					
External Grants, Incentives & Promotions	Industry level commitment, governmental support					
Global Standardization	Common standards, protocols					
IPD Type Contracts	Integrated delivery system					
Planning of BIM Execution Process	Making an implementation plan					

33) BENEFITS - Please indicate the importance level of the relevant critical success factor in your project (1 Lowest - 5 Highest)

	Description	1	2	3	4	5
Project Financial Benefits	Cost and time reduction					
Right and Accurate Construction Activities	Less rework, better site planning, reduce risk, high quality					
Right and Accurate Technical Office Works	Minimize errors, better estimates, clear results					
Improve Staff Performance	Staff understandig and awareness of the project					
Knowledge Management Benefits	Better documentation, easy tracking					
Project Management Benefits	Reduce RFIs, claims, change orders					
Reduction of Facility Management Costs	Reduced maintenance & usage costs					
Client Satisfaction	Happy client					
Improve Communication & Collaboration	Low number of meetings, effective communication					
Improve Energy Savings	Better energy analysis					

34) IMPACTS - Please indicate the importance level of the relevant critical success factor in your project (1 Lowest - 5 Highest)

	Description	1	2	3	4	5
Company's Productivity Improvement	Improved business value					
Corporate Management Improvement	Better administration, marketing, organizational structure					
Expanding Company's Scope of Services	New services					
Enable New Businesses	Competitiveness, reference projects					
Improve Corporate Financial Performance	Increased ROI					
Generate Corporate Knowledge	Archive of knowledge and information					

Figure A.2. Case Study Interview Form (2/2)