ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

AN INVESTIGATION INTO THE BUILDING INFORMATION MODELING APPLICATIONS IN THE CONSTRUCTION PROJECT MANAGEMENT

MSc THESIS

İmge KIVIRCIK

Department of Architecture

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

İNŞAAT PROJE YÖNETİMİ AŞAMALARINDA YAPI BİLGİ MODELLEMESİ KULLANIMI ÜZERİNE BİR İNCELEME

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İmge KIVIRCIK, a **MSc** student of ITU, **Institute of Graduate School of Science Engineering and Technology** student ID **502141411**, successfully defended the thesis entitled "**AN INVESTIGATION INTO THE BUILDING INFORMATION MODELING APPLICATIONS IN THE CONSTRUCTION PROJECT MANAGEMENT**", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signature are below.

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FOREWORD

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ABBREVIATIONS

AIA: American Institute of Architects

AIM: Asset Information Modeling

BEP: BIM Execution Plan

BIM: Building Information Modeling

BREEAM: Building Research Establishment Environmental Assessment Methodology

CAD: Computer Aided Design

CIC: Construction Industry Council

EIR: Employer's Information Requirements

ENR: Engineering News Record

FM: Facility Management

ICT: Information and Communication Technology

IFC: Industry Foundation Classes

IT: Information Technologies

LEED: Leadership in Energy and Environmental Design

LOD: Level of Detail

MIDP: Master Information Delivery Plan

PIM: Project Information Modeling

PIP: Project Implementation Plan

PMI: Project Management Institute

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AN INVESTIGATION INTO THE BUILDING INFORMATION MODELING APPLICATIONS IN THE CONSTRUCTION PROJECT MANAGEMENT

SUMMARY

Building Information Modeling (BIM) technology is an innovative construction technology which aims to improve design, construction and operation phases by creating a digital information model. This parametric and 3D object based model support collaborative working of different disciplines, thereby communication and coordination increases between the project stakeholders. In literature, BIM usage is classified as 3D BIM to 7D BIM according to their implementation scope. For 3D BIM, project models are designed as 3D models, and this model enables to working of different designers simultaneously on the project. Through 3D modeling clashes can be detected and corrected in the design phase, and 3D model provides to present visually more understandable project to the customer. Software should be used e.g. Navisworks Manages, in Industry Foundation Classes (IFC) file format that can transfer the information from the 3D model to implement 4D and 5D BIM. In 4D BIM time information is added to the model. Work schedule is created and visualized on the model, thereby workflow can be checked during the construction phase. Similarly, in 5D BIM cost information is added to the model. Bill of quantities has more consistent results with the calculation from 3D model, and project total cost and progress payments can be checked during the construction. In 6D BIM implementation project is aimed to build with sustainability criteria. Through 6D BIM technology building's energy consumption is monitored more accurately, and project is designed in a way that to minimize the energy consumption. In 7D BIM, updated "as-built" project which contains all the specifications, warranty and maintenance and operation information is delivered to the client. The BIM model of the project helps to optimize and monitor the cost analysis and energy consumption of the project throughout the project lifecycle. According to these implementations, BIM technology facilitates construction project management areas, and it improves the project management success.

Building modeling concept based on to 1970's, and in 1987 ArchiCAD launched a CAD software that can create 2D and 3D graphic designs. BIM concept has become a widely used term in construction industry in the last decade. Thus, the software companies as; Autodesk, Bentley, Allplan and Graphisoft have began to launch software that can enable to produce digital information model of the project. BIM technology aims to create a database that stores all the information about the building, and also aims to be used this information actively throughout the lifecycle of the building. Therefore, design software that can produce 3D model of the project such as; Revit, ArchiCAD, MicroStation and Allplan, and Industry Foundation Classes (IFC) file format software that are capable of receiving data from design

program and can work coordinately with them such as; Navisworks Manage should be used to achieve successful implementation of BIM.

This study concentrates on how to use BIM technology effectively on all phases of construction project management, the contribution of BIM technology to project management areas, and the reasons for using BIM technology is not spread enough in Turkish construction sector. In this study, firstly the research purposes and objectives are explained, and the international literature review study is presented. Particularly, the articles that focus on the relationship between the project management and BIM technology are analyzed. Following chapters indicate the research methods and objectives, and the research results. This research results created by survey results and the interviews made with 18 BIM experts from the medium large scale Turkish construction companies. According to research findings, the contribution of BIM technology to the project management and connection between them are revealed, and the implementation methods in the Turkish construction industry is evaluated by the author. In addition, the proposals have been developed for the widespread use of BIM in Turkish construction industry.

BIM implementations have increased during the last 10 years especially in the American and European construction industries with the rapidly developing technology. The United States and the United Kingdom have the leadership in BIM development. The main reason for this situation, the countries required the BIM applications in the contracts of government projects after a certain date. Furthermore, particularly Germany, France, the majority of the Nordic countries, Singapore and Australia have accelerated the BIM adaptation process by investing in IT and establishing strategic organizations.

The research results have been prepared based on the responses of BIM users who are participated to the interviews and survey study. According to the research findings, the main advantages of BIM usage are working on 3D model together with the different disciplines, strengthening the coordination between the project stakeholders, eliminating of project errors in design phase which results in cost and time benefit, and creating a building information database that helps the facility management process. The company may face with some potential difficulties while adapting BIM technologies such as; lack of educated employee about 3D design and BIM implementations, employee resistance, subcontractor adaptation problems, and the documentation process that BIM requires etc.. To overcome these difficulties and accomplish BIM adaptation process companies should make some organizational and administrative changes. The beneficial changes can be summarized as; hiring new and BIM experienced employees, establishing a BIM team within the company, investing in BIM technologies and providing training for employees to improve BIM consciousness.

The research results show that technological developments and global tendency has raised an awareness toward BIM in Turkish construction industry. Main reasons for implementing BIM technology are employer demand, involvement of BIM criteria in the contract and gaining global competitiveness in the construction industry. The incentive factors for widespread using of BIM technology are being necessity of BIM implementation in government tenders, increasing education about BIM in academic institutions, promoted using of 3D CAD programs and increasing conference and panel about the BIM implementation in the construction sector.

In conclusion, BIM technology greatly supports the project management knowledge areas, and it affects the project cost, time, quality and communication performance in a positive way. In current situation, BIM applications are carried out as producing 3D model of the project and work schedule in Turkish construction industry. Although the construction sector in Turkey following BIM movement a few year behind of the world, companies are increasing the scope of investment and BIM applications accordance with the growing interest and demand in the sector.

İNŞAAT PROJE YÖNETİMİ AŞAMALARINDA YAPI BİLGİ MODELLEMESİ TEKNOLOJİSİ KULLANIMI ÜZERİNE BİR İNCELEME

ÖZET

Yapı Bilgi Modellemesi (YBM), parametrik ve nesne tabanlı modeller kullanarak bir yapının yaşam döngüsü boyunca; projelendirme, inşaat ve işletim süreçlerini geliştirmeyi hedefleyen, dijital bir bilgi paylaşım ortamı yaratan ve bu bilgi paylaşım ortamıyla proje paydaşlarının iletişim ve koordinasyonunu artırmayı hedefleyen inşaat sektöründe yenilikçi bir teknolojidir. Literatürde YBM kullanımları 3 boyutlu YBM'den 7 boyutlu YBM'ye kadar sınıflandırılmıştır. Bu sınıflandırma özetle boyut artırımına paralel olarak gelişen YBM uygulama kapsamını temsil etmektedir. 3B YBM kullanımında proje çizimleri 3 boyutlu model olarak tasarlanmakta ve bu model diğer proje paydaşlarının üzerinde eşzamanlı olarak ortak çalışmasına imkan sunmaktadır. 3B modelleme sayesinde; projenin 3 boyutlu simülasyonu oluşturulur, detaylı çakışma kontrolleri tasarım aşamasında kontrol edilir ve müşteriye görsel olarak daha anlaşılır bir proje sunulması sağlanır. 4B & 5B BIM; 3B model bilgileriyle entegre çalışabilen yazılımlar (Navisworks Manage gibi) ile uygulanır. 4B YBM uygulamasında modele zaman bilgileri eklenir. Model üzerinde yapılacak işlerin sırası ve süreleri tanımlanır. İş akışına bağlı iş programı oluşturulur ve bu iş programı model üzerindeki ilerlemeye bağlı olarak görselleştirilir; inşaat süresince kontrol edilir. Benzer şekilde 5B YBM uygulamasında modele maliyet bilgileri eklenir. Model oluşturulurken kullanılan tüm malzeme ve miktarlar kayıtlı tutulur. Keşif metraj hesapları 3B model üzerinden hesaplandığı için daha tutarlı sonuçlar verir. Böylece projenin toplam maliyeti ve ilerleme aşamalarına bağlı harcama tutarları inşaat süresince kontrol edilir. 6B YBM uygulamasında ise inşa edilen yapının sürdürülebilirlik kriterlerine uygun bir yapı olması hedeflenir. 6B YBM teknolojisi sayesinde binanın enerji sarfiyatı daha doğru şekilde hesaplanır. Tasarım aşamasında bu giderler öngörülebildiğinden, yapı tasarımı enerji sarfiyatını minimize edecek şekilde uygulanır. 6B YBM teknolojisiyle hazırlanan proje modelleri LEED ve BREEAM gibi enerji başarı sertifikalarını edinmek için yararlı bir araç olabilir. 7B BIM uygulaması tesis yönetimi olarak tanımlanır. 7B YBM uygulamasında, müşteriye inşaat süresi boyunca güncellenmiş olan 'as-built' proje teslim edilir. Bu proje kapsamında projenin tüm teknik şartnameleri, projeye ait garanti bilgileri, bakım-onarım için gerekli bilgiler bulunur. Binanın YBM modeli, işletim süresi boyunca binanın enerji sarfiyatını izlemeye, maliyet hesabının yapılmasına ve optimize edilmesine yardım eder. Böylece 7B YBM sayesinde tasarım aşamasından itibaren tüm proje bilgilerinin düzenli bir şekilde tasnif edilmiş olması, proje yaşam döngüsünün büyük bir kısmını oluşturan işletim süresi boyunca bina ihtiyaçlarını gidermeyi kolaylaştırır. Bu açılardan incelendiğinde YBM standartları bir inşaat projesine tamamıyla adapte edilebilirse proje yönetim alanlarının tümüne yarar sağlar. 3B, 4B, 5B, 6B, 7B şeklinde kategorize edilmiş olan YBM teknolojisi uygulamaları projenin maliyet, zaman, kalite, iletişim gibi kriterlerine olumlu etkide bulunarak proje yönetimi başarısını artırır.

Bina modellemesi 1970'lere dayanan bir kavram olsa da 1987 yılında ArchiCAD tarafından üretilen CAD programı 2 boyutlu ve 3 boyutlu grafik tasarımları üretmesiyle proje görselleştirmesi konusunda bir standart yarattı. Uluslararası platformlarda "BIM" adıyla bilinen YBM teknolojisi yaklaşık son 10 yıldır inşaat sektöründe yaygın kullanılan bir kavram haline geldi. Autodesk, Bentley, Graphisoft, Allplan gibi yazılım üreticileri binanın dijital bilgi modellemesini üretebilecek yazılımlar üretmeye başladılar. YBM teknolojisi binanın yalnızca 3 boyutlu modelini üretmeyi değil; bina ile ilgili tüm bilgilerin saklandığı bir veritabanı oluşturularak, projenin yaşam döngüsü boyunca bu bilgilerin aktif şekilde kullanılabilmesini hedeflemektedir. Bu hedefle, YBM teknolojisinin başarılı şekilde uygulanabilmesi için 3 boyutlu model üretebilen tasarım programları (Revit, ArchiCAD, Allplan, MicroStation gibi) ve bu tasarım programlarından veri alabilen ve onlarla koordineli çalışabilen, iş programı ve maliyet bilgisinin eklenebildiği "Industry Foundation Classes" (IFC) dosya formatındaki yazılımlar (Naviswork Manage gibi) kullanılmalıdır.

Tez çalışması kapsamında, proje yönetiminin bütün aşamalarında YBM teknolojisinin nasıl etkin bir şekilde kullanılabileceği, YBM kullanımının proje yönetimi alanlarına katkısı ve Türk inşaat sektöründe YBM kullanımının yaygınlaşmamış olmasının nedenleri incelenmiştir. Bu çalışmada, öncelikle araştırmanın konusu, amacı ve hedefleri açıklanmakta; konu ile ilgili çalışmalar ışığında uluslararası kaynak taraması sunulmaktadır. Özellikle YBM ve proje yönetimi ilişkisi üzerinde yoğunlaşan makaleler incelenmektedir. İlerleyen bölümlerde araştırma yöntemi ve hedefleri belirtilerek, araştırmanın sonuçları sunulmaktadır. Bu araştırma sonuçları, Türkiye'deki orta ve büyük ölçekli 18 inşaat firmasındaki YBM ile ilgili etkin kişiler tarafından cevaplanan anket ve mülakat sorularının cevapları doğrultusunda oluşturulmuştur. Araştırma bulguları sonucunda YBM teknolojisinin proje yönetimine katkıları, aralarındaki bağlantılar ortaya konulmuş, Türk inşaat sektöründeki uygulama yöntemleri yazar tarafından analiz edilerek değerlendirilmiştir. Ayrıca, Türkiye'de YBM kullanımının yaygınlaşması için öneriler geliştirilmiştir.

YBM teknolojisinin Dünya üzerindeki örnekleri incelendiğinde; son 10 yıl içerisinde hızla gelişen teknolojiyle birlikte Amerika ve Avrupa inşaat sektörlerinde YBM uygulamaları yoğunlaşmıştır. Özellikle İngiltere ve Amerika'nın YBM kullanımında lider konumda olduğu tespit edilmiştir. Bu durumun başlıca sebebi; ülkelerin belirli bir tarihten sonra ihale edilen tüm devlet projelerinde YBM uygulamasını zorunlu kılmalarıdır. Ayrıca Almanya, Fransa ve Kuzey Avrupa ülkelerinin büyük çoğunluğu, Singapur ve Avustralya YBM uygulamalarını arttırmak için altyapı hazırlıkları, bilişim teknolojilerine ve araştırmalara yatırım yapma, stratejik organizasyonlar kurarak YBM teknolojisini yaygınlaştırma gibi yöntemlerle adaptasyon sürecini hızlandırmışlardır.

YBM kullanımının başlıca avantajları; 3 boyutlu model üzerinde çalışılması, aynı model üzerinde tüm disiplinlerin tasarım yapabilmesi, proje paydaşları arası işbirliğini güçlendirmesi, proje hatalarının büyük oranda giderilmesi, proje hatalarının giderilmesi sonucu maliyet ve zaman kazancı sağlanması, böylece proje yönetimi performansını artırması, yapının işletim aşamasında kullanımında "tesis yönetimini" kolaylaştıracak yapı bilgi portföyünün/veritabanının oluşmasını sağlaması ve model üzerinden enerji sarfiyatının izlenebilmesi sayesinde sürdürülebilirlik kavramını desteklemesi olarak özetlenebilir. Kıyaslama yapılacak olursa, 2 boyutlu CAD yazılımlarında oluşturulan proje tasarımları paydaşlar

arasındaki tasarım farklılıklarından dolayı birçok kez revizyon gerektirmekte; ve yine de tasarım aşamasında belirlenemeyen projedeki çakışmalar uygulama aşamasında birçok hatalı imalata, ek bekleme sürelerine ve maliyete sebep olmaktadır. YBM sistemiyle gelen ortak veritabanı oluşturma kültürü proje paydaşları arasındaki iletişimi ve işbirliğini güçlendirerek; ortak hedeflere daha kısa sürede ulaşılmasını sağlar.

YBM sistemine geçiş yapan şirketlerin karşılaşacağı olası zorluklar ise iş kültürünün kısmen değişmesi sonucu adaptasyon sürecindeki problemler olarak düşünülmektedir. Bunlar; 2 boyutlu tasarım yapan ekibin 3 boyutlu tasarım üretmesi, çalışan direnci, ilk yatırım maliyeti, BIM sisteminin gerektirdiği şirket içi YBM uygulama planı; BEP, PIP, MIDP vb. dokümanların üretilmesi süreci, altyüklenici adaptasyonundaki zorluklar veya Türkiye'de henüz yaygın bir talebin oluşmamış olması gibi sebepler olarak özetlenebilir.

Bir inşaat projesinde başarılı bir YBM uygulaması yapabilmek için şirket içinde bazı organizasyonel değişiklikler yapılmalıdır. Öncelikle bir projeyi YBM sistemiyle üretmek; proje katılımcılarının sistemli ve birlikte çalışabilmesi ile mümkündür. Proje süresince düzenli YBM toplantıları düzenlenmeli, hatalar eksikler tasarım aşamasındayken farklı disiplinlerle birlikte belirlenmeli ve giderilmelidir. YBM kullanımında şirket içi adaptasyonu artırmak için yapılabilecek düzenlemeler arasında; YBM kullanımını destekleyen yazılımlar satın almak, YBM konusunda tecrübeli çalışanlar işe almak, şirket içinde YBM prosedürlerine uygun çalışmalar yürüten ayrı bir ekip kurmak, tüm çalışanlara şirket içi YBM eğitimleri vermek ve YBM konusunda tecrübeli profesyonellerden YBM danışmanlığı almak gibi seçenekler sıralanabilir.

Küresel ekonomik krizden en çok etkilenen sektörlerin başında gelen inşaat sektöründe; uluslararası inşaat sektörü dergisi ENR (Engineering News Record) verilerine göre Türkiye 2015 yılında dünya çapında 43 şirketle 2. sırada yer almaktadır. Bu verilerle beraber Türk inşaat sektörü ülke ekonomisine büyük katkı sağlayan sektörlerden biridir. Türkiye'deki inşaat faaliyetlerinin artan bir ivmeyle ilerlemesi inşaat sektöründe yüksek rekabeti de beraberinde getirmektedir. Bu sebeple, rekabet avantajı elde edebilmek için inşaat şirketleri ürettiği projelerde kalite, maliyet, zamanlama gibi faktörleri optimize ederek öne çıkmaları gerekmektedir. Bu koşullarda inşaat sektöründeki müşterilerin de inşaat firmalarının da pratik çözümlere, yenilikçi yaklaşımlara ihtiyacı vardır. YBM teknolojisi sağladığı birçok yenilik ve avantaj ile uluslararası inşaat sektöründe yeni bir dönem başlatmaktadır. YBM teknolojisine karşı uluslararası boyutta artan ilgi ve uygulamalar sonucu Türkiye'de de YBM uygulamaları konusunda girişimler başlamıştır.

Araştırma sonuçları; anket ve mülakatlara katılan şirketlerin cevapları baz alınarak hazırlanmıştır. Sonuçlar Türk inşaat sektörünü tümüyle yansıtmıyor olsa da genel anlamda büyük ölçekli şirketlerin piyasaya yön verdiği düşünülürse sonuçlar yanıltıcı olmayacaktır. Bu bulgulara göre Türk inşaat sektörünün bugünkü koşullarında BIM kullanımı çok yaygın olmamakla birlikte sektörde YBM konusunda bir farkındalık oluşmuştur. Özellikle uluslararası inşaat sektöründe iş yapan inşaat firmaları hem BIM kullanımına karşı artan eğilimi fark ederek, hem de bazı ülkelerde sözleşme şartları arasında yer alan YBM ile iş yapma şartı olmasından dolayı YBM teknolojisini kendi şirketlerine adapte etmeye çalışmaktadırlar. YBM kullanımına

geçişin temel sebepleri işveren talebi, sözleşmede YBM kriterinin yer alması, ve küresel rekabet gücü kazanmak olarak belirlenmiştir.

Türk inşaat sektöründeki çoğu firma YBM teknolojisini daha çok tasarım ve planlama aşamasında kullanmaktadır. Şirketler YBM kullanımından en çok 3 boyutlu tasarım modeli üzerinden çakışma analizleri yaparak yararlanmışlardır. Ayrıca, YBM kullanımının proje katılımcıları arasındaki uyumu ve işbirliğini arttırdığını vurgulamışlardır. Araştırmaya katılan şirketlerin büyük çoğunluğu YBM uygulamasının proje maliyetini, proje tamamlanma süresini, inşaat süresi boyunca oluşan toplam revizyon sayısını azalttığı yönünde; proje kalitesini arttırdığı yönünde görüş bildirmişlerdir. Çoğu inşaat şirketi YBM kullanımına geçişteki başlıca zorlukları ise, YBM konusunda bilgili/donanımlı çalışan eksikliği, altyüklenicilerin adaptasyon problemleri, çalışan direnci, sözleşmesel düzenlemelerdeki eksiklikler ve YBM teknolojisinin Türkiye'de henüz yaygın olarak kullanılmayışı olarak belirtmişlerdir.

Araştırma sonuçlarına göre bir şirketin YBM kullanımına geçişini en çok teşvik eden faktörler; diğer şirketler arasında küresel rekabet gücü kazanmak, sözleşme koşullarında YBM kullanımı şartı olması, sektörde yenilikçi bir role sahip olmak ve şirket yöneticilerinin vizyonu olarak sıralanabilir. Türkiye'de YBM kullanımının yaygınlaşabilmesi için teşvik edici unsurlar ise; YBM uygulamasının devlet ihalelerinde zorunlu hale gelmesi, akademik kurumlarda YBM konusunda eğitimlerin artırılması, YBM ile üretilen binalarda vergi avantajı sağlanması, inşaat sektöründe YBM konusunda seminer, panel ve konferansların artırılması ve 3 boyutlu çizim programlarının kullanımlarının yaygınlaştırılması olarak şirketler tarafından belirtildi.

Sonuç olarak, YBM teknolojisi proje yönetimi bilgi alanlarına büyük ölçüde destek vermektedir ve YBM uygulamaları projenin maliyet, süre, kalite performansını olumlu yönde etkilemektedir. Mevcut durumda, Türk inşaat sektöründe, YBM uygulamaları daha çok 3 boyutlu model üretme ve modele bağlı iş programı oluşturma seviyesinde yürütülmektedir. Bugünkü koşullarda Türkiye'deki inşaat sektörü yaygınlaşan YBM akımını birkaç yıl geriden takip etse de; sektörde YBM teknolojisine karşı artan ilgi ve talep doğrultusunda, şirketlerin YBM konusunda yatırım ve uygulama kapsamları artmaktadır.

1. INTRODUCTION

Building Information Modeling (BIM) is a system that targets to the development, use and the transfer of the digital information model of a building project to enhance the design, construction and operation phases of a project (BIM Project Execution Planning Guide, 2010: 1). The National Building Information Modeling Standards (NBIMS) Committee defines BIM as:

"… a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the life-cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of the stakeholder."

Today, as a result of the rapid development of technology, all industries are looking for more practical ways for their commercial activities. In the construction industry, different ways have been developed in years for providing more practical and easier design and construction processes. In the second half of the 20th century architects and engineers have reformed their traditional drawing and calculation tools, and currently the most accepted tools by the design engineers are CAD/CAE systems (Czmoch and Pekala, 2014: 210). Respectively, BIM system offers more comprehensive use, and it will become a preferred and widely used technology in few years.

Construction industry is a highly competitive sector, and to survive in this sector it is necessary to adapt innovations very quickly. Companies which adapt to use of BIM technology will achieve positive results on various project parameters, such as; budget of project, completion time of the project, quality of project and operation process of the project etc.. Thus, companies should get used to implement BIM

system on their projects as earliest as possible to gain competitive advantage in future projects.

BIM system can be used and integrated in every phase of the construction project. It provides a consistent set of data. However, it is more beneficial and practical to implement BIM from the beginning phase of the project, because the significant decisions that affect the project performance during its lifecycle made especially in contract and design phases. Therefore, BIM areas of usage are more effectual in pre-construction phase. To clarify, planning phase mainly covers the drawing model, cost estimation, scheduling and the site analysis. Accordingly, BIM supports the communication and collaboration between stakeholders throughout these phases. Moreover, with the help of the new technological and compatible software better coordination and organization can be provided between stakeholders. Creating 3D model of the project together with the other disciplines, preparing budget estimates and duration estimates of the project, and recording all the data about building materials and quantities are some of the prominent advantages of the BIM usage. Thus, BIM system provides significantly positive effect by supporting collaboration and the creation of 3D model of the project together and at the planning phase.

Project management can be defined simply as executing and controlling all the construction processes, and successfully delivering the project. The essential responsibilities of a project manager are increasing productivity, efficiency, and project value, and decreasing lifecycle expenses, time wastes and project risks (Fazli et al., 2014: 1117). According to the PMBOK Guide, project management consist of 5 processes as; initiating, planning, executing, monitoring and controlling, and closing the project. Furthermore, project management covers 10 knowledge areas, which are (PMI, 2012);

- Project integration management
- Project scope management
- Project time management
- Project cost management
- Project quality management
- Project human resource management
- Project communications management
- Project risk management

- Project stakeholders management
- Project procurement management

BIM usage affects almost all of these knowledge areas by its processes and procedures. BIM can be utilized in project management as an efficient tool to simulate project conditions to avoid redundant works and waste of time and cost (Fazli et al., 2014: 1116). BIM consists of an advanced process to plan, design, build, use and maintain an installation from a consistent information model which contains useful information for project's lifecycle (National Institute of Building Sciences, 2008; Eastman et al., 2011). Therefore, BIM generates an integrated operation tool that includes the all phases of a construction project. In this way, BIM implementation directly impacts the project management areas, and positive effects of implementation can be observed in all phases of the project.

Currently, BIM technology is not widely used in Turkish construction industry, but BIM awareness is growing. Mostly, large scale construction companies are in discovering and adaptation process for now. Dissemination of the use of BIM will bring significant benefits by means of project management performance. To provide major adaptation in the industry some strategic methods should be developed. Governmental enforcement and regulations and academic training ensure the systematic and organized ways for widespread use of BIM. As implemented in many countries, governmental regulations have become a driving force for the construction companies. According to BIM competent, training and raising consciousness about BIM should be increased both at academic institutions and construction companies.

This research attempted to evaluate BIM usage, classify the thoughts about BIM implementations and determining the necessary strategies for widespread use of BIM in the Turkish construction industry. The research based on an analysis of current industry approaches and difficulties about the BIM implementation and detailed interviews with the substantial Turkish construction companies. Companies' BIM adaptation approaches have been examined, and their thoughts and experiences about the BIM requirements have been recorded. Interviews and surveys conducted with medium and large scale companies, thus more professional approaches and applications are gathered from the big industry players. BIM usage has been analyzed in many aspects. The survey questions are prepared to measure what drives the companies to practice BIM and how the implementation of BIM can be improved

throughout the industry. This paper presents a literature review on BIM system and BIM implementations all over the world, and discusses incentive factors to promoting BIM implementations.

Purpose of the research:

In this study, how to use Building Information Modeling effectively in the all phases of the construction project, support of Building Information Modeling in different project management areas, and why the use of Building Information Modeling is not spread enough in Turkish construction industry will be examined. Furthermore, in this study, proposals will be developed for the widespread use of Building Information Modeling in Turkish construction industry. To achieve these objectives, the international literature review, structured interviews with BIM experts working in the Turkish construction industry. The aims of this research are;

- Investigation of the effective use of BIM in all stages of the construction project management
- Determining the strategies for widespread use of BIM in the construction industry
- Identification of organizational changes required in the BIM implementation

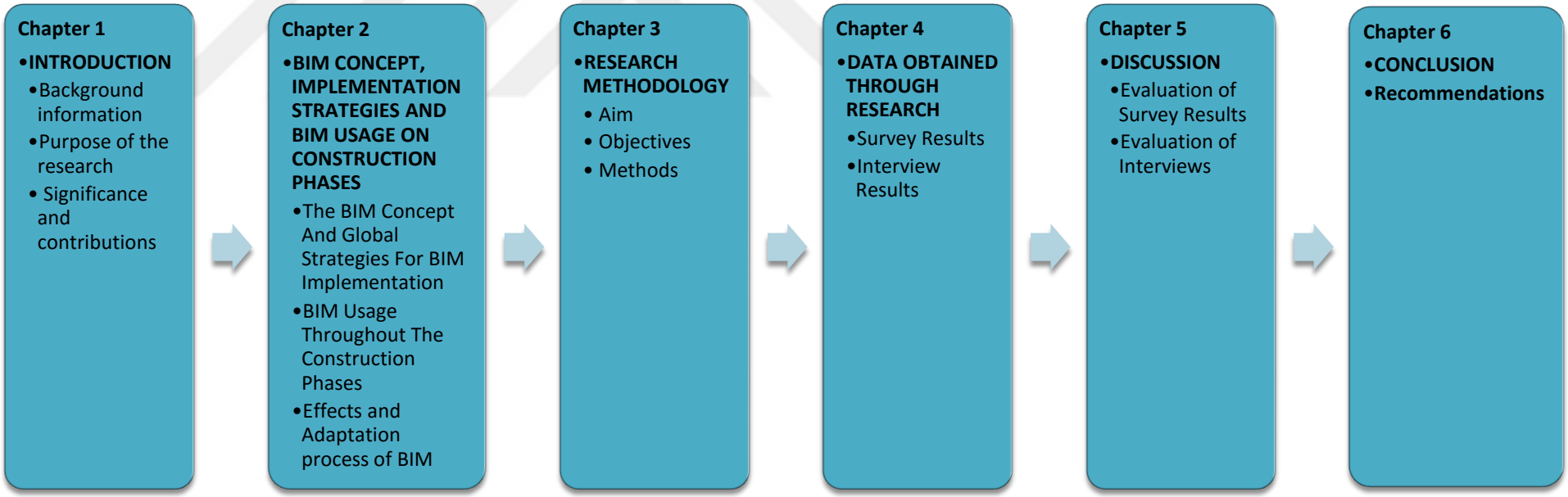
With these aims 18 experienced BIM experts have participated to this study. Detailed information on the research methods have been provided in Chapter 3.

Significance and contributions:

The research's major contributions to the literature can be summarized as the followings,

- Identification of how to use BIM effectively in all the construction project management phases,
- Identification of the main reasons for why the BIM technology is not used widespread by Turkish construction industry,
- Determination of proposals that provide widespread use of BIM in Turkey

Figure 1: Dissertation flow chart.



The distribution of the thesis topics and flow of topics are represented in Figure 1.

2. BIM CONCEPT, IMPLEMENTATION STRATEGIES AND BIM USAGE ON CONSTRUCTION PHASES

In this section, definition of BIM, history of BIM and global BIM implementation strategies have been examined under the title of "The BIM concept and global strategies for BIM implementation". The subheading, **"**BIM use throughout the Construction Phases" covers the contributions of BIM usage in pre-construction, construction and post-construction phases. Lastly, benefits and difficulties about the use of BIM and necessary organizational changes to successfully adapt BIM processes have been explained as part of the "Effects and Adaptation process of BIM" subheading.

2.1. The BIM Concept And Global Strategies For BIM Implementation

In this part, BIM definitions and history of BIM have been summarized from many international and different sources. Thereafter, global BIM implementations have been analyzed, and a summarizing table has been developed according to the data from the articles.

2.1.1. Definition of the BIM technology

Being a fragmented and project-based industry, the construction industry dealing with uncertainties (Dave and Koskela, 2009). BIM is an emerging new technology which can enhance the collaboration and coordination between interdisciplinary project participants. BIM can support construction project management process and the construction companies in overcoming the difficulties and uncertainties of the construction industry.

BIM can be defined in various ways. BIM is "*…a digital representation of a building, an object-oriented three-dimensional model, or a repository of project information to facilitate interoperability and exchange of information with related software applications*" (Succar, 2009: 357). As quoted from the Building SMART (2010), the American National Building Information Modeling Standards (NBIMS)

Committee defines BIM as National Information Model Standard Project Committee defines BIM as '*a digital representation of physical and functional characteristics of a facility...and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition*'". Another definition of BIM has been done by the British Standard Institution Specification for information management for the capital/delivery phase of construction projects using building information modeling (PAS 1192-2:2013). According to the PAS 1192-2: 2013, BIM is defined as '*the process of design, construction and use of the building or facility infrastructure using information about virtual objects*.'" (PAS 1192-2:2013). BIM is a useful tool for parametric modeling and spatial visualization, and simulation of the behavior of the building, as well as for enhancing efficiency of the project management and collaboration among the project participants (Succar, 2009: 357). BIM takes the construction site as a unit of interrelated "elements and standards" effecting each other (Volkov and Sukneva, 2014: 377-378).

BIM has various dimensions which can be described as follows (Czmoch and Pekala, 2014: 212-213):

- **BIM 3D** covers virtual 3D parametric model which is an extended version of the 2D design.
- **BIM 4D** covers scheduling in addition to the BIM 3D functions
- **BIM 5D** covers estimating functions in addition to the BIM 4D functions
- **BIM 6D** covers sustainability in addition to the BIM 5D functions
- **BIM 7D** covers Facility management functions in addition to the BIM 6D functions.

As the BIM's dimensions are extended, new levels of interoperability and collaboration can emerge which can result in reduced design mistakes and increased productivity (Succar, 2009: 357)

2.1.2. History of BIM

The history of BIM goes back to the 1970s when solid modeling programs emerged, to 1980s when the ArchiCAD software program has been developed and to 2000s when the Revit software program developed (Bergin, 2010). The need for integrated and interoperable software was recognized in the 1970s (Björk, 1995: 12). Architects and engineers have shifted from using traditional drawing and calculation tools to

CAD/CAE systems from which they are shifting towards BIM usage (Czmoch and Pekala, 2014: 210). BIM is an evolution of CAD systems which provides more "intelligence" and interoperable information compared to them (Miettinen and Paavola, 2014: 84).

2.1.3. Global BIM implementation trends and strategies:

BIM concept has been emerged in the 1970s and 80s, and with the development of Revit software in 2000 real move toward efficient BIM implementations started (Bergin, 2010). Today BIM implementations are gaining power in all over the world. Contrast to manufacturing and engineering industries, BIM technology has been adopted relatively slow in the construction sector (Smith, 2014: 483). In the last decade, there are some rapid evolution in UK, USA and European Construction Industry by suggesting different contract procurement system than traditional design-bid-build system in the past decade (Jones, 2014: 529). As clients and government entities turn into motivator force for the adoption of BIM by authorizing its use on their projects, and regulating the implementation problems, the delay for adopting the process will be decreased (Smith, 2014: 483).

Various researches are conducted to analyze BIM implementation problems for the industry (Bryde et al., 2013, Ahmad et al., 2013, Sacks &Pikas et al., 2013) and to reveal the advantageous points of efficient implementation to key industry players (Cook 2014, Love et al., 2013). McGraw Hill (2014) pursues the development and implementation of BIM in the global construction industry since 2007 with worldwide surveys. McGraw Hill Construction (2013) determined the BIM adoption had grown 17% in 2007 to 71% in 2012 in North America which indicates that BIM has become prevailing technology in the industry (Smith, 2014: 477). Similar advancement of BIM implementation has been identified in United Kingdom, where the local government has forced construction industry to procure all public sector's construction projects will be delivered using as minimum Level 2 BIM by 2016 (HM Government 2012, BIM Task Group 2014). Moreover, BIM interest is growing with public clients having a leadership role and requires BIM usage in their projects, e.g. a large public client of infrastructure aims to increase productivity by concentrating on the implementation process of BIM in Sweden (Lindblad and Vass, 2015).

Many of the countries have strategies to implement BIM technology; United States, United Kingdom and Scandinavian region countries are dominant ones to lead the way. Organized government support and leadership are the critical strategies, further improvement of BIM standards, BIM certification, and education and training about BIM technology are the other important strategies to use BIM successfully (Smith, 2014: 482). Today, BIM is widely used all over the world and BIM standards efforts in the United States, Europe, or abroad considering that this digital information is shareable, is interoperable among different stakeholders' information systems, is based on accepted open standards, and is definable in contract language (Kubba, 2012: 220).

United States: The United States have the leadership in BIM development and implementation in construction industry (Wong et. al., 2009). In the United States the US General Services Administration (GSA) launched the BIM implementations in public projects, and in 2003 they established a 3D-4D BIM program through its Public Buildings Service (PBS) Office, than in 2007 they administered the use of BIM in spatial program validation on all of its projects (Khemlani, 2012). The spatial program validation, 4D phasing, laser scanning, energy and sustainability, circulation and security validation and building elements are the next objectives of GSA for exploring the use of BIM technology throughout a project's lifecycle (BuildingSmart Australasia, 2012: 53). Therefore, the GSA are the obvious leaders in supporting and enhancing BIM adoption initiatives (CIBER, 2012). " The US Government is moving to require BIM on all of their building projects. The US Army Corps of Engineers, Air Force and Coast Guard have all moved down the BIM path." (CIBER, 2012)

United Kingdom: The United Kingdom Government Construction Strategy incited the construction industry in 2011 to require BIM on all of government projects by 2016 through a 5 year staged implementation plan, and due to UK government's objective, 20% saving in procurement costs is expected with BIM usage (Cabinet Office, 2011). The UK Government has announced the BIM implementation strategy by examining the advanced BIM implementations in the world (HM Government, 2012). The aim is to change the UK industry to a global BIM leader in a short time (Withers, 2012). This strategy had a significant effect on the UK construction industry as firms confront the reality of improving the technological capabilities to

meet these requirements (Smith, 2014: 485). The UK government has established a BIM Task Group to help and support both the public sector clients and private supply chain in reorganization of their work practices to promote BIM delivery (McGraw Hill, 2014). To help establish BIM on public projects, a task group, directed by the chairman of the UK Government BIM Group Mark Bew, determined a guide and cascade in BIM over a period of five years, and if this plan attains god outcome, the U.K. construction industry will need to go through a steep learning curve (Kubba, 2012: 221). "Still, one example of the successful employment of BIM is Heathrow Airport Terminal 5, where its use reduced project costs by £210 million." (Kubba, 2012: 221)

Germany: According to the "Smart Market Report (2010)", "German adopters as a group use BIM 47% of the time on 30% or more of their projects." In Germany, architects has %77 of adaptation rate which is the highest rate among the industry professionals, than it is followed by engineers with the 53% adaptation rate, and lastly contractors have the lowest adaptation rate with 10% (Kubba, 2012: 222). BIM implementations of The U.S. Army Corps of Engineers have reached to the Europe, and the number of projects that are required to construct with BIM system has increasing rate, but it is expected to take some time to fully integrate BIM into the Europe District construction process broadly, because of the legal issues and the agreements between the U.S. and German governments (Kubba, 2012: 222).

France: According to McGraw-Hill Construction's "SmartMarket Report" (2010), BIM systems have high rate of adaptation in France; 72% of adopters use BIM on 30% or more projects, and French users get the benefit from BIM through reduced conflicts during construction with 76%, and improved common understanding of design objectives 71% (Kubba, 2012: 222).

Finland: The Finnish government have highly invested in IT technologies in the construction industry since 1970s (Granholm, 2011). Finland government requires all public projects are constructed with BIM technology, therefore Finland has accomplished extensive implementation of BIM comparing the other Scandinavian countries based on the survey results indicates that architects are the main users of BIM in their projects (approximately 93%) and engineers use is roughly 60% in Finland construction industry (Kubba, 2012: 222).

Norway: In Norway BIM implementations are controlled under the leadership of Statsbygg company, which responsible from construction, management and development of government facilities, and they implement BIM technologies in their projects since 2007 and required IFC compliant since 2010 (BuildingSMART Australasia, 2012).

Denmark: Danish government is an active and effective supporter of BIM and spends money in research and development (Granholm, 2011). Similarly with Finland, Denmark have forced that all the public-sector projects are built with BIM system in 2007, so general BIM use is increasing in the region (Kubba, 2012: 223). "Danish government clients such as the Palaces & Properties Agency, the Danish University Property Agency and the Defence Construction Service all require the use of BIM on their projects." (BCA, 2012) According to a survey conducted in 2006 (cited in Kiviniemi et al., 2008), approximately 50% of architects and 40% of engineers were using BIM in their projects (Kubba, 2012: 223).

Singapore: The Singapore Building and Construction Authority (BCA) have established a method to have BIM implementation on public projects by 2015 (Granholm, 2011). The government has also developed a Construction Productivity and Capability FUND (CPCF) of $250 million with BIM a key target (Smith, 2014: 485). Construction and Real Estate Network (CORENET) program was established in 2000, as a strategic initiation to change the use of information technology amongst all the project stakeholders, and this system strengthens and supports the use of BIM (BuildingSmart Australasia, 2012).

China: Currently, China is the world's largest construction boom, and building information modeling brings a competitive benefit to Chinese architects and engineers, and by grasping BIM, the Chinese building industry can get benefit on productivity that surround a digital building methodology (Kubba, 2012: 225). However the Chinese construction industry is in the first stage of BIM adoption; according to the survey undertaken by the China Construction Industry Association in 2012, results show that less then 15% of 388 surveyed Chinese construction companies used BIM (McGraw Hill, 2014).

Japan: According to the McGraw Hill (2014) study, Japan was found to have higher level of BIM implementation, additionally interesting findings show that almost all

of the contractors stated they obtained positive Return of Investment (ROI) with their BIM involvement (Smith, 2014: 486).

South Korea: Surprisingly, BIM implementations and involvements are relatively low in South Korea compared to the region, although it is known as the "high-tech country" and being one of the global leaders in the use of information technologies (Smith, 2014: 485).

Australia: In Australia, there is no government mandate and construction companies do not implement BIM technologies widely, but in past 5 years BIM adoption is enhancing as a result of the potential productivity is gaining competitive advantage (CIBER, 2012). The 'buildingSmart' organization is the leading actor in BIM development and implementations in Australia, and it carries 'Open BIM Alliance of Australia' that contains an alliance with a number of software vendors (CIBER, 2012).

Brazil: According to the McGraw Hill (2014) international survey of contractors stated that Brazilian construction industry was relatively new to using BIM technologies, but there are a number of international construction firms that are influencing and promoting the level of BIM usage, however there is lack of authority and a coordinated approach from government in the industry (Smith, 2014: 486).

India: Today, Indian construction market is valued at US $140 billion with a dramatic estimated growth to $620 billion by 2020 and that many international firms are shifting their operations to India, and this will encourage to bring BIM system into the market (McGraw Hill, 2014). Mostly the larger construction companies are using BIM on large-scale projects, thereby the implementation costs are high and the industry demands more extensive training and development (Smith, 2014: 487).

Turkey: Construction companies in Turkey have been started to invest in BIM implementations. The industry is in the search and exploration phase for now. Various software manufacturers have been focused to promote softwares which can provide the BIM based working standards. Major companies are aware of future of the construction industry will be BIM based technologies. Recently, government projects have started to require BIM applications especially in trasportation projects. Apparently this approach will motivate and encourage other clients and contractors to apply BIM standards in their projects.

Table 2.1 is developed according to the research results from different articles, and it presents a grouped data that shows general tendency toward BIM usage and which strategies can be developed to promote BIM usage on the construction projects

Table 2.1: Global Strategies to increase the implementation of BIM

Strategy	Country	Author
Requiring BIM usage on public projects	USA, UK, Finland, Denmark	Khemlani, 2012; CIBER, 2012; Cabinet Office, 2011; Granholm, 2011
Establishing BIM Task Group to help and support public sector clients and private sector supply chain	UK	McGraw Hill, 2014
Investing in IT technologies in the construction industry	Finland	Granholm, 2011
Investing in research and development	Denmark	Granholm, 2011
Establishing strategic initiation programs, such as; Construction and Real Estate Network (CORENET) program, spatial 3D – 4D BIM program	Singapore, USA	BuildingSmart Australasia, 2012; Khemlani,2012
Carrying 'buildingSmart' organization, which is the leading actor for BIM development	Australia	CIBER,2012
International construction firms are promoting the BIM usage level	Brazil, India	McGraw Hill, 2014; Smith, 2014
Construction industry is relatively new to using BIM technologies, and adaptation level is at low level	China, South Korea, Brazil	McGraw Hill, 2014; Smith, 2014

The most prominent and effective strategy seems as government enforcements. Governments have strict rules and movements to promote BIM usage, mostly as United Kingdom, United States, Finland and Denmark. Furthermore, establishing strategic initiation programs and organizations is one of the effective methods that provides to carry out BIM procedures systematically, and countries as United Kingdom, United States, Australia and Singapore have been preferred to develop such programs. Afterwards, investing in IT technologies and researches comes into

prominence by countries as; Finland and Denmark. Besides, research results show that international construction firms are increasing the BIM maturity level in Brazil and India rather than the local construction markets. Consequently, BIM system is the fast developing and spreading technology since last years, and countries such as China, South Korea and Brazil is relatively less competent among the global industries.

2.2. BIM Usage Throughout The Construction Project Management Phases

BIM adoption has major impact on design and construction phases, and to totally utilize BIM many firms are altering their approach to the process (McGraw Hill, 2010). Complication of the construction projects, multiple phases of construction project lifecycle, using heterogeneous software and hardware systems, inclusion of multi-disciplinary teams creates a requirement of integration to achieve effective collaboration (Shen et. al., 2009: 196). Starting from the initial design to facility management BIM models are used throughout the construction's lifecycle (Henttinen, 2012). Despite the complexity of projects, requirements and schedules have been continuously tightening, according to Brady (2011). Therefore, integration and management of the project and project teams require more collective participation (Halttula et al., 2015: 533).

Building information modeling (BIM) contain an advanced process to plan, design, build, maintain and operate model that consist of all the useful data for building's lifecycle (National Institute of Building Sciences, 2008; Eastman et al., 2011), that brings in more attention to the construction industry (Brito and Ferreira, 2015: 375).

In the Figure 2.1, BIM use is classified properly throughout the project lifecycle. It emphasizes that planning is the most applicable phase for the BIM use which contains project characteristics, participants' goals and capabilities, and risk allocations.

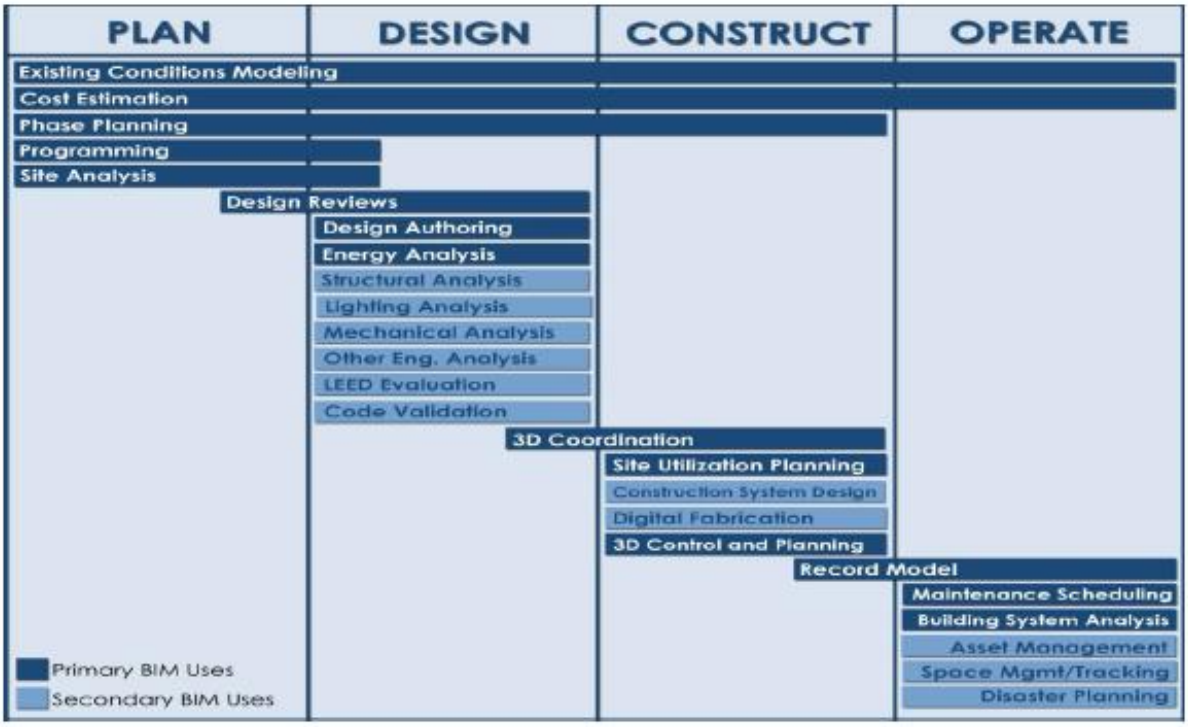


Figure 2.1: BIM Uses throughout a Building Lifecycle (BIM Project Execution Planning Guide, 2010: 9).

Project Management Phase

Project management phase is a process that covers each stage of the construction process, and effective implementation of project management significantly increases the project productivity. The main concern in the building industry is increasing productivity and efficiency of the construction projects, and BIM seen as an essential tool for it (Eastman et al., 2011). Through the developed Information and Communication Technologies (ICT), project management practice could more clearly recognize and manage the interdependencies that are prevalent throughout the construction projects, thereby capacity of the ICT can be utilized to improve overall project performance (Froese, 2010: 532). The essential responsibilities of a project manager are increasing productivity, efficiency, and project value, and decreasing lifecycle expenses, time wastes and project risks (Fazli et.al., 2014: 1117). Therefore, a project manager can get benefit from BIM implementations.

To determine whether a project is delivered successfully or not there should be some criteria to evaluate it. According to Antvik and Sjöhol, a project can be described as successful if it has been delivered; (Antvik and Sjöholm, 2005: 14-15)

- According to its specifications,
- Within budget and time,

- To the satisfaction of the client and end-users,
- With the help of a satisfied project team.

BIM can be utilized in project management as an efficient tool to simulate project conditions to avoid redundant works and waste of time and cost (Fazli et. al., 2014: 1116). BIM provides the establishing of an integrated operation tool that includes the all phases of a construction project. In this way, BIM implementation positively impacts the project management areas. According to the PMBOK Guide, project management consist of 5 processes as; initiating, planning, executing, monitoring and controlling, and closing the project. Furthermore, project management covers 10 knowledge areas, which are; (PMI, 2012)

- Project integration management
- Project scope management
- Project time management
- Project cost management
- Project quality management
- Project human resource management
- Project communications management
- Project risk management
- Project stakeholders management
- Project procurement management

The success criteria can be grouped based on the Project Management Institute's (PMI) Project Management Body of Knowledge (PMBOK) Knowledge Areas (PMI, 2008). The knowledge areas are created as they present an extensive high level of structure involving all aspects of success (Fazli et al., 2014: 1120).. The project management knowledge areas and their success criteria are presented in the Table 2.2. The role and influence of BIM affects almost all of these knowledge areas by its processes and procedures. For this reason, BIM usage and project management are highly interactive concepts, and usage of BIM supports project management areas considerably.

Table 2.2: Success criteria based on PMBOK knowledge areas. (Fazli et. al., 2014: 1120; PMI, 2008)

PMBOK knowledge area	Definition	Criterion	Positive consideration
Integration Management	Unification, consolidation, articulation, and integrative actions	Coordination	Improvement
Scope Management	Defining and controlling what is and is not included in the project	Scope	Clarification
Time Management	Accomplish timely completion of the project	Time	Reduction or Control
Cost Management	Planning, estimating, budgeting, and controlling costs	Cost	Reduction or Control
Quality Management	Quality planning, quality assurance, and quality control	Quality	Increase or Control
Human resource Management	Organize and manage the project team	Organization	Improvement
Communications Management	Timely and appropriate generation, collection, distribution, storage, retrieval, and disposition of project information	Communication	Improvement
Risk (uncertainty) Management	Increase the probability and impact of positive events, and decrease the probability and impact of adverse events	Risk	Negative risk reduction
Procurement Management	Purchase or acquire the products, services, or results needed from outside the project team to perform the work	Procurement	Help

3D models of the projects are easier to understand by project stakeholders, and applying changes can be effortless through the model. Moreover, communication process is obviously enhanced through BIM system. Therefore, the decision making process can be more realistic and reasonable with the BIM, comparing traditional method (Fazli et al., 2014: 1120). According to the Allison (2010), Table 2.3 summarizes the potential benefits of BIM usage to the project management.

Table 2.3: Potential benefits of using BIM for project managers. (Fazli et. al., 2014: 1120)

Potential benefit for PMs	Why?
Organize the project schedule and budget	An integrated 5D BIM model immediately updates both the schedule and budget when any design change occurs
Work well with the Design Team	By using the integrated 5D BIM model to visualize and explore the impact of changes, s/he can keep project scope in check and become a trustworthy liaison between the designers and Owner
Hiring and controlling the Subcontractors	Having a handle on clash detection and coordination plays a key role in keeping Sub-contractors' work predictable
Requests For Information (RFIs) and Change Orders	Utilizing Coordination Resolution in preconstruction, these numbers can be brought to near zero.
Optimize the Owner's experience and satisfaction	Owner received a big injection of confidence in the GC when the PM showed him/her how design decisions impacted cost and schedule
Project closeout	PM to present a 6D BIM – a facilities resource with information on warranties, specifications, maintenance schedules, and other valuable information
Profit margin	By thoroughly understanding the project in 5D, the PM has more tools at his disposal to keep tight reins, and more reports to monitor progress
Progressive Owners are mandating BIM on their projects:	Becoming the BIM expert, in both preconstruction and out in the field, makes the PM invaluable and a key player.
PM Firm Growth	Project's success with 5D BIM means the opportunity to grow the firm's reputation and helps the corporate team win new business.

Project management also covers the process of preparing the required building information for its operation process. Today, information about many existing buildings is fragmented, insufficient or no longer in use (Becerik-Gerber et al., 2012), (Gursel et al., 2009). Missing or inadequate building information may cause

limited and incompetent project management, hesitant process results and time loss or cost increases in maintenance and retrofit processes (Volk et al., 2014: 110). Through BIM system, building's data can be kept recorded in each stage, and this enables to operate building throughout its lifecycle more effectively.

2.2.1. Pre-construction phase

Pre-construction phase plays an important role through the project lifecycle. Decisions made in the pre-construction phase affect the construction life-cycle performance directly. By providing a set of data, BIM system provides to plan and design effectively. Thus BIM may have huge impact on pre-construction phase.

Contracting Phase

Traditional methods (e.g., design-bid-build) have mainly been depended on bilateral contracts and the lowest bid, so this method does not support collaboration because the project stakeholders desire to maximize their own profits and minimize the risks (Halttula et al., 2015: 533). Because of this challenge the industry pursues new contract methods to establish better participation, such as relational project delivery arrangements (RPDA), as considered by Davies et al. (2007), Brady et al. (2006) and Aapaoja et al. (2013)." (Halttula et al., 2015: 533).

The essence of the suggested BIM procurement system leans on partnership, team working and trustful relationship receding from opposing contract conditions, by supplying better construction service for clients (Jones, 2014: 529). BIM technology is expected to improve and increase tendering process and "… address the problem of inaccurate, incomplete and ambiguous information so that emergence of unnecessary additional capital delivery costs amounting to 20-25% can be eliminated" (PAS 1192-2: 2013). According to UK government's objective, 20% saving in procurement costs is expected with BIM usage (Cabinet Office, 2011).

To successfully implement BIM a comprehensive and detailed plan and some standard documents must be prepared by the project team at the beginning phase of the project. At this stage preparation of **BIM Execution Plan** (referred as **BEP**) is significantly important. BEP document is a part of contract documents on a BIM project. According to PAS 1192-2:2013 documents BEP document describes how the information modeling aspects of a project will be carried out, and this plan is

prepared by the suppliers. BEP document summarizes and plans BIM implementation details for the project team, and to effectively integrate BIM in all project phases detailed BEP document should be developed in the early phases of the project and continually updated and revised as needed (BIM Project Execution Planning Guide, 2010). A detailed prepared BEP provides all project participants to be aware of their own responsibilities, risks and opportunities (BIM Project Execution Planning Guide, 2010), project-specific issues, directions on how to complete construction works, and a checklist within the scope of BIM usage (energy analysis, cost analysis, needed software etc.) associated with the BIM project workflow. To develop the BEP document, a planning team should be established, which consists of representatives from owner, designer, contractor, sub contractor and facility manager. BEP defines the

BEP document;

- Defines the scope of BIM implementation on the project,
- Classifies the process flow for BIM tasks,
- Specifies the information exchanges between the parties, and
- Defines the project and company requirements and necessary infrastructure needed to sustain the implementation (BIM Project Execution Planning Guide, 2010).

PAS1192-2 presents that during the procurement stage, a **pre-contract BEP** is prepared by the possible suppliers, arranging their proposed approach, capacity and competence to accomplish Employer's Information Request (EIR). When the contract signed by the parties, the successful suppliers prepares **post-contract BEP** to confirm supply chain's capabilities including **Master Information Delivery Plan (MIDP)**. MIDP is the initial plan about the project information explains that when the project information is to be prepared and by whom, using which protocols and procedures including all related task information delivery plans (PAS 1192-2:2013).

Generally, the fragmentation of the construction industry prevents the successful implementation of BIM. There are many project participants as; owner, contractor, subcontractor and supply chain, and there are many processes as; project planning, construction, and operation. Therefore, in contract phase, all the responsibilities and duties of project participants must be clearly defined in the contract and BEP

document. Providing BIM training for subcontractors and supply chain will be effective and helpful to work coordinately in the project, and they can be competent for BIM implementation.

Another document that should be involved in tender documents is **Employer's Information Requirements (EIR)**. "EIR is a pre-tender document setting out the information to be delivered, and the standards and processes to be adopted by the supplier as part of the project delivery process" (PAS 1192-2:2013). EIR describes which models are needed to be produced in which stages of the project with the required level of detail information (BIM Task Group). The core contents of EIR document are divided into 3 groups as; technical, management and commercial, and they establish requirements including software, level of detail, coordination, review processes and content of key deliverables etc. These requirements are implemented through the BEP document.

Project Implementation Plan (PIP) is included in comprehensive BEP documents. "PIP is the statement relating to the suppliers' IT and human resources capability to deliver the EIR." (PAS 1192-2:2013) PIP enables the project owner to evaluate competence, experience and capability of potential supplier to deliver the information required by EIR (PAS 1192-2:2013).

Design Phase

In the development of computer-aided design, BIM provides further approach by having 3D model with a huge database instead of many specialized documentations containing architecture design, landscape design, construction and installation designs as well as bills of quantities and cost estimates (Czmoch and Pekala, 2014: 212). Parametric modeling, which is the core characteristic of BIM, enables the quick implementation of changes in 3D model when it is necessary during the interdisciplinary coordination process (Czmoch and Pekala, 2014: 212). This facilitates to create design options, and compare them with many different criteria and materials. Furthermore, 3D model of the project enables to check clashes efficiently. **Clash detection** is explained in the PAS 1192-2:2013 as a rendition of the original format model file to be used specifically for spatial coordination processes (PAS 1192-2:2013). Through the clash detection many multidisciplinary conflicts and discrepancy can be solved before the construction phase. In this way,

many possible problems, such as; reworks, delays and increased costs can be prevented through BIM usage. This process may cause the extension of design time, but totally it brings cost and time benefit at the end of the project. Therefore, the design phase can be developed with the help of BIM and ICT (Breit et al., 2008).

Creating 3D model of the project and working on collaboratively with the other participants require determining some agreed level of model detail. PAS 1192-2:2013 explains the **LOD** as a collective term used for and including "**level of model detail**" and the "**level of information detail**". "Level of the model detail" is the description of graphical content, and the "level of model information" is the definition of non-graphical content of models at each of the stages defined for example in the CIC Scope of Services (PAS 1192-2:2013). **CIC Scope of Services** is a multi-disciplinary scope of services published by the Construction Industry Council (CIC) for project team members to utilize from it on large-scale projects (PAS 1192-2:2013). According to the definition in The American Institute of Architects (AIA), Level of Definition, **LOD**, represents the purpose and scope of each step can be used for model data that users need to determine the level of objects (The American Institute of Architects, 2007). Through LOD data, the scope of the information is defined, and model information can be gathered in the different phases of the project (Choi et, al., 2014: 19). Additionally, LOD categories identify the design scope and detail level.

BIM can be implemented in every phase throughout the project, but in the countries which are recently adapt to BIM technologies mostly implement BIM only on design phase. However, designing process has still many requirements to comply with the BEP documents and contracts. According to Kautto (2012), in detailed design phase of the building projects structural design should involve connections between structural elements an all cast-in reinforcements in the BIM model based on the contract. There are not so many software capable of implementing this in an economic way, that's why due to high demand of advanced features required by high level of BIM complete implementation may take long time (Tulenheimo, 2015: 472).

Selection of subcontractors and designer company is crucial for successful BIM implementation. In the BIM addendum, Design Model and Construction Model are identified, and contractors and subcontractors should develop the model of the project coordinately. Subcontractors should be oriented or trained if their BIM

applications or knowledge is not satisfactory. Thus, the project team can work coordinately and effectively.

BIM upholds the integrated design phase through improved collaboration between the stakeholders, and it provides better analysis of a project as a whole (McGraw Hill, 2010). The incorporation of end-users and contractors in the design process supports leanness of the process, thereby the need for variation amount in the construction process can be reduced (Sertyesilisik, 2014: 193). Through the enriched communication between project participants, design phase becomes target-driven, and demands and solutions can be created mutually.

2.2.2. Construction phase

During the construction phase, planning and controlling activities are promoted, and enhanced via visual management (Sertyesilisik, 2014: 193). Through the 3D model of the building, effective visual management is provided and communicated deliberately between the managers (King, 2009). Today, recent computer-based tools, produced by ICT, collaborates with the BIM for project modeling and integration, further it claims considerable increment in the effectiveness and efficiency of designing and managing construction projects (Froese, 2010: 531).

Through the useful 3D renderings, BIM technology can be used for calculating quantity takeoffs and preparing cost estimates by construction managers, furthermore schedule integrated BIM known as 4D BIM can be used for animations, safety analysis, and to prepare site logistic plans (Fazli et al., 2014: 1117). Due to many benefits and resource savings during design, planning and construction of new buildings, there is growing interest toward BIM (Nepal et al., 2008, Bryde et al., 2013).

In construction phase, BIM can be used for working coordinated with subcontractors, updating schedule and costs, and creating as-built building information model to the owner's maintenance team (Fazli et al., 2014: 1117).

BIM usage provided better planning in the design phase and more effective monitoring in construction phase, thereby construction waste can be minimized with the help of the BIM technology. "The construction industry has been identified to be responsible for: (1) more than 30% of energy consumption in Organization for Economic Cooperation and Development (OECD) countries, including the United

States, the European Union, Japan, and others, (2) 16% of freshwater withdrawals in the United States and about 20% worldwide, and (3) about 33% of global greenhouse gas emissions, just to name a few." (Pearce et al., 2012)

Construction waste generation directly impacts the environmental footprint as well as on the efficiency of the construction industry (Formoso et al., 2002)."Approximately "21–30% of cost overruns occurred in construction projects due to material wastage (Ameh and Daniel, 2013)." (Udawatta et al., 2015: 73) These environmental impacts force the construction industry to shift from traditional to sustainable construction (Matar et al., 2015: 2). Construction phase plays crucial role for the achievement of sustainability and for decreasing of excessive usage of the materials and reducing the amount of waste generated (Dobson et al., 2013), and through BIM usage all the material consumption is controlled accurately.

2.2.3. Post-construction phase

After construction works have been completed, the building is handed over to owner and building operator. At this stage, obtaining building's data model is significantly useful and profitable for them. BIM implementation provides the data record from at the early phases of the project. Therefore, with the help of these organized and detailed documents facility management becomes much more effective.

Operation and Maintenance Phase

To create an effective building operation model, proper identification of the information is crucial, therefore building's operational performance aimed to be improved (McArthur, 2015: 1105). BIM usage is beneficial in the whole life-cycle process of a project, including operation phase. At the end of the construction phase, facility manager can provide from the valuable and useful information for asset management, space planning, and maintenance scheduling, and this way the long-term performance of the facility and portfolio of the facility improves (BIM Project Execution Planning Guide, 2010).

BIM usage in the early design phase facilitates the operation implementations, and reduces the expenses. Bogenstätter indicates that early design phase decides up to 80% of building operational costs, as well as of environmental impacts (Bogenstätter, 2000). Moreover, at the end of the BIM implemented construction project, project

team can evaluate the reasons of defect manufacturing, incurred increased costs for the modeling service, schedule delays due to missing information or unnecessary effort results with no added value to the project (BIM Project Execution Planning Guide, 2010). According to LaSalle graph in Figure 2.2, changeability is getting more expensive and revision possibility is decreasing while the project phases progresses (Kovacic and Zoller, 2015: 1). The early design phase has critical importance on whole lifecycle performance of the building, and at this stage optimization potential is more available with inexpensive costs (Kovacic and Zoller, 2015: 1).

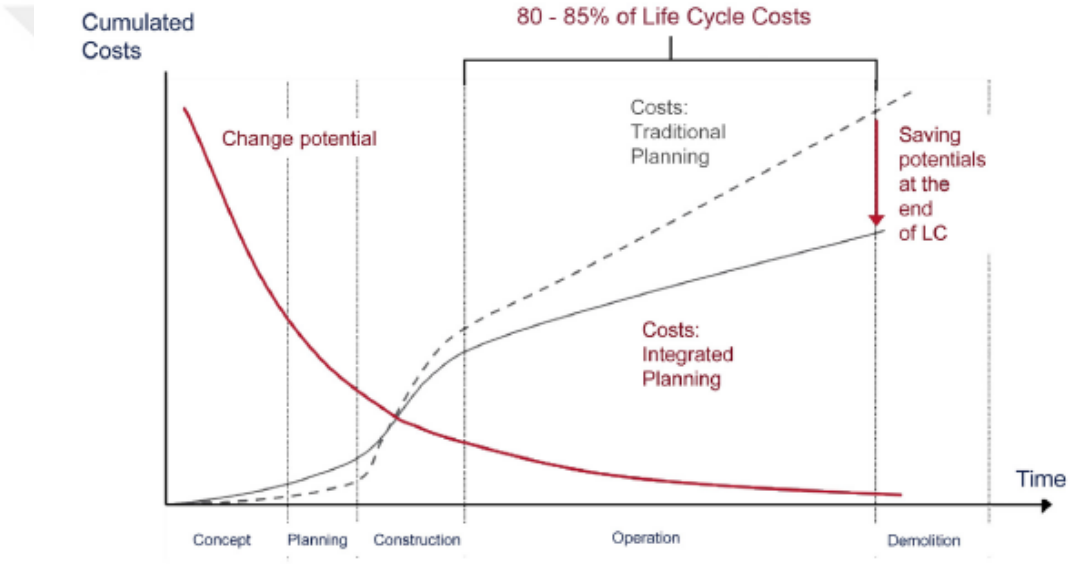


Figure 2.2: Cost development vs. change potential over building life cycle (LaSalle, 2008).

BIM provides to manage detailed building information over the whole LC (Liu et al., 2012), it is able to support data of maintenance and deconstruction processes (Eastman et al., 2011; Akbarnezhad et. al., 2012; Cheng and Ma, 2012). Project participants can supply maintenance and operation information through BIM in a structured way, and this helps facility management process (Becerik-Gerber, 2012).

Similarly, given the level of effort required to populate a BIM model with operational data, the strategic identification of operational information is critical. This data will vary enormously from project to project based on specific user systems, organizational structure and scope of the model but will be related to one of three rough areas: space planning, maintenance activities, and front-of-house (occupant comfort, sustainability, etc.).” (McArthur, 2015: 1105)

BIM implementation obviously increases productivity in facility management processes, by providing assembled and detailed information of the whole lifecycle of building. **Project Information Model (PIM)** can be useful for operation phase. According to the PAS 1192-2:2013, PIM is an information model that developed during the design and construction phase of a project. PIM is accumulation of all information about the construction; it develops progressively. As the design progresses, level of detail increases, specifications and method statements are attached along with the information. PIM should be created in accordance with the MIDP. At the end of the construction project, the PIM extends and becomes **Asset Information Modeling (AIM)** to be used during the operation phase

Facility managers can facilitate from BIM during the operation & maintenance phase (Rundell, 2006). BIM promises to improve the quality of FM by visualizing of building's all information (Motamedi et al., 2014: 73). At this point,. Becerik-Gerber et al. performed interviews with FM personnel to identify the role of BIM in FM. According to their study most of the FM functions are being controlled manually and using BIM in FM can increase efficiency and decrease the possibility of mistakes (Motamedi et al., 2014: 74) (Becerik-Gerber et al., 2012).

"Potential benefits of using BIM in FM seem to be significant (Becerik-Gerber et al., 2012) (Arayici, 2008) (Akcamete et al., 2010), e.g. as valuable 'as-built' (heritage) documentation (Eastman et al., 2011), maintenance of warranty and service information (Becerik-Gerber et al., 2012) (Arayici, 2008), (Singh et al., 2011), quality control (Boukamp and Akinci, 2007), (Akinci et al., 2006), assessment and monitoring (Eastman et al., 2011) (Becerik-Gerber et al., 2012) (Arayici, 2008), energy and space management (Becerik-Gerber et al., 2012), (Cho et al., 2010), emergency management (Arayici, 2008), or retrofit planning (Mill et al., 2013), (Arayici, 2008). To diminish errors and financial risks deconstruction processes can also take advantage from structured current building information, e.g. through deconstruction scheduling and sequencing, cost calculation, rubble management, optimization of deconstruction progress tracking or data management (Volk et al., 2013: 110).

2.3. Effects And Adaptation Process Of BIM

BIM implementation attempts reveal some advantageous points and barriers for implementing BIM. In addition, to achieve successfully implementation of BIM, companies should accomplish some organizational changes for adaptation.

2.3.1. Benefits of BIM usage

One of the most significant benefits of BIM system is improved collaboration and coordination between the project participants. Thus, strengthened information flow provides avoiding mistakes in the early phase of the project. Enhancing productivity and efficiency is the most prominent concern in the construction sector, and BIM supports this improvement by eliminating the design errors, facilitating management of processes in construction, deepening the collaboration and communication between the stakeholders and clients during construction phase (Eastman et al., 2011:19–25). BIM can support design and construction lifecycle process through enhanced quality, and efficiency (Henttinen, 2012). As a construction project includes different software tools obtained from various suppliers to conduct specific tasks (e.g. design structural analysis' project management and control) by individual parties, the demand for sharing information among the project participants has increased during the project lifecycle (Shen et al., 2009: 197-198). Shareable digital information, interoperable information systems of different stakeholders, depending on the accepted standards and apparent contract forms encourage the countries to implement BIM standards (Kubba, 2012: 220).

Parametric model of the project is prepared and used through the BIM system, so it is easier to understand project information by all the project participants and clients. Sharing data among multi-disciplinary project participants requires all participants to work on the same data model to understand and produce the project data (Shen et al., 2009: 197-198). Having a 3D model of the project with a database including all information provides practicality and usefulness instead of working on several specialized documentations such as; architecture design, landscape design, construction and installation designs as well as bills of quantities and cost estimates (Czmoch and Pekala, 2014: 212). Through a common objective model, building information can be generated once and it can be reused or enhanced during the lifecycle of the project (Shen et al., 2009: 197-198). Parametric modeling, which is

the core characteristics of the BIM technology, enable the quick evaluation of different implementations and changes in 3D model, therefore interdisciplinary decision making process and coordination are getting easier (Czmoch and Pekala, 2014: 212). Common and objective model offers reasonable solutions in heterogeneous applications and enable data sharing for AEC and FM, so repeated model creating process and errors are eliminated, and through this elimination project quality increases (Shen et al., 2009: 197-198).

In the following, there are 4 major aspects of the BIM promises frequently used in the BIM definitions, which are the qualifications included in the vision of BIM;

1) By the help of common data archive, all relative data needed in the design and construction of a building will be involved in a single BIM model or is easily available with BIM tools,

2) Enabling interoperability between data (shared with open standards like IFC)

from several native design models, BIM becomes a collaboration tool that allows new integrated ways of working.

3) BIM system and its database will be preserved and used throughout the lifecycle of the building.

4) BIM is expected to increase considerably the efficiency and productivity of the building industry (Miettinen and Paavola, 2014: 85).

Data from the research company McGraw-Hill Construction (2010) reveals that the most prominent and high-rated benefits of BIM include: reduction of the errors, entering new markets, rework reduction, creating new service for clients and reduction in deadlines respectively (Vysotskiy et al., 2015: 1144).

BIM system and lean management have parallel aims. BIM technology supports the applicability of lean management philosophy, which has the essence of elimination of all waste; continuous improvement (kaizen); manufacturing at a rate equal to true customer demand, just when the customer wants it (JIT); and ensuring quality by determining mistakes and stopping production until the causes are found and corrected (jidoka) (King, 2009: 10-11). Requirements of lean construction and aims of the BIM technology are correspond to each other. Both of the approaches need detailed planning and control of onsite activities and logistic processes (Breit et al.,

2008: 182). According to the BS 1192:2007 wasteful activities can be prevented by decreasing;

• waiting and searching for information;

• over-production of information with no defined use;

• over-processing information, simply because the technology can; and

• defects, caused by poor co-ordination across the graphical and non-graphical data set which require rework (PAS 1192-2: 2013).

The built environment seriously affects the environment, economy and society. To minimize the negative impacts of construction industry sustainable construction should be implemented, and BIM standards facilitates to implement sustainable construction. Construction waste generation has been determined as a primary issue as a result of its effects on the environment (Formoso et al., 2002). "Buildings are the largest consumers of energy and greatest contributors to climate change in the United States; the building sector consumes approximately 49% of energy produced in the U.S. and contributes close to 47% of greenhouse gas emissions." (United States EIA, 2011) Sustainable construction can be defined as providing effective social and economic development while keeping the negative environmental impact at the lowest level (Hakkinen and Kiviniemi, 2008). Using BIM system improves the overall information flow, therefore collaborative work and communication develops between stakeholders and this results waste reduction (HM Government, 2008). Energy consumption, waste water, maintenance cost or recyclability criteria and considerations can be monitored through BIM use, and due to these adjustments represented environmental effects are enlarged, further consumption and emission values of certified structures are verified (Volk et al., 2013: 123). The energy efficiency of a building can be evaluated as equipment and the structure of the building is determined and completed in traditional method (Cao et al., 2015: 450), with the BIM use it is easier to optimize them regularly for the purpose of energy saving.

2.3.2. Difficulties about the use of BIM

Adapting a new system and required implementations of it seems as a burden to construction companies. Due to disruptive nature of the construction industry,

learning new technologies and adapting to their implementations can be a difficult task for employees (Tulenheimo, 2015: 471). Most of the companies resist the changes at the early stages of a new technology because of the complexity of the adaptation process. For instance, purchasing fast developing BIM software and training users about this new technology requires an additional cost and effort. Many years ago AutoCAD software got similar reaction, but it is now became traditional CAD software (Tulenheimo, 2015: 473). Adaptation of BIM technology necessitates companies to make organizational changes such as; investing in BIM technology and training their staff, thereby they can become BIM competent (Brynjolfsson and Saunders, 2010; Lindblad and Vass, 2015: 180). Tulenheimo (2015) argues that especially small firms do not tend to acquire resources to implement BIM technology because of the additional investment cost and the adaptation process. Consequently, companies may recede to shift their system to BIM technology because of the necessities of BIM adaptation process.

Another one of the main obstacles about BIM usage is that there is a gap between the BIM perception and real BIM. BIM awareness level is not satisfactory in the sector. Customers do not always know what they want and need, so they may not want to pay for new technologies (Tulenheimo, 2015: 471). Many contractor firms suppose the BIM technology as a 3D model tool, and check the clashes. If the scope of BIM technology is totally understood, industry players may eager to transform their traditional construction system to BIM method, and they can ignore the effort and cost in the adaptation process.

The fragmented structure of the construction industry makes difficult to provide BIM adaptation and integration of project teams. In construction industry, project organization may change one project to other. Required BIM maturity level and understanding of BIM tools by stakeholders may change in each project. It is expected that the implementation of BIM technology improves the coordination and collaboration in project teams (Eastman et al., 2011). However, according to the (Volk et al., 2013), BIM use have not reduced the problems of working together in design and construction teams. “Fragmentation is still one of the main obstacles in the industry that has to be solved locally in each building project. The uses of different team integration mechanisms are also attempts to decrease the effects of fragmentation in design and construction teams.” (Kerosuo, 2015: 202).

Other difficulty to implement BIM technology is that project participants should work on the same level of BIM technology, and create building model in same LOD. There are different levels of BIM and to work in a BIM project coordinated, every project participant should meet the same agreed level, so necessary technology implementations should be agreed accordingly (Tulenheimo, 2015: 471). Compromising about working on the same level of detail and compatible software can be a challenge for industry players, but the conditions should be identified completely in the contract.

BIM is gaining momentum in the construction industry, however, for site operations there are more demands as generating consistent data model, powerful procedures to change the processes, and as built documentation (Bargstäd, 2015: 59). Mostly, updating BIM use during the construction phase cause disputes, and a recent research (Volk et. al., 2013: 122) results show that owners, facility managers and deconstructors are barely involved in the BIM functionality development (Miettinen and Paavola, 2014: 86).

In the Figure 2.3, Tulenheimo grouped the 23 factors that can block the successful implementation of BIM under the 5 main titles as customer, company, social aspects, technology and supporting elements.

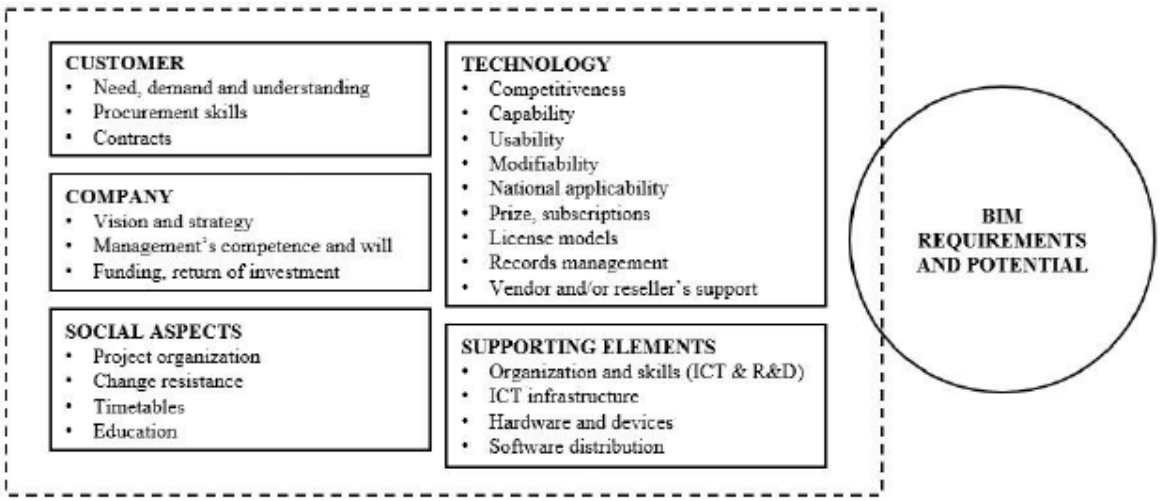


Figure 2.3: Key challenges of implementing new technologies in the world of BIM (Tulenheimo, 2015: 475).

2.3.3. Adaptation of BIM

Companies should innovate some changes within their company to successfully adopt BIM procedures. According to the Succar (2010) in order to implement BIM

successfully, and make use of its potential benefits, users should know how the implementation of BIM is dependent upon conducting the necessary changes in the organization (Lindblad and Vass, 2015: 180). In a similar way, Froese (2010) argues that project participants are required to practice and gain ability and make changes in the organization to use BIM with its full potential (Lindblad and Vass, 2015: 180). In more advanced level of BIM implementations, inter-organizational cooperation will be targeted, and organizational changes should be applied collectively between disciplines (Succar, 2009).

One of the most significant changes that will help to transform project delivery system to BIM process is investing in IT. Companies should develop new business processes and conceive advanced forms of organizational funds which can be decentralizing decision-making process, inventive information sharing methods, establishing economic motivation and investing in IT training (Brynjolfsson and Saunders, 2010) (Lindblad and Vass, 2015: 180). Brynjolfsson & Hitt define how information technology helps the improvement of the organizations' business and work process, further by such changes productivity can be raised (Lindblad and Vass, 2015: 180).

Investing in IT technologies increases the productivity if the adaptation is achieved to this new technology. Creating the appropriate conditions to successfully implement BIM technology requires some important changes which are on management systems, assessments of BIM, BIM skills and expertise and BIM training and resources (Lindblad and Vass, 2015: 181). In order for IT to reach its full potential; firms must make changes to their organizations and their business processes and work practices such as; revising organizational roles and responsibilities, awaring of the importance of providing leadership for IT (Venkatraman, 1994). However, IT changes made to the business processes and work practices should integrated within the organization and include the network of partners of the organization, because the benefits of IT can be obtained completely only once the changes include the organizations network of partners (Lindblad and Vass, 2015: 180). Establishing construction project team within the company, and the degree of their integration changes due to the adopted team practices and procurement approaches (Baiden et al., 2006). Therefore, partners of the organizations and employees should participate to this process, and they should be

qualified about the BIM methods and mechanism of procedures. The more the companies increase the training about the BIM system, the more qualification can be gained within the organization.

3. RESEARCH METHODS

The aims of this research are

- Investigation of the effective use of BIM in all stages of the construction project management
- Determining the strategies for widespread use of BIM in the construction industry
- Identification of organizational changes required in the BIM implementation

This dissertation has been written in İstanbul, Turkey in 2016. The aims, objectives and research methods have been provided in Table 3.1. To realize these goals, 18 experienced BIM experts have participated to this study. Survey has been conducted with 18 respondent companies, and 12 of them could attended to face-to-face interview up to their availability. The interviews were structured interviews. The survey questions have been provided in the Appendix 1. The interview questions provided information on:

- Professional experience and position (Q's 1,2,3)
- Scale and type of the analyzed project (Q's 4,5,6)
- BIM usage level on the project phases (Q7)
- Difficulties experienced with the BIM usage (Q8)
- Preferred way and organizational changes for BIM adaptation (Qs 9,10)
- Observation on subcontractors' and supply chain's adaptation (Q11)
- Effect of BIM usage on disputes between the project parties (Q12)
- BIM effect on cost, time, quality, sustainability, waste management, variation order, bidding process and design process performances of the project (Qs 13,14,15,16,17,18,19,20,21,22)
- Positive BIM effect on waste reduction in terms of sustainability and leanness (Qs 23&24)
- Motivating factors for BIM adoption (Q25)
- The advantages of the use of BIM (Qs 26&27)

- The disadvantages of the use of BIM (Qs 28&29)
- Incentive factors which may promote the use of BIM in Turkish construction industry (Q30)

The research aims, objectives and methods are shown in the Table 3.1.

Table 3.1: The aim, objectives and the methods of the project.

AIMS	OBJECTIVES	METHODS
Investigation of the effective use of BIM in all stages of the construction project management	Use of BIM at pre-construction phase	• Literature review • Structured interviews • Survey
	Use of BIM at construction phase	• Literature review • Structured interviews • Survey
	Use of BIM at post-construction phase	• Literature review • Structured interviews • Survey
Determining the strategies for widespread use of BIM in the construction industry	Determining the advantages that BIM use can bring	• Literature review • Structured interviews • Survey
	Determining the disadvantages that BIM use can bring	• Literature review • Structured interviews • Survey
	Examination of BIM strategy of countries that have pioneered the widespread use	• Literature review • Structured interviews • Survey
Identification of organizational changes required in the BIM implementation	Investigate the effects of changes about way of doing business to the organization	• Literature review • Structured interviews • Survey
	Transformation of contracts with BIM	• Literature review • Structured interviews • Survey
	Constitute of the supply chain that is compatible and authorized about BIM	• Literature review • Structured interviews • Survey

4. DATA OBTAINED THROUGH THE RESEARCH

In this section, research analysis is presented through the structured survey and interviews.

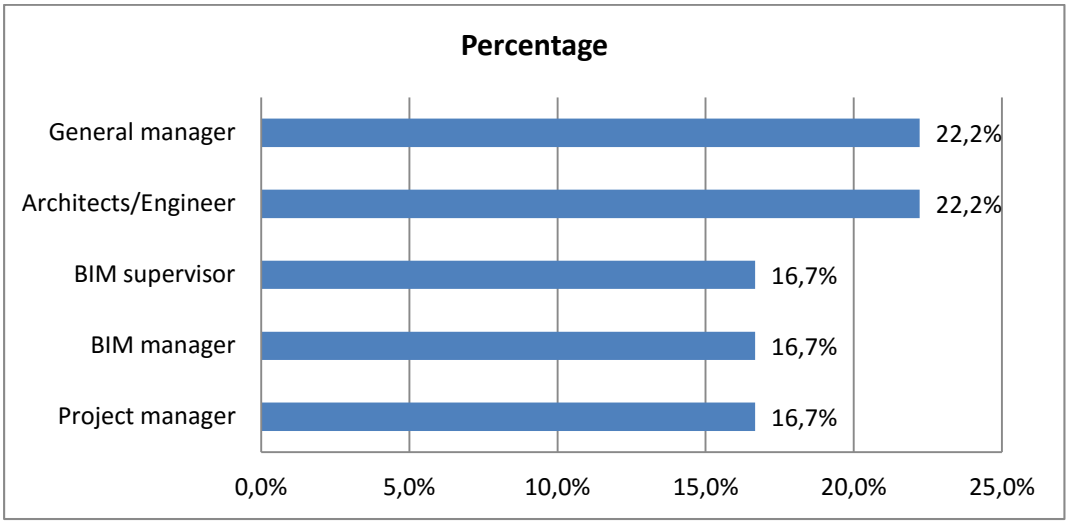
4.1. Data Obtained Through The Survey Analysis

The survey questions were prepared to evaluate the use of BIM in Turkish construction industry. Questions are mostly designed to emerge the impact of BIM on project management areas. Questions are concentrated on effects of BIM on topics, such as; cost, time, quality, sustainability, lean management, organizational changes etc. In overall, total of 18 people – workers from different type of companies and at different level of status - answered these questions. Respondents filled out the survey based on a project that their company produced it with BIM. However, they left unanswered some questions which fall outside of their expertise area. These questions were shown according to their percentage rate.

Q1) Respondent's position in the company:

BIM survey was answered by a total of 18 architects and engineers who are working on different positions. Among these different positions; 4 of them are "company managers", 3 of them are "project managers", 3 of them "BIM managers", 3 of them "BIM supervisors", while the other 4 consist of "architects/engineers" as seen in the Table 4.1.

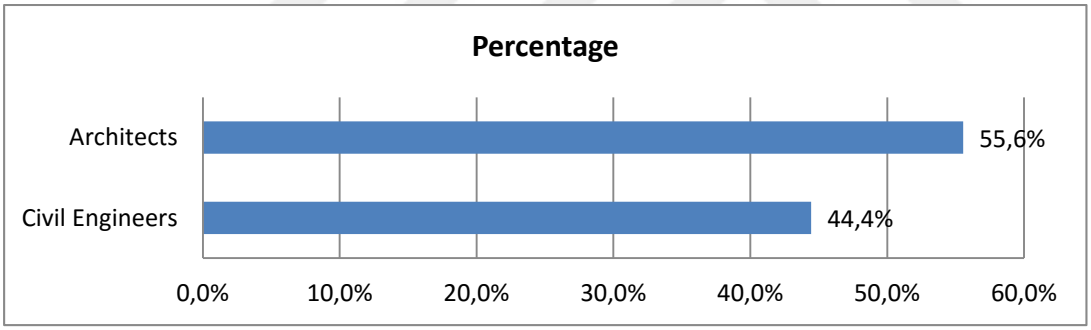
Table 4.1: Respondent's position in the company



Q2) Respondent's profession:

10 of the respondents were architects(56%), and 8 of the respondents were civil engineers(44%) in the survey as seen in the Table 4.2.

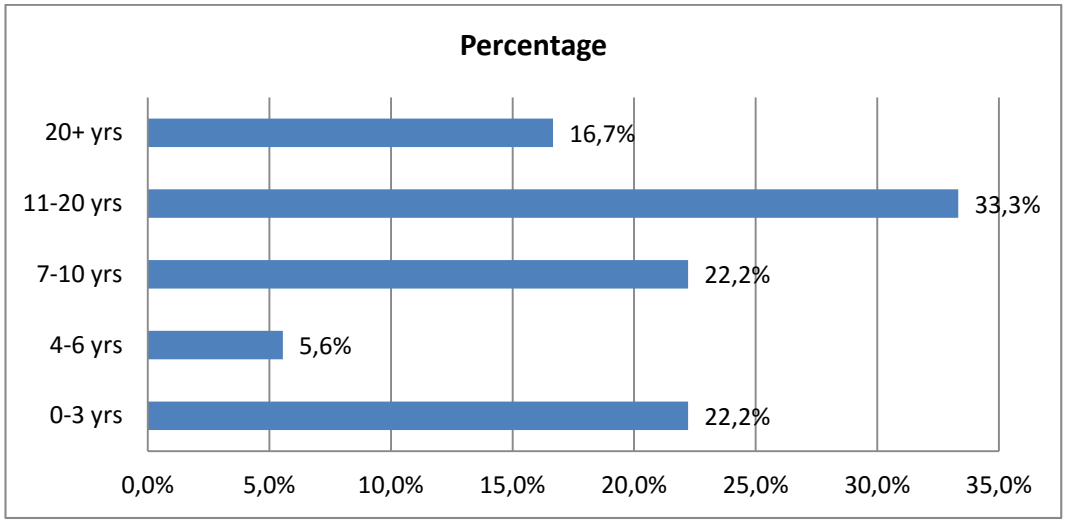
Table 4.2: Respondent's profession



Q3) Respondents' experience in the construction industry:

13 (72%) of the respondents working in construction industry more than 7 years. 6 (%33) of them working between 11-20 years, and 3 (17%) of them are working 20+ years as seen in the Table 4.3.

Table 4.3: Respondent's experience in the construction industry

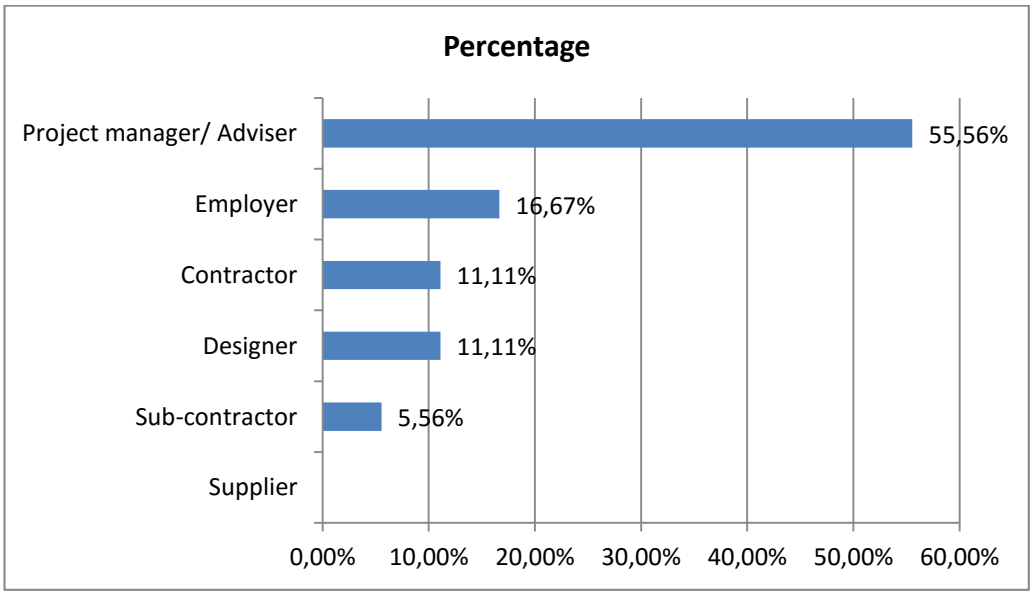


Information of the analyzed project…

Q4) Role of the respondent's company in the BIM project:

While the 10 (56%) of respondents are "project manager" in the survey, there are different answers recorded by companies which are in charge of "employer", "contractor", "sub-contractor" or "designer" as seen in the Table 4.4.

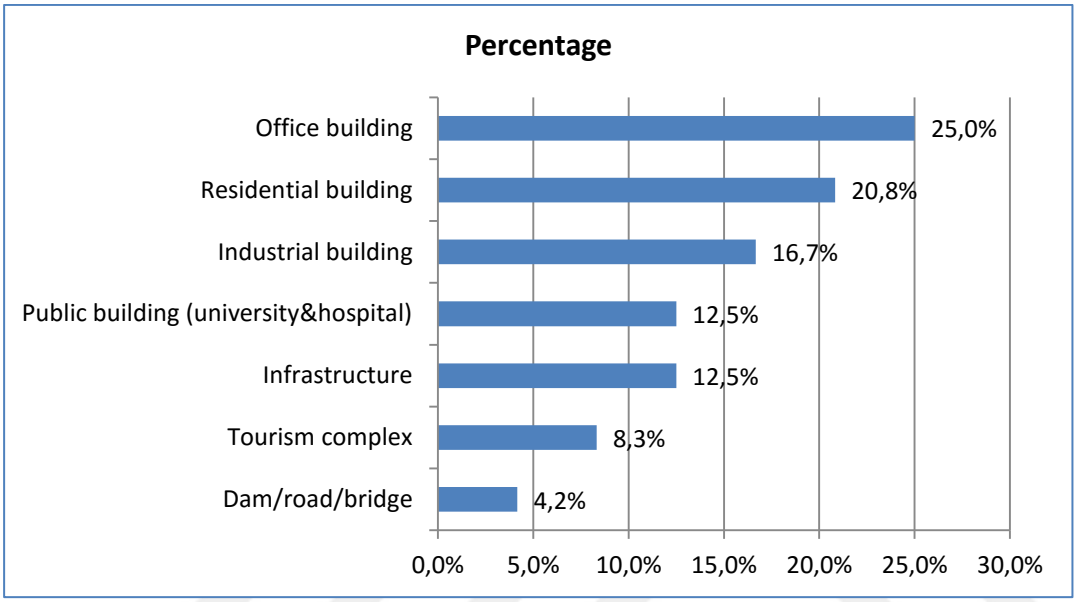
Table 4.4: Role of the respondent's company in the BIM project



Q5) Type of the project:

Respondents' companies are involved in many different project types. However, most of the construction types are "office buildings" (25%) and "residential buildings"(21%) that are built with BIM. Table 4.5 shows the BIM project types.

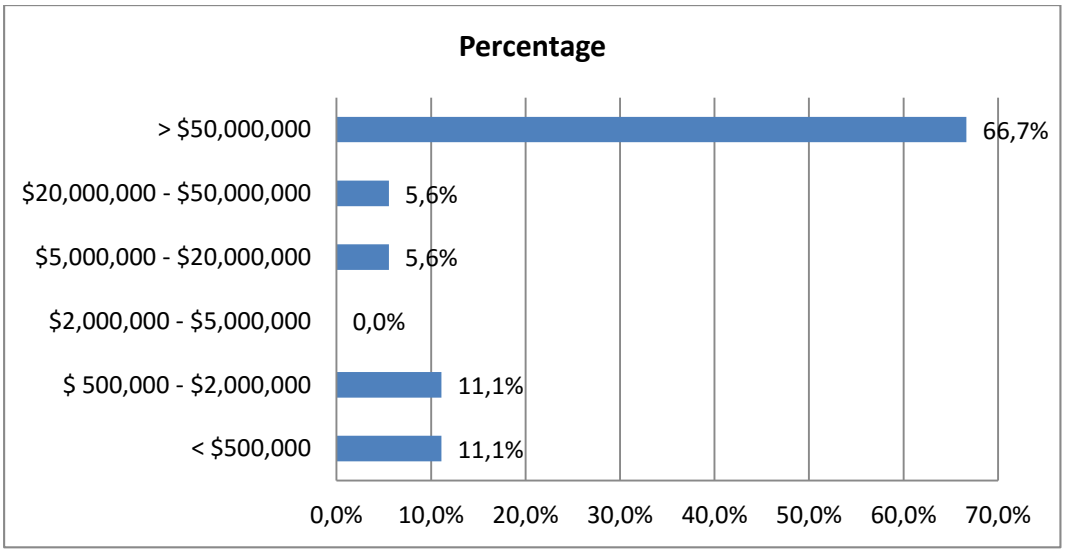
Table 4.5: Type of the project



Q6) Budget of the project:

Overall, the BIM technology is preferred to use in large-scale projects as seen in the Table 4.6 (budget over $50,000,000).

Table 4.6: Budget of the project



Q7) BIM has been used in following phases: (Multiple options can be marked.)

BIM technology is mostly used on “pre-construction phase” and in “design phase” as seen in the Table 4.7a. Table 4.7b shows that the construction companies in Turkey, mostly prefer to use BIM in the design phase, because the general opinion about the advantage of BIM is analyzing clash-detection through 3D models of the project. Furthermore, respondents emphasized that ‘interdisciplinery coordination’ became easier in every phase of the project.

Table 4.7a: BIM has been used in following phases

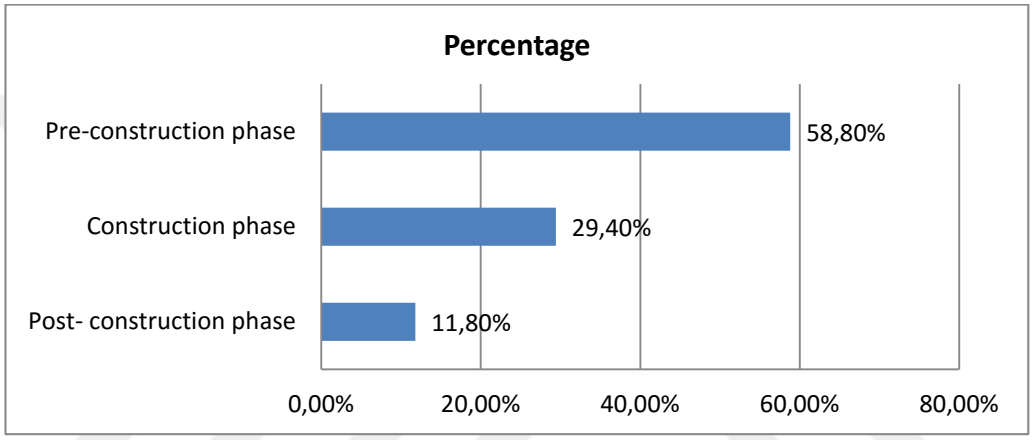
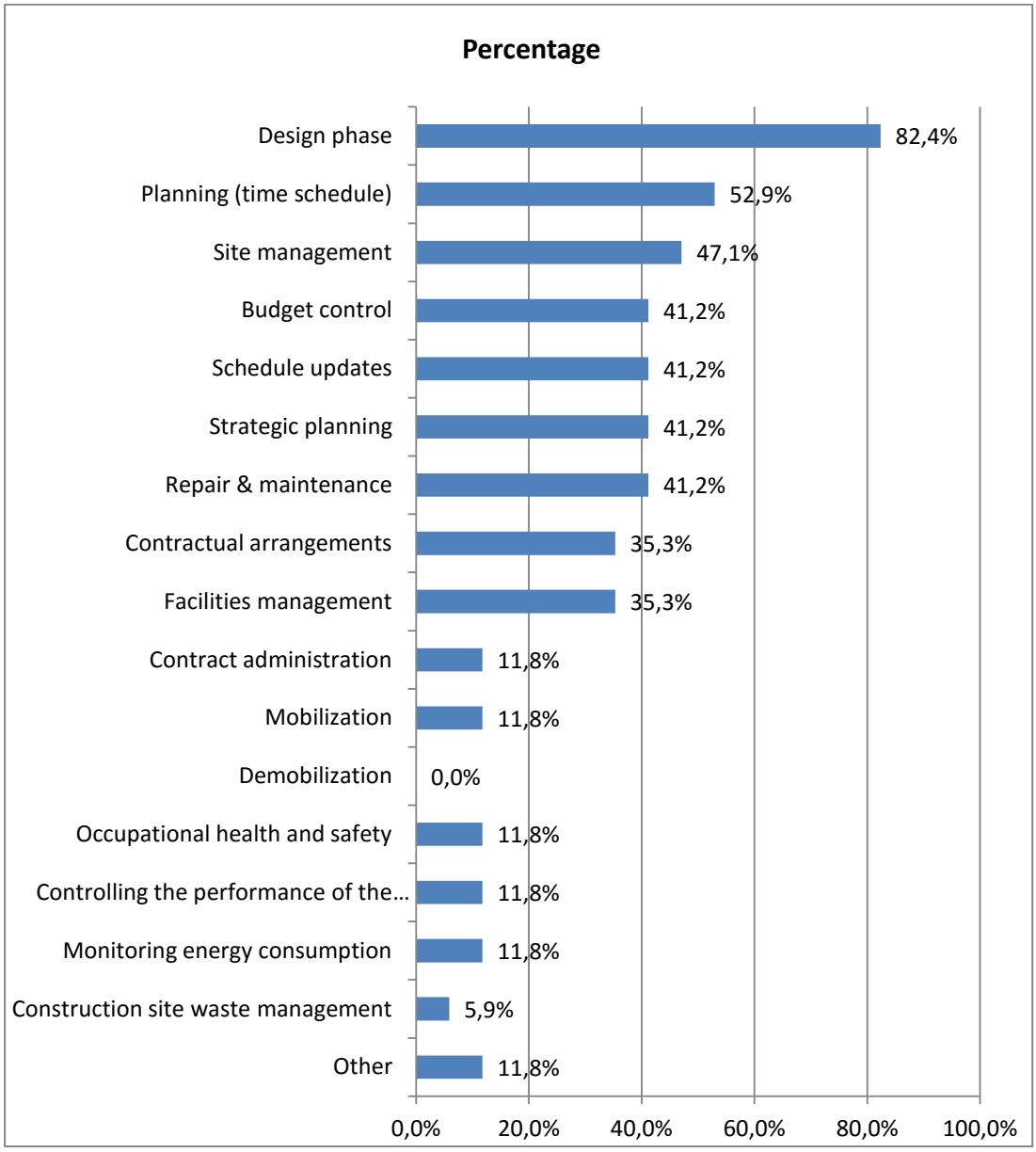


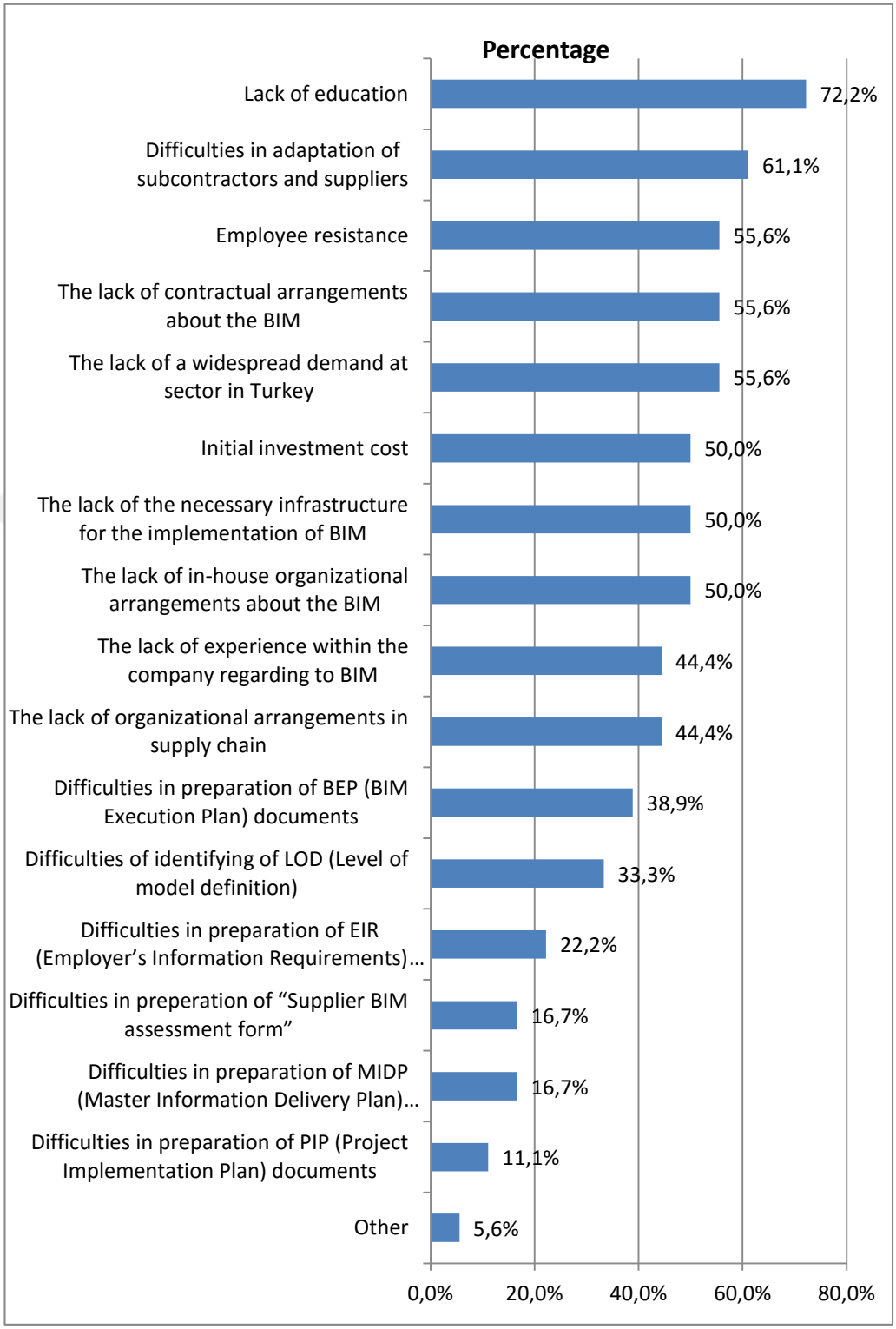
Table 4.7b: BIM has been used in following phases



Q8) Following difficulties experienced in the use of BIM: (Multiple options can be marked.)

When the survey results analyzed, it is determined that “lack of education”, “adaptation of subcontractors and suppliers” and “employee resistance” are the biggest difficulties in the use of BIM as seen in the Table 4.8.

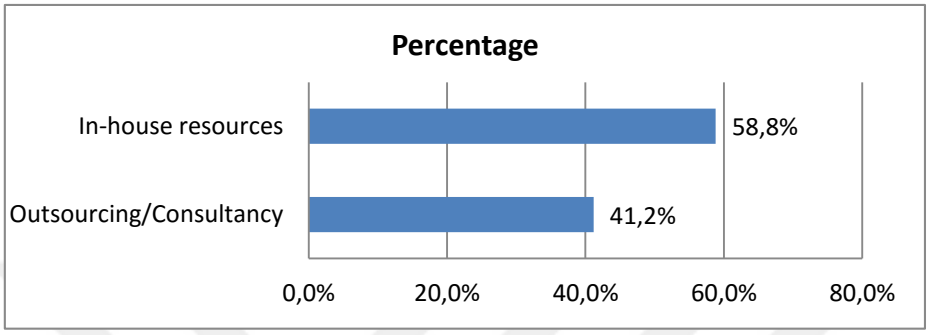
Table 4.8: Difficulties experienced in the use of BIM



Q9) Companies' preferred way while setting up BIM:

Even the companies those prefer "in-house resourcing" are little ahead according to the Table 4.9; usually these companies are hiring new employees who are experienced on BIM. Thus, it can be said that companies get support from informed and experienced employees.

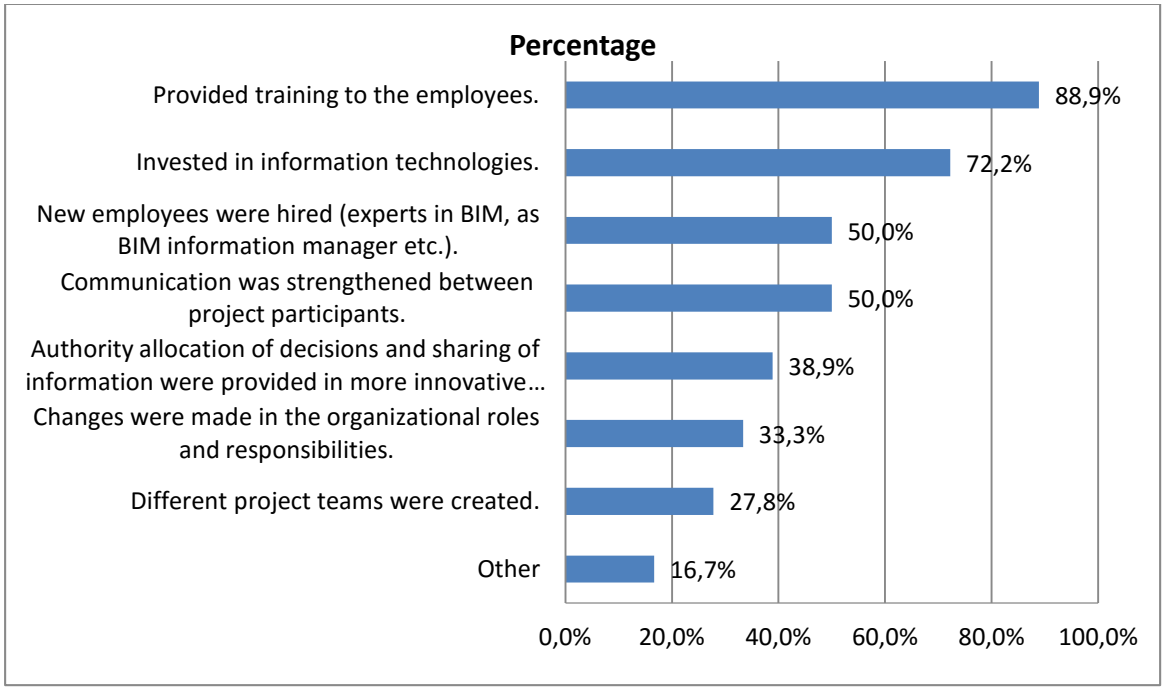
Table 4.9: Companies' preferred way while setting up BIM



Q10) Administrative and organizational changes that have been made for the implementation of BIM: (Multiple options can be marked.)

General approach for implementing BIM technology is make an organizational change by "providing training to the employees". "Investing in new Technologies" and "hiring experienced employees" are also found approval by companies according to the Table 4.10.

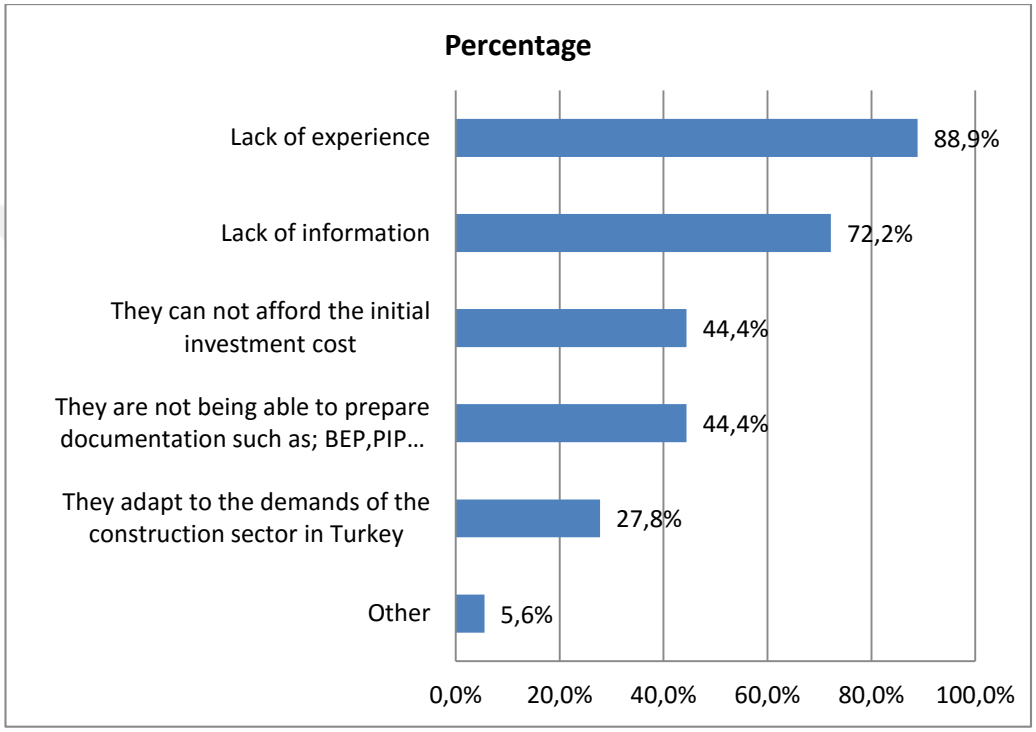
Table 4.10: Administrative and organizational changes that have been made for the implementation of BIM



Q11) Respondent's observations about the supply chains' / subcontractors' adaptation of BIM: (Multiple options can be marked.)

According to the construction industry workers, the most obvious problems about sub-contractors' and suppliers' adaptation are "lack of experience" and "lack of information". In addition, "initial investment cost" is a deterrent factor. The "other" option includes the "lack of organizational structure" and "lack of job description".

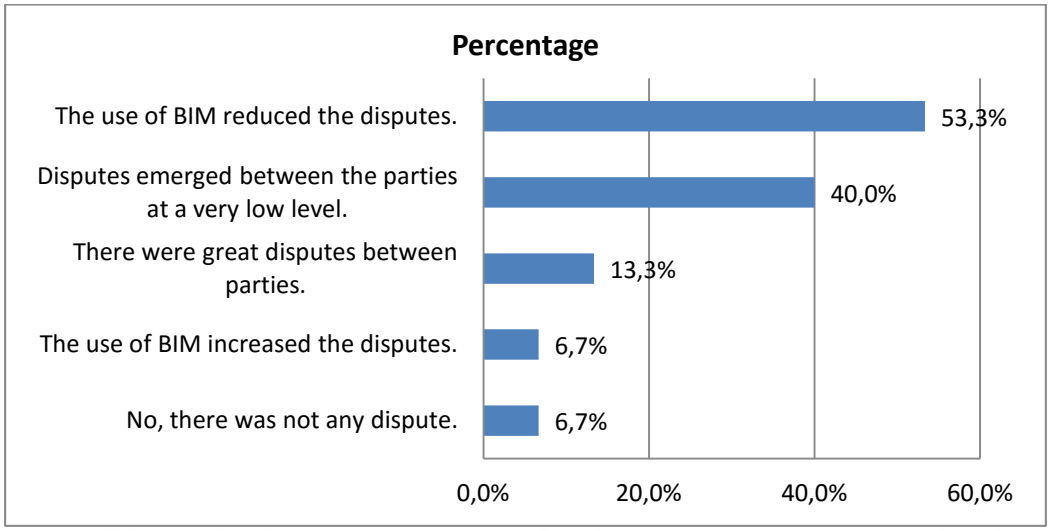
Table 4.11: Respondent's observations about the supply chains' / subcontractors' adaptation of BIM



Q12) Respondent's perception about the BIM effect on disputes which arise between the parties during the project: (Multiple options can be marked.

According to the respondents, having little disputes during construction project is a common thing. However, high rate of responses show that using BIM technology reduced disputes between parties as seen in the Table 4.12.

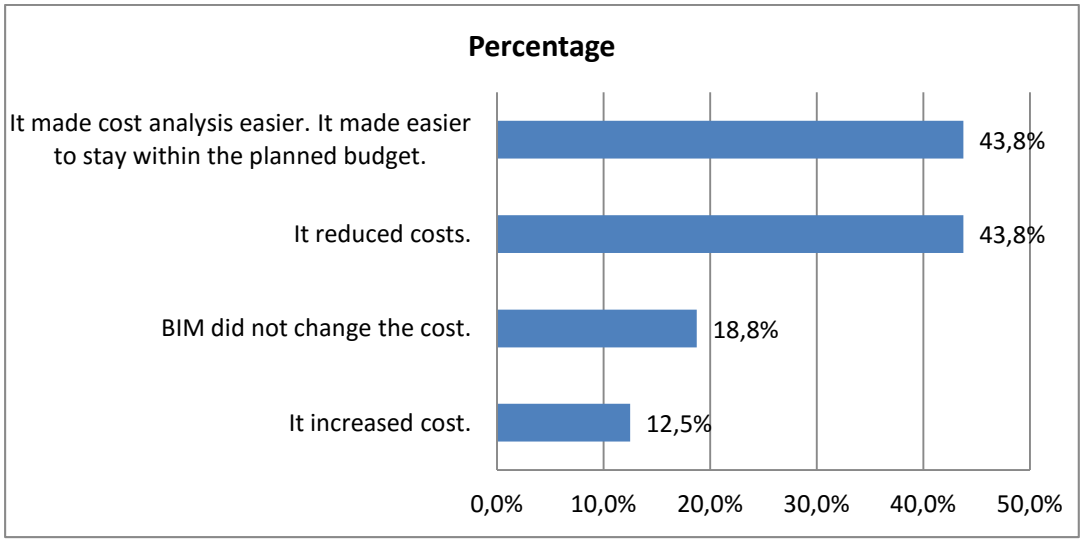
Table 4.12: Respondent's perception about the BIM effect on disputes which arise between the parties during the project



Q13) Respondent's perception about the BIM effect on the COST performance of the construction project: (Multiple options can be marked.)

Some BIM users do not believe that BIM can bring significant cost benefit. However, according to the Table 4.13, most of the BIM users experienced that BIM affected the cost performance positively. BIM provided to make cost analysis easier.

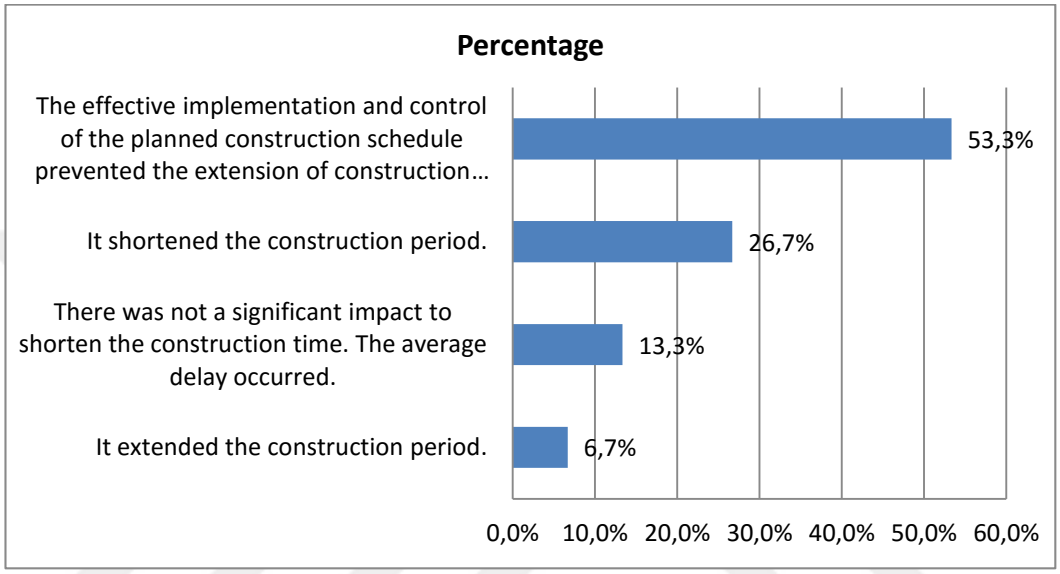
Table 4.13: Respondent's perception about the BIM effect on the "cost" performance of the construction project



Q14) Respondent's perception about the BIM effect on the TIME performance of the construction project:

Many of the BIM users do not think that BIM shortens the project duration. However, Table 4.14 shows that BIM provided monitoring of work schedule more effectively, so it prevented the delays.

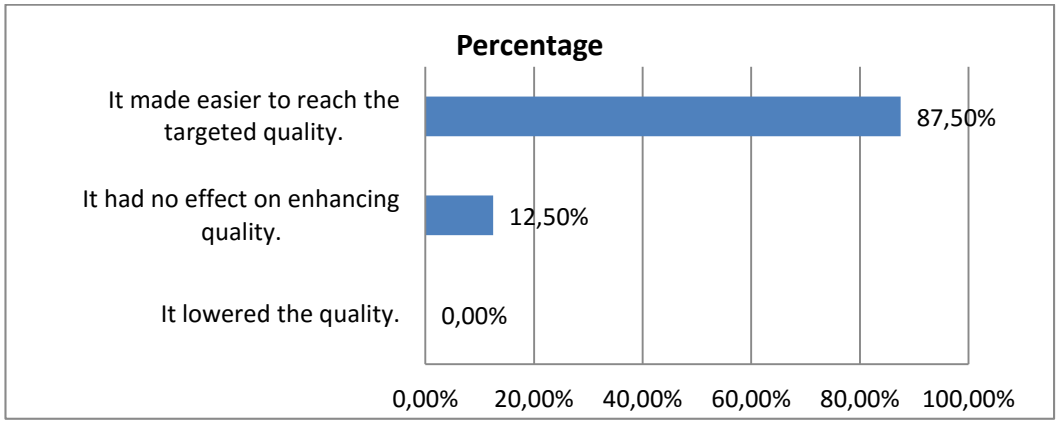
Table 4.14: Respondent's perception about the BIM effect on the "time" performance of the construction project



Q15) Respondent's perception about the BIM effect on the QUALITY performance of the construction project:

Most of the BIM users think that BIM made easier to reach the targeted quality as seen in the Table 4.15.

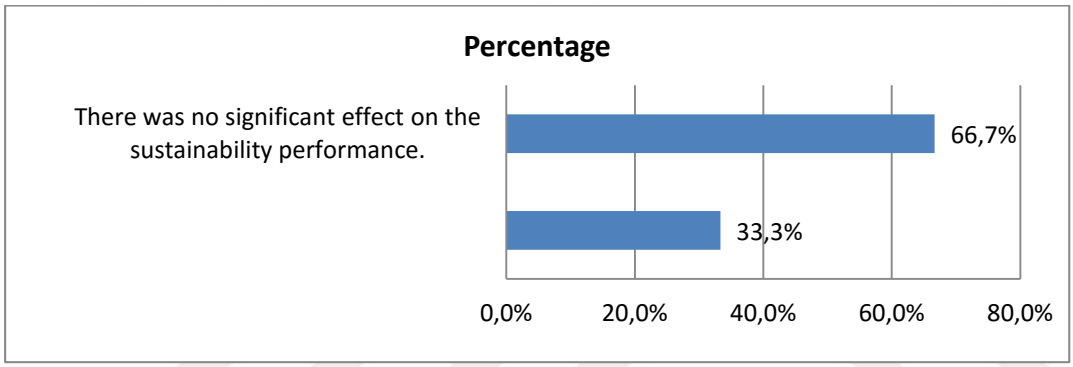
Table 4.15: Respondent's perception about the BIM effect on the "quality" performance of the construction project



Q16) Respondent's perception about the BIM effect on the SUSTAINABILITY performance of the construction project:

12 respondents answered this question. They evaluated the BIM as a separate concept than sustainability. General approach was stating that there is no connection between BIM technology and sustainability. As it can be seen in Table 4.16, many of the construction industry workers (67%) think that BIM does not affect the sustainability performance. However, rest of the respondents (33%) argued that a well-established relationship can be established between the BIM and the sustainability concepts through improvement in waste management.

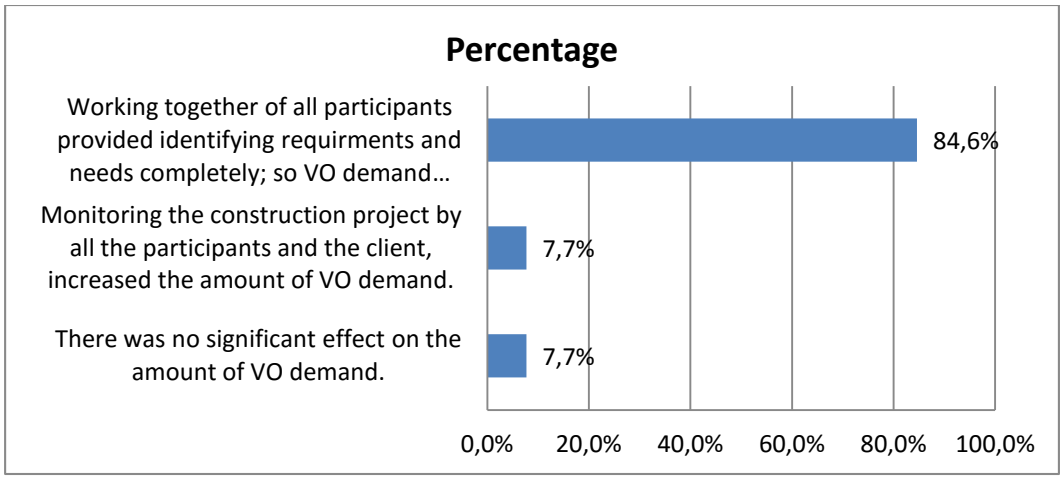
Table 4.16: Respondent's perception about the BIM effect on the "sustainability" performance of the construction project



Q17) Respondent's perception about the BIM effect on 'Variation Order' demand of construction projects:

13 respondents answered this question. Almost all of the respondents agree that BIM reduced the VO demand in the project as seen in the Table 4.17.

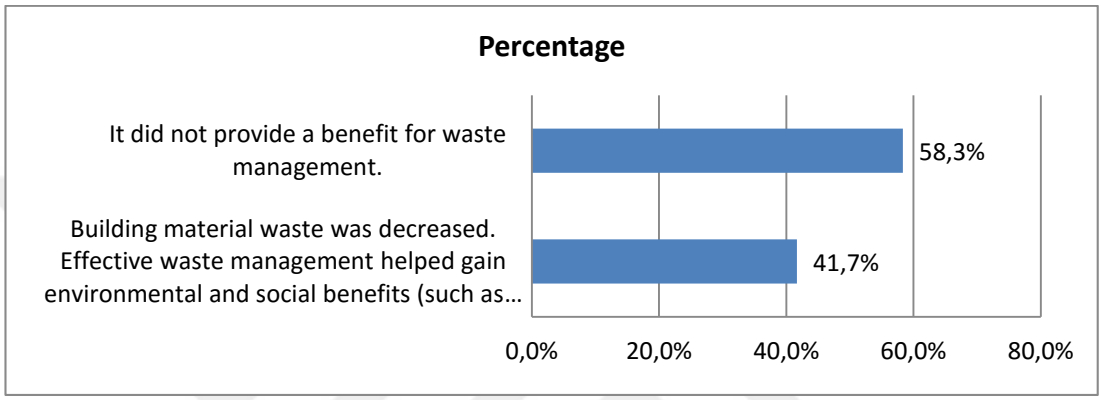
Table 4.17: Respondent's perception about the BIM effect on 'Variation Order' demand of construction projects



Q18) Respondent's perception about the BIM effect on the WASTE MANAGEMENT (in terms of sustainability) of the construction project:

12 respondents answered this question. According to the answers; there are no adequate parameters to monitor the waste management efficiently. Thus, the survey results are close to each other. However, majority (58%) thinks that BIM did not provide a benefit for waste management as seen in the Table 4.18.

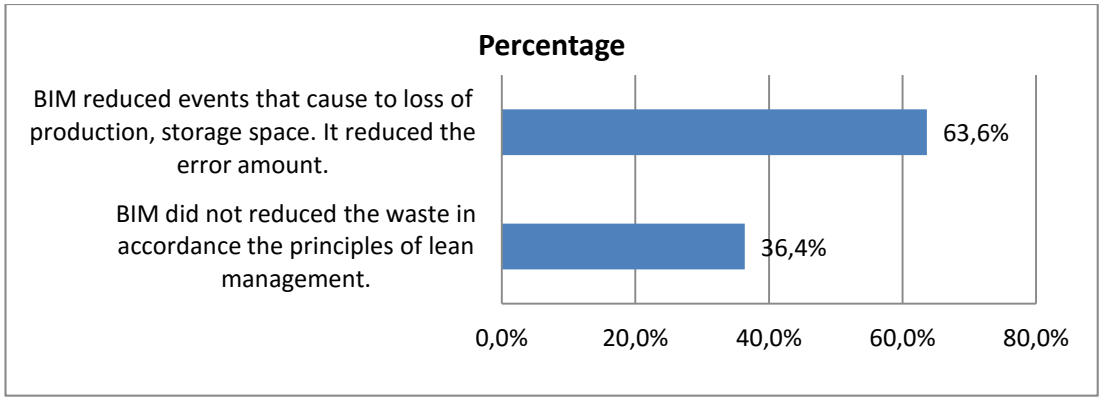
Table 4.18: Respondent's perception about the BIM effect on the "waste management" (in terms of sustainability) of the construction project



Q19) Respondent's perception about the BIM effect on the WASTE MANAGEMENT (in terms of lean management) of the construction project:

11 respondents answered this question. 7 of the respondents (63,6%) thinks that BIM provide reduction in waste in terms of lean management principles as seen in the Table 4.19.

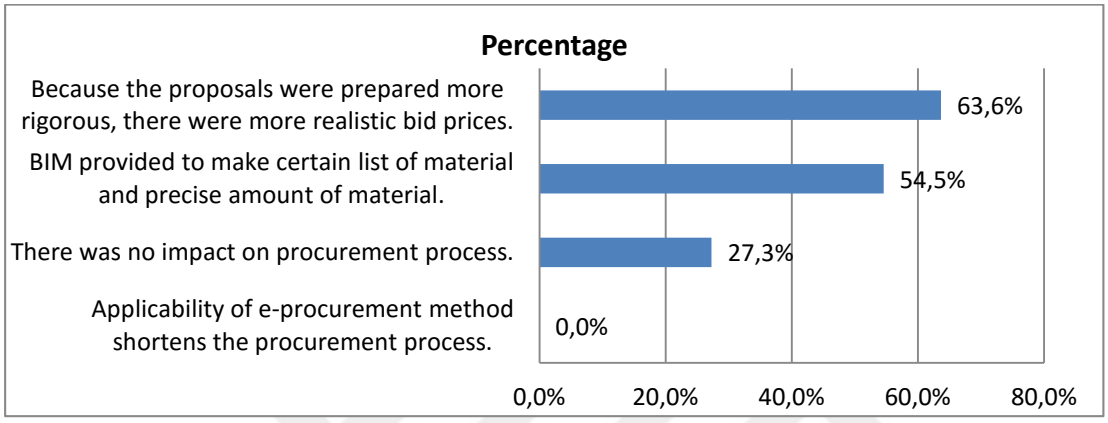
Table 4.19: Respondent's perception about the BIM effect on the "waste management" (in terms of lean management) of the construction project



Q20) Respondent's perception about the BIM effect on the BIDDING PROCESS of the construction project (Multiple options can be marked.)

According to the results, majority thinks that BIM made easier the "bidding process" as it can be seen in the Table 4.20. Preparing detailed and certain materials lists helped to submit more realistic bids.

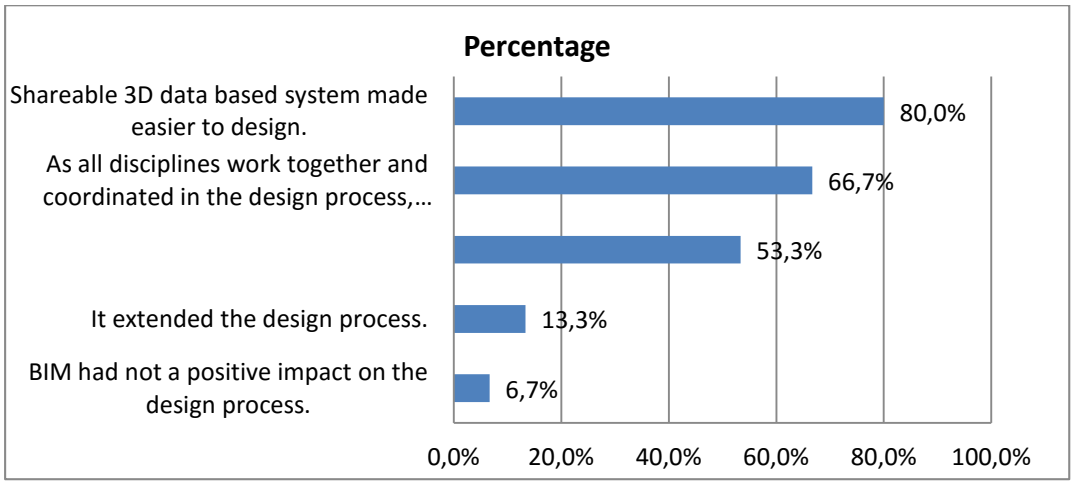
Table 4.20: Respondent's perception about the BIM effect on the "bidding process" of the construction project



Q21) Respondent's perception about the BIM effect on the DESIGN PROCESS of the construction project: (Multiple options can be marked.)

According to the Table 4.21, majority of the respondents agreed about that BIM provided to have more efficient design process. Shareable 3D data system, inter-disciplinary coordination and better collaboration with client provided significant benefit in design process. Thus, it is obvious that BIM provides an important contribution to the design phase.

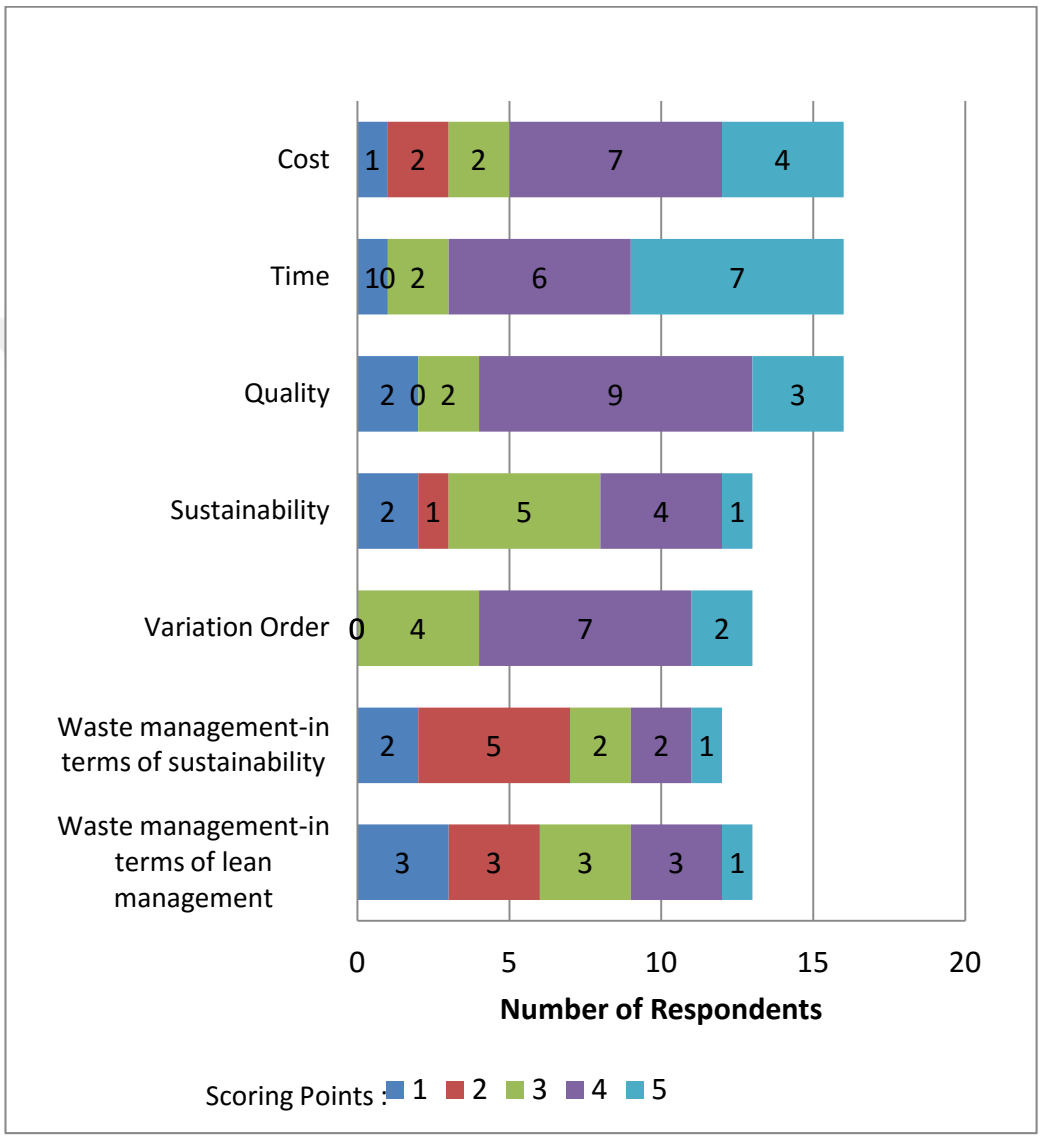
Table 4.21: Respondent's perception about the BIM effect on the "design process" of the construction project



Q22) Evaluation of following factors' performances on BIM:

Respondents' evaluation about the effect of BIM on the following project performances are demonstrated on the Table 4.22.

Table 4.22: Evaluation of following factors' performances on BIM

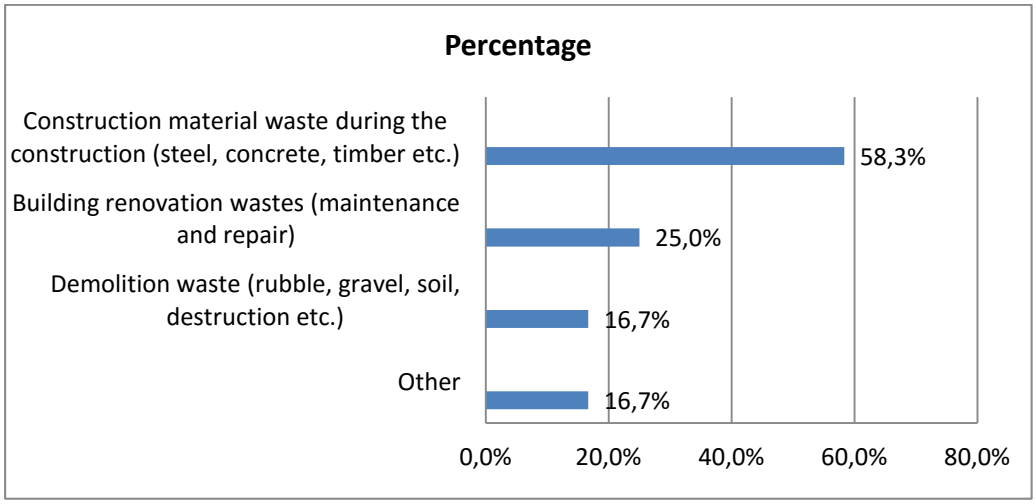


Q23) BIM use reduced the construction waste in:

(Multiple options can be marked.)

Most of the BIM users indicated that using BIM technology reduced the construction material waste during the construction as seen in the Table 4.23. Other option involves the installation works and finishing works.

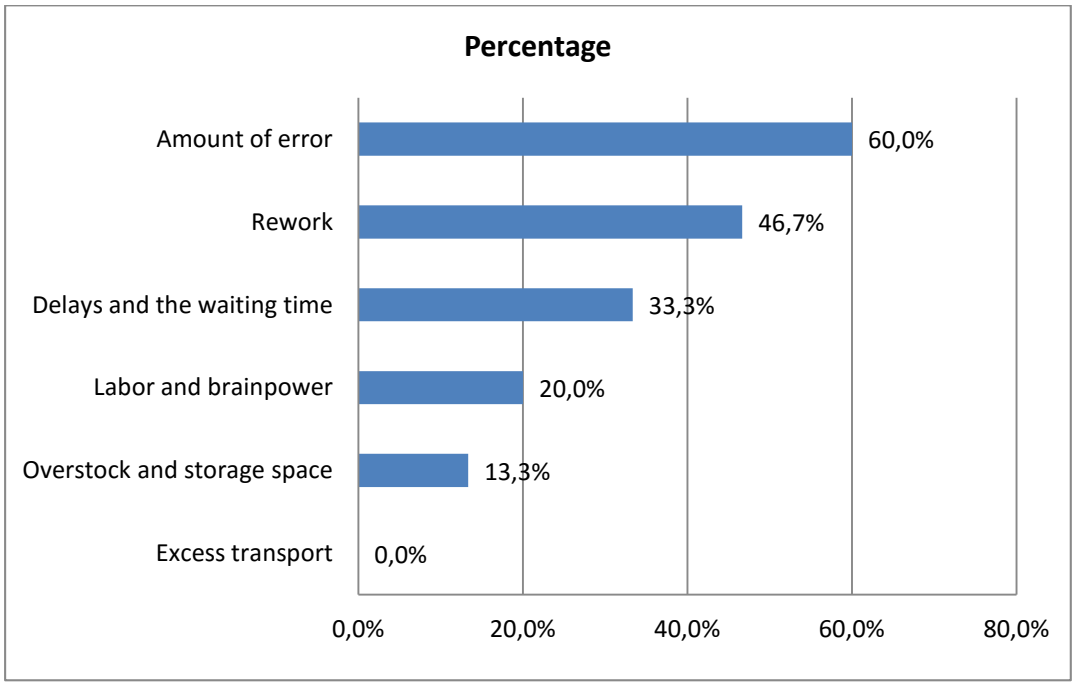
Table 4.23: Reduced construction wastes through the BIM use in terms of sustainability



Q24) Following waste was saved through BIM use, during the all events that led to waste in the construction process: (Multiple options can be marked.)

According to the Table 4.24, majority of respondents represented BIM use has contributed to the reduction of error amount. Especially, BIM prevented the implementation of erroneous project details in pre-construction phase. Thus, BIM reduced the wastes that may arise during construction phase.

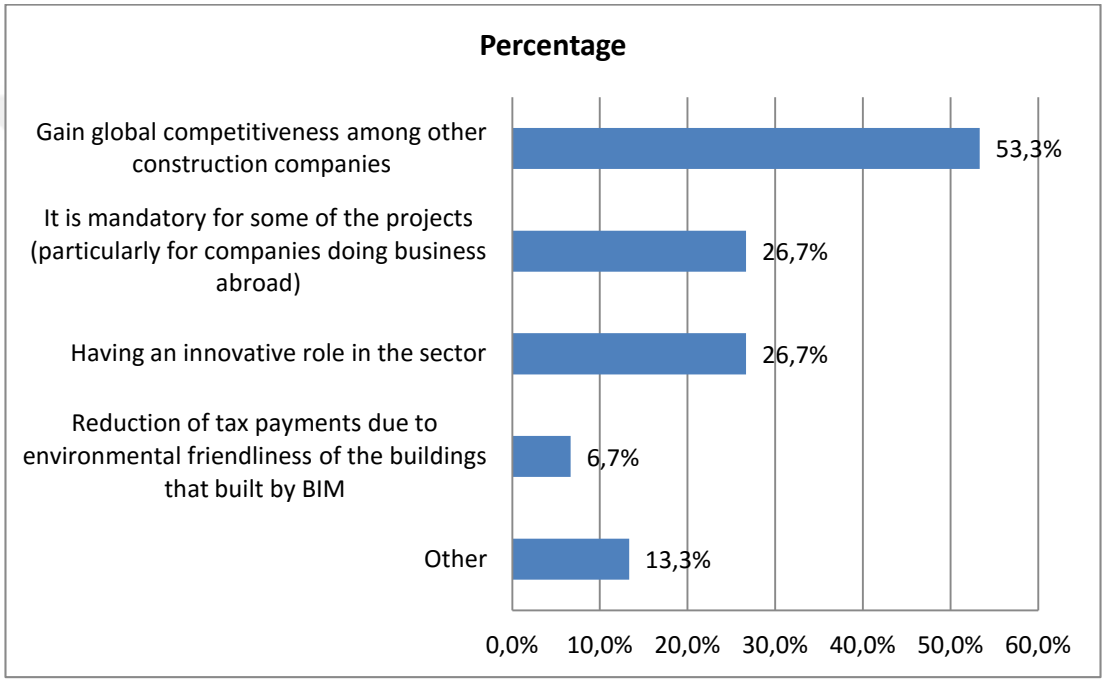
Table 4.24: Saved wastes through BIM use in terms of lean management



Q25) According to the respondents, the motivating factors for a company to use BIM: (Multiple options can be marked.)

Gaining global competitiveness among other construction companies is the most prominent motivating factor in the Turkish construction industry. Furthermore, having an innovative role in the sector and being mandatory of using BIM in some projects are driving factors that lead to the use of BIM, as it can be seen in the Table 4.25. Other option involves having a vision of company managers and improving planning capabilities in the company.

Table 4.25: Motivating factors for a company to use BIM



General opinions about BIM;

Mark each option according to its importance level.

Q26) The advantages of the use of BIM in construction projects:

(Score the factors; 5 for the factor that provide biggest advantage, and 1 for the minimum benefits that you think.)

This question was structured based on scoring system. Each offer was scored by the respondents due to their satisfaction and thought about BIM from 1 to 5 points. The histogram data was created according to the average weighted of total score for each offer.

Table 4.26: Advantages of the use of BIM in construction projects

Q27) Specified advantages that brought by the use of BIM in construction process:

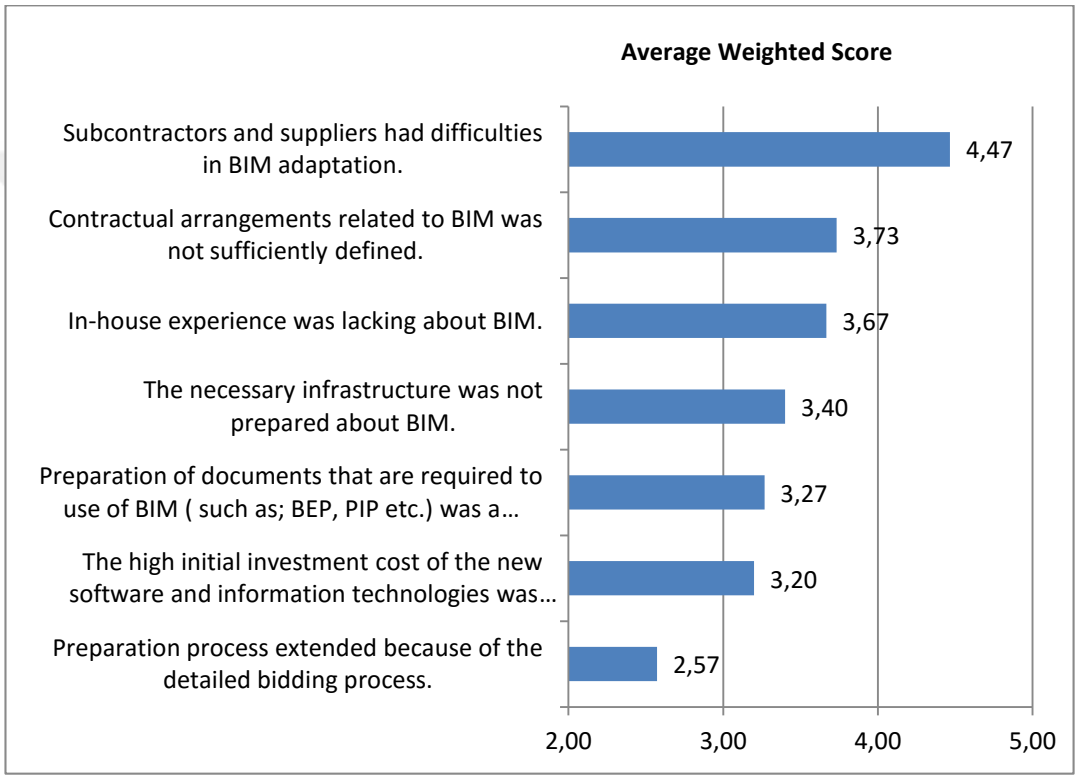
The answers of this question are independent than each other and reflects respondent's ideas.

- Errors are identified through clash detections in pre construction phase, so demolition and destruction is decreased.
- The cost and the time factor can be kept under control at all stages.
- It is only way to secure and deliver projects.
- The impact of a change in the design can be analyzed faster and more accurate.
- BIM should be used widespread especially in large-scale projects, because it eases the project management

Q28) The disadvantages encountered by the use of BIM in construction projects: (Score factors; 5 for the factor that cause the biggest disadvantage and 1 for the minimum disadvantage that you think.)

This question was structured based on scoring system. Each offer was scored by the respondents due to their satisfaction and thought about BIM (from 1 to 5 points). The histogram data was created according to the average weighted of total score for each offer.

Table 4.28: Encountered disadvantages by the use of BIM in construction projects



Q29) Specified disadvantages that encountered by the use of BIM in construction process:

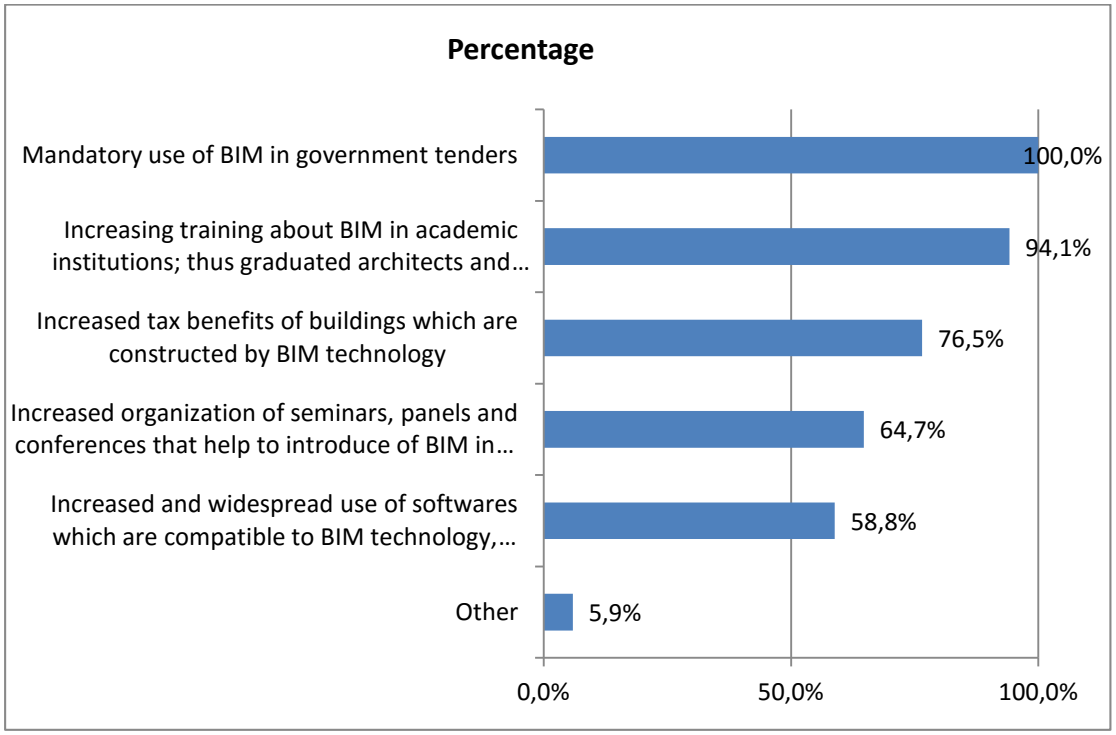
The answers of this question are independent than each other and reflects respondent's ideas.

- There is lack of contractual arrangements and legislative regulation
- BIM increases the design cost.
- There is lack of experience – workers who can use BIM are inexperienced on job, and competent are not able to use BIM. The important thing is providing these 2 groups to work together.

Q30) Respondent's thoughts about the factors that will be effective for widespread use of BIM in Turkish construction industry: (Multiple options can be marked.)

According to the Table 4.30, all of the respondents agree about "mandatory use of BIM in government tenders" will be a driving factor to widespread use of BIM in Turkish construction industry. Almost all of them support that BIM training in academic institutions should be increased. Furthermore, majority of respondents expressed that implementation of tax benefits, as administered on abroad, would encourage the use of BIM.

Table: 4.30: Effective factors for widespread use of BIM in Turkish construction industry



4.2. Data Obtained Through Interviews

Interviews conducted with 12 different large scale construction companies. Many of the respondent companies operate in different countries. Company names are lettered to keep company information details confidential. Mainly, A,B,D,F,I,K,L lettered companies are significantly large scale companies, and also the others are medium-large scale companies. Evaluation of the interviews is prepared by grouping the similar answers and indicated the number of agreed companies with the statement.

The advantages of BIM usage

- Analyzing detailed "clash detection" through 3D model of the project prevents the errors and reworks. *(10 companies) (A,B,C,D,E,G,I,J,K,L)*
- It is easier to analyze cost and work schedule. Material changes can be compared instantly. Thus, more design alternatives can be created. *(6 companies) (A,B,C,D,E,L)*
- Many different disciplines can work on the same model, so it facilitates communication. Therefore, inefficiency and disputes are decreasing, because coordination provided better. *(3 companies) (A,C,H)*
- Recording all the used materials and equipment information in a database, accessibility to the data of these devices, keeping maintenance records during the operation phase made working on "post-"construction" phase more organized and efficient. *(3 companies) (D,F,K)*
- Quantity takeoff jobs became easier, and errors are decreased. Thus, projects were produced more accurately. *(3 companies) (B,C,G)*
- Project risks can be analyzed more detailed and reduced. *(2 companies) (E,F)*
- Producing projects in Revit (3D model) lasts shorter than in CAD system. *(2 companies) (G,H)*
- Visualization of the project provides to work in a more understandable common platform, for all the participants especially for the client. *(2 companies) (C,L)*
- BIM provides convenience to see the effects of the materials on the sustainability. *(1 company) (L)*
- Bids can be prepared more accurately in the tendering process. *(1 company) (A)*

Reasons for preferring the BIM usage

- BIM technology has been started to use, mostly because it is prerequisite for the project. Moreover, if the owner/employer work with BIM technology other companies tended to use BIM. *(3 companies) (A,B,C)*
- BIM technology preferred to use, because it eliminates the inefficiencies about the coordination, material and labor. Thus, costs are reduced and cost analysis done better. *(3 companies) (C,D,G)*

- To adapt the increment in the demand of BIM use in the Turkish construction industry the in the last 3-5 years. *(2 companies) (A,K)*
- To produce projects with recorded database of the building more organized and practical with BIM technology. *(2 companies) (D,H)*
- To have the 3D model of the project and detect the clashes in the model BIM use preferred. *(1 company) (I)*
- To reduce disruptions on the communication & information flow between the project participants. *(1 company) (A)*

The deficiencies and the problems of the BIM usage

- The most obvious deficiency about BIM is lack of informed and educated employees. 3D drawing software cannot be used by architects and engineers sufficiently. *(6 companies) (B,D,E,G,H,K)*
- All participants are not using same type of software, and all participants may not be working on same format or level of detail, so this cause disputes and time waste. *(3 companies) (E,H,L)*
- 3D modeling is more detailed process and extends the design process compared to 2D drawings. *(3 companies) (A,F,L)*
- Companies, which have older average age, experience difficulties about changing business culture and they cannot adapt technologic innovations easily. *(2 companies) (B,D)*
- Other companies in the sector are not using BIM technologies, so this makes difficult to switch BIM technology. *(2 companies) (A,K)*
- There are lack of contractual arrangements, and the uncertainties about the scope of work in BEP document cause disputes. *(2 companies) (F,L)*
- There is not secure sharing of 3D model. *(1 company) (F)*
- High expectations and request on BIM because of the first time experience of many companies. *(1 company) (C)*
- Facilitating ways should be created for adaptations of subcontractors. *(1 company) (A)*
- Initial investments to new software and technologies is a deterrent factor that increases the cost. *(1 company) (D)*

- The absence of a specific BIM standard in Turkey. There is no large project produced by BIM technology as a sample. *(1 company) (C)*

The necessary organizational changes for BIM:

- In-house training provided to employees (basic Revit trainings, or BIM philosophy trainings etc.) *(4 companies) (B,G,H,K)*
- Separate BIM teams are established within the company, and worked with BIM managers as a consultant. *(4 companies) (A,C,G,K)*
- Recruitment of new employees who are experienced on BIM. *(2 companies) (B,C)*
- Invested in new technologies and started to use new software (Revit, Allplan, Navisworks, M-files etc.). *(3 companies) (B,G,K)*
- BIM meetings are organized periodically to provide adaptation better. *(2 companies) (A,G)*

Preparing BEP document process:

- Before starting to BIM implementation on the project, detailed BEP document which includes the job descriptions, responsibilities and scope of work was prepared. *(4 companies) (A,G,H,J)*
- While preparing BEP documents, studied on the existing templates of universities. *(2 companies) (C,G)*
- Preparing appropriate BEP document took long time. *(1 company) (G)*
- All projects are produced by BIM, so a specific system established and there is no problem relating to producing BEP documents. *(1 company) (H)*

BIM experiences of the companies:

- An awareness began to emerge about the use of BIM in Turkey. However many project participant company have used the BIM technology for the first time. *(4 company) (D,G,H,K)*
- There is an increasing demand for BIM, however there is not a defined customer request. Most companies do not fully aware of what is BIM. *(3 companies) (A,G,J)*
- Switching to BIM system has become more advantageous and easier for the companies those carrying out “design & construction & operation” jobs together. *(2 companies) (A,F)*

- Some companies have taken the decision to produce all the project with BIM system. Those companies could create a certain system, and made an equipped BIM teams which can produce projects more practical. *(2 companies) (E,H)*

BIM approaches of the subcontractors:

- Contractor companies do not expect subcontractors to make drawing in 3D model. Some of the companies had the transformation job of 2D drawings to 3D modeling done to teams at foreign companies. Contractor companies have made an agreement with those teams for only produce the 3D model of the project and make clash detection analysis. *(2 companies) (A,D)*
- The roles and the responsibilities of the subcontractors may not be defined sufficiently explicit in contract or BEP document. Duties of subcontractors should be defined in BEP documents. *(2 companies) (A,F)*
- Because the BIM technology is not widely used in the Turkish construction industry, subcontractors do not have experience and knowledge about BIM. *(1 company) (B)*

Preferred resource while switching to BIM system (in-house/consultancy)

- In-house resources *(2 companies) (A,H)*
- Both establishing a BIM team within the company and receiving consultancy *(2 companies) (E,J)*
- Consultancy based outsourcing *(2 companies) (C,D)*

Sustainability perspective

- Minimizing waste arising from reworks provide savings in terms of environmental and monetary during construction phase. *(2 companies) (A,H)*
- Through the tools of BIM system, it is easier to implement sustainability philosophy and monitor the environmental effects during operational phase of the building. *(2 companies) (A,F*)
- Project can be designed based on the energy analysis, because it is easier to create different design alternatives during the design phase. Materials can be chosen according to their C emission level. Architectural lighting can be design among many alternatives. In short, design alternatives increases

through the BIM system. Comparing the cost of the project and sustainability impact, alternative designs can be created easily. *(2 companies) (F,H)*

Lean management perspective

- BIM use has provided to determine errors and clashes in the model, especially in electro-mechanic works. Thus, manufacturing defects are minimized, and reworks are reduced. Waste of time and financial loss reduced to minimum, which are arising from reworks. (6 companies) (A,B,C,E,G,L)
- Number of revisions are decreasing during the design and construction phases, and the revisions and project changes can be applicable on the 3D model easily and quickly. (3 companies) (A,C,L)
- BIM system provides to analyze project risks detailed, so necessary precautions have been taking. Thus, risk amount are reduced. (2 companies) (E,F)
- Quantity takeoff jobs have become easier, so the errors came down to minimum level. (2 companies) (A,B)

5. DISCUSSION

5.1. The Advantages Of BIM Usage

Construction companies in Turkey are beginning to implement BIM technology in their projects. BIM awareness tends to raise in Turkish construction industry. At this stage, respondent companies tended to think that the first advantage of BIM is working on 3D models. Therefore, BIM is mostly used on design phase of the projects. By working on the 3 dimensional model, errors and conflicts are analyzed, and they can be corrected on the project before the construction phase. "Clash detection" appears the most obvious benefit according to the sample construction companies. Re-works in the field decrease through these corrections, and this provides substantial temporal and monetary profit, especially in electro-mechanic systems. This is the most significant advantage of the BIM by far according to the sample Turkish construction companies.

Secondly, in BIM applications time and cost information can be connected to the workflow, particularly such as "Navisworks Manage" software, which are capable of receiving data from the 3D drawing softwares (Revit, Allplan, Bentley, ArchiCAD… etc.). Thus, the work schedule and the budget control can be displayed on 3D model. Employers and contractors are able to follow the workflow easier. Therefore, time and cost controlling benefit is ranked as second by the respondent companies.

Another advantage highlighted by the companies is that BIM provides to perform material takeoffs and bill of quantities easier through the 3D model. Performing quantity takeoffs is easier in 3D models, compared to 2D drawing software.

The respondent companies, especially those produce larger projects (airports, hotels, hospitals, shopping malls, etc.), indicates that the outstanding advantage of BIM is data recording. Material information and all the data about used elements in the construction are recording in a database. This database provides a great benefit on successful implementation of "facility management". Today, a few Turkish

construction companies are awarded of the FM concept, and this database is providing significant contribution on applicability of FM. Accessing all the materials and their quantities, their brands, the data of all the devices and equipment is a huge benefit gained during the operating period of the building.

The companies tended to think as the last advantage of BIM usage is that customer can see and understand the projects by means of visually in 3D model, even if s/he does not have the technical information. This makes the projects revisions more understandable. Even a technician and an architect, working on the same project, cannot understand the 2D model in the same extent. Therefore, using an active 3D model of the project, connected to the progressive work schedule, offers a more comprehensible platform for all participants.

5.2. Reasons For Preferring The BIM Use

Usually responses show that the most important factor to use of BIM is being mandatory condition of BIM standard for tendering in some projects. There is a few company in sample companies has been made the BIM technology as a company philosophy itself to produce projects with BIM system. Mostly, contractors have been using BIM, if there is a BIM requirement on the specification of the project.

Especially, large construction companies in Turkey have begun to realize this tendency of the market in abroad. However, the sector is trailing the world trend 5-10 years behind. Having a BIM standard in the tender specifications led companies to have a BIM experience, especially for companies doing business abroad.

5.3. The Deficiencies And The Problems Of The Use Of BIM

According to the respondents, generally, the biggest difficulty encountered with BIM is not having an enough awareness of BIM in the Turkish construction industry. Finding knowledgeable and experienced employee about BIM is difficult in the industry. The number of architects and engineers, who are able to use software that allow to design 3D projects, are not enough. Therefore, in the big picture, there is lack of trained and educated employee in the sector.

The other deficiency in respondent companies is that particularly over middle age company managers and employees have difficulties in adapting to new technologies.

Especially, 50+ years- large construction companies tended to have a business culture that the old generation used to have. So, sometimes even the young employees offer to use BIM technology, it is not easy to impose using BIM systems to old generations. Changing the business culture Thus, the employee resistance is another difficulty to switch to the use of BIM.

Another experienced problem while switching to BIM is being unable of other project participants to work with BIM. To implement BIM system in an efficient way, it is necessary that all the project participants to produce drawings in the same Level of Definitions. This means, if the contractor has decided to implement BIM technology in the project, the other contractors and sub-contractors should adapt to this change. Otherwise, if sub-contractors do not adapt to BIM use, there would inevitably be great difficulties in coordination. So in fact, one of the most important benefit of BIM, which is working in collaboration and coordination between project participants, is ruled out. On the contrary, this situation creates additional work and extends the processes. In many firms, the main contractor creates the 3D drawings for BIM systems, while they are producing 2D drawings for sub-contractors and suppliers. In some companies, the 2D drawings are transferred to 3D drawings at other countries (at lower costs). Another problem arising from technology differences is not working on the same software tools of all companies. For example; while most firms design on Revit, some firms prefer software such as Allplan or Bentley. This cause inefficiencies or confusions in applicability of BIM technology. Fragmentation of construction industry entities is slowing down the adaptation process. Therefore, when evaluated the technological incompatibilities, not working on same formats of each discipline is a problematic issue in the use of BIM.

One of the important deficiencies about the use of BIM is lack of contractual arrangements, and this can lead the uncertainties about the scope of work of the project participants. Thus, the companies those prefer to implement BIM should manage this process and follow a certain strategic plan. These companies should prepare detailed BEP, and job descriptions need to be specified in detail in this document.

5.4. The Necessary Organizational Changes For BIM

Majority of the respondent companies have purchased the 3D model drawing software and the software which can add planning data to this model (such as; Revit, Allplan, Navisworks Manage). The companies has provided trainings about how to use these software to their employees. According to the companies, the biggest organizational changes are investing in new technologies, and organizing training for employees.

Another organizational change about BIM is establishing a separate BIM team within the company. Companies usually prefer to hire experienced workers about BIM, and they establish teams on project basis. In different type of projects (e.g. subway project) information flow is provided by setting up a joint team between experienced engineers about the subway construction and the engineers who are able to use 3D drawing programs.

Some companies have different solutions to provide organizational adaptation. For example, in the airport project BIM meetings with all participants are organized for every week. Thus, communication and the cooperation is strength between the participants. The progress of the project is recorded, and deficiencies are identified through these meetings. After that, participants seek a solution to compensate the deficiencies. In some large-scale projects BIM theaters are established to carry out BIM process successfully. Arranging BIM meetings is an important step to achieve one of the BIM targets which is the improved collaboration of the stakeholders.

5.5. BEP Applications

Respondent few companies of construction sector in Turkey, which implement BIM technologies, are informed about BEP documents, and almost all of them preparing appropriate BEP documents according to BIM standards. In some projects, e.g. the airport project, very detailed content of BEP documents were prepared up to 300 pages. Some companies have provided from resources that appropriate for their companies such as *Pennsylvania State University – BIM Project Execution Planning Guide V2.1* template.

Sample companies those started to use BIM technologies recently reviewed that the BEP preparation as long and laborious process. However, some of the architecture

offices producing project with BIM for a long time have established a certain system, so BEP documentation process has become a simple procedure for them.

Most of the companies emphasized that role and responsibility of the project participants should be defined explicitly in BEP documents. Otherwise, the confusion of job descriptions can be become communication problems and conflicts in projects, even these confusions can be turned into monetary penalties, in the consequence of subcontractors' claims.

5.6. BIM Experiences Of The Companies

When the sample companies' BIM experiences are evaluated, almost all of the companies has started to implement BIM technologies since last 5 years. Usually, the projects, which produced by BIM, are the first BIM projects of the companies, and they are still in construction phase. Therefore, there are scarcely any constructed buildings built by BIM. The survey answers also show that companies do not have a BIM experience in all phases of a project. Most of the companies have started to use BIM after tender process, or in construction phase. BIM mostly used in work schedule, design and the site management phases. It has used to identify "clash detections" and to fix them in design process.

Considering the resources that are used to implement BIM, establishing in-house team or getting support from consultant companies' have almost equally rates. In this regard, interview results reveal that even the companies establish a BIM team within the company, they get support from a BIM consultant. Therefore, BIM decisions are taken in accordance with the mentoring of this consultant.

5.7. BIM Approaches Of The Subcontractors (observations)

The majority of the respondent construction companies consider the subcontractors as they do not have enough knowledge and the experience about BIM. There are adaptation problems of subcontractors about the BIM, because BIM is not widely used in Turkish construction industry yet. For this reason, construction companies do not expect from the subcontractors to design projects in accordance with the BIM procedures. Instead, the drawings of the subcontractors are carried out in 2D version. This 2D models are transferred to 3D models for BIM integration. Some of the

sample companies have this conversion job made to the technicians at foreign countries (e.g. India), because they provide better quality models and cheaper labor. In this way, 2D and 3D models are executed together. This way kills the practicality and advantages of BIM. Maybe after a certain adaptation process, subcontractors can design in 3D format, prepare their own BEP documents, and produce their projects eligible to BIM system.

5.8. Resources While Switching To BIM System (in-house/consultancy)

Companies have tended to follow different strategies while switching to BIM technology. Some of them has preferred to establish a BIM department within the company and trained them in accordance to BIM experienced mentor, or hired new employees experienced about BIM, who will get involved in these teams. Some of the companies have worked with consultancy firms. They explain that the investment cost can be much higher if they establish a BIM team within the company. One of the interview result show that a certain large-scale company profit up to 70% by working a consultant company, instead of establishing a BIM team within the company. Therefore, companies mostly got support from BIM experts can be said.

5.9. Sustainability Perspective

Respondent companies generally do not have an approach toward BIM use would bring more efficiency on sustainability concept implementation. They do not think BIM has a significant impact on sustainability, or do not have parameters to monitor their interaction. Therefore, the reviews and information was not sufficient about the BIM use and sustainability interaction. However, some companies emphasized the points that have positive impact on sustainability. The most prominent one from these points is a significant waste reduction by eliminating errors in the design phase. Through a detailed 3D model of the project, clash detections can be identified and resolved before application. This waste reduction, in terms of both material (affects directly the cost), and time (elimination of rework) can provide a significant benefit with big profits. Unnoticed errors cause big waste of money and time during construction. To eliminate these errors serious disruptions may occur, such as; wall demolition, column decimation etc. Trying to redesign after applied errors such as; overlapped electro-mechanic systems in ceiling, shaft openings in wrong place and seek solutions to these problems during construction is a hard job. At the same time,

a halt at this time, waiting of workers and halting jobs disrupting each other, and this cause a chain of errors. 3D modeling, which is a requirement of BIM system, prevents significant waste amount by minimizing these errors.

Another important factor of BIM usage, that supporting sustainable construction, is comparing project materials easily. Making of detailed modeling and recording of all data about materials and quantity takeoffs in BIM usage provides to make changes and compare them immediately. In other words, design costs can be checked easily when a material replaced by an equivalent or similar product. Information about the lifetime and cost of this material, environmental effects of the material, and usage of renewable materials make easier to build sustainable buildings.

There are no buildings were built with complete BIM 6D technology among the respondent companies. However, some of the companies tend to implement sustainable construction. For targeting implement BIM in 6^{th} dimension, recorded information such as; CO2 emissions of buildings, resource consumption and operation energy simplify facility manager's job.

5.10. Lean Management Perspective

Technology, employees and processes are managed well through BIM technology. Thus, this makes a major contribution to the implementation of lean management philosophy. Lean management philosophy can be defined as eliminate all kinds of activities which are not creating added values (positive value) to the any job. In this respect, the error rate and causing huge waste reworks in the construction works (in all applications from pre-construction phase to post-construction phase) can be reduced to minimum with the scope of lean management philosophy. The applicability of this waste reduction is increasing through BIM.

The overall object of the respondent companies is analyzing project in pre-construction phase by providing coordination. Thus, errors and reworks decrease to minimum during construction phase. Therefore, defective manufacturing is eliminated, and the additional cost and time is eliminated thereby.

Work flow can be created in most efficient way through the BIM usage. Lean management aims to maximize performance of productivity. Efficient work schedule

with BIM helps to have continuous work flow which is basic principle of lean management. Waiting times can be decreased to minimum with BIM usage.

According to the company responses, project risks are analyzed better through the use of BIM. Because BIM use minimize possible damage that may occur during the construction phase, and this provides financial benefit. Therefore, determining the project risks and taking precautions against these risks, eliminate many potential errors, and this also provides to implementation of lean management. Thus, the advantages inherent in the use of BIM extremely compatible with lean management principles, and combination of them in project management result with effective company management with high profits. However, currently, Turkish construction companies do not implement BIM technologies with full capacity or widely, so they are not exactly aware of the potential benefits.

6. CONCLUSION AND RECOMMENDATIONS

The construction industry is among the largest and the most leading sectors of Turkey's economy. Increasingly intense competitive conditions in the sector created requirements as taking innovative roles and providing client satisfaction. To survive in the innovative construction industry, companies should follow the world trend, and utilize the existing technology as much as possible. Furthermore, they should bring innovation to the sector to compete in global market. However, especially these types of rooted sectors do not accept the innovation immediately. Employers of large-scale companies may not change the business culture at once, and they may face with difficulties on adaptation process to new technologies.

BIM technology is not only an innovative technology for the sector, it is described as "game changer" by the authorities. BIM system is not software, it is a management philosophy as a whole. To implement the BIM system in projects, company managers should construct an infrastructure, and change their ways for it. In order to measure the current situation and the development, construction industry has to demonstrate a method in accordance with the goals and objectives. In this study, Turkish construction companies' behaviors and thoughts are monitored about BIM in this adaptation process. To evaluate the usage of BIM in Turkish construction industry, interviews and surveys have been conducted. Majority of the companies noticed that the BIM technology has a positive impact on cost, time and quality of the projects which are the base criteria of project management.

In this study, how to use Building Information Modeling effectively in the all phases of the construction project management, support of Building Information Modeling in project management areas, and why the use of Building Information Modeling is not spread enough in Turkish construction industry topics have been examined. Furthermore, in this study, proposals have been developed for the widespread use for Building Information Modeling in Turkish construction industry. To achieve these goals, the international literature review, interviews with Turkish construction

companies, questionnaire and a case study have been conducted. In the scope of questionnaire and case study, BIM implemented projects are examined, and they have planned to use for data analysis. Having interviews has been beneficial to identify difficulties encountered and to make detailed examination of the case studies.

According to the study results Turkish construction companies started to invest in BIM technologies. Respondent companies have started to establishing BIM departments within their company or getting consultancy from the BIM advisors. Mostly, respondent companies are large-scale companies and BIM projects have high cost of budget.

Respondent companies use the BIM technology considerably more on pre-construction phase. At this stage, companies mostly reap the benefit of 3D modeling of this technology. Majority of them are aware that BIM is not 3D modeling tool or software for projects, but 3D model of the project seem visually more understandable for all the stakeholders. By working on the 3 dimensional model, errors and conflicts are analyzed, and they can be corrected on the project before the construction phase. "Clash detection" appears the most obvious benefit according to the sample construction companies. Through clash detection, errors are fixed before construction phase, so BIM is mostly used in design phase. Re-works in the field decrease through these corrections, and this provides substantial temporal and monetary profit, especially in electro-mechanical systems.

Turkish construction companies should make some improvements to reduce shortcomings about BIM usage. The study results show that the most distinct problem about usage of BIM is lack of educated employees. Architects and engineers are not able to use 3D modeling software, or they are unable to have a good grasp of BIM technology. In addition, before switching to BIM technology, a BIM setup should be done comprehensively in companies. For organized BIM system, required documents should be prepared carefully, such as, BIM Execution Plan, Project Implementation Plan (PIP), Asset Information Model (AIM), Master Information Delivery Plan (MIDP), Level of Model Definition (LOD) etc. With regard to interviews, subcontractors, one level of smaller scale companies, do not really aware of BIM technology. Especially, adaptations of subcontractors are not sufficient to apply BIM system in projects. In this adaptation process, government,

owner or contractor companies should set a course for BIM implementations. Owners or main contractors have to determine some standards in contracts and define all the responsibilities of subcontractors in the contract. In this way, the main deficiencies about the usage of BIM can be reduced in Turkish construction industry.

Respondent construction companies have tried several different methods and made some organizational changes to provide BIM adaptation within their companies. In the adaptation process, almost all of the companies invested in new technologies, and provided training to employees to accomplish BIM process better. Many of the companies hired new employees or started to working with BIM experts or specialists. Briefly, some changes have been implemented to succeed in BIM process.

Results show that, Turkish construction industry started to invest in BIM technology, and companies desire to catch the trend in BIM usage. However, there are some deficiencies to implement BIM system in projects such as; educated employees, wrong perception about BIM, subcontractor adaptation etc. The respondent companies have been realized the advantages and potential benefits about cost, time and quality. Furthermore, if companies want to put forward a difference especially on sustainability and lean management, BIM system will enable to apply principles of them. Currently, in government tenders, BIM implementations are tried to adapt in some infrastructure projects. BIM specifications have been started to produce in some government tenders. Thus, at least a perception about BIM initiated for the bidder companies. Developments should be made on contract conditions from government to increase the awareness and usage of BIM. Academicians intensified the studies about BIM in universities, so courses may be enhanced with BIM contents. Accordingly, the BIM awareness and knowledge will be raised rapidly in the next graduates.

Results show that there is a significant benefit of BIM on project management principles. There are some measurable and immeasurable profits behind the BIM usage. Measuring the benefit of BIM is not easy, because there should be exact conditions and built exactly same project with stakeholders. There are some examples to measure the benefit of BIM by comparing pretty similar projects in

literature. Nevertheless, still it is difficult to obtain completely accurate data. However, big investors, BIM experts and professionals are aware of possible profits and revolutionist side of BIM. At this point, in the first place besides achieving some monetary profit through BIM, having an innovative role and brand name in the sector, increasing the competitiveness and doing business in the global market with the equal technologies should be more important for visionary company managers.

The adaptation process of BIM implementations requires effort and determination. Changing business culture is not an easy job, and implementing BIM requires full collaboration with all project stakeholders. Companies that practice BIM implementations must provide at least the following requirements;

- Effective use of 3D CAD software
- Coordinated and collaborative working environment with other project participants
- Efficient implementation of document management system both in-house and intercompany
- Preparation of necessary documents as BEP, PIP, MIDP etc. to clarify roles and responsibilities of project stakeholders, BIM work details and processes
- Creation of master coding system

BIM usage requires systematic work of many different criteria. Therefore, BIM managers, BIM coordinators or whoever authorized about BIM within the company should resist against to problems encountered and continue to develop adaptation process. Only in this way, companies can achieve this adaptation process.

Switching to BIM technology is a strategic and visionary management decision. Companies which are eager to implement BIM on their projects should be determined, and arrange their organizational scheme up to the BIM procedure. Today, companies need to invest in BIM technologies professionally. Initial investments, setting up a BIM system within the company, or getting training about the BIM technologies may seem difficult or deterrent at the beginning stage. However, the companies should calculate the return investment; how much the companies are going to pay and how much they are going to gain back should be evaluated. At this point, legal obligations or subvention should have become incentive for companies. As the samples in Europe, there may be some amount of tax

reductions for BIM buildings, so BIM system can become promotive for the companies.

In academic institutions BIM awareness and knowledge should be raised. Intensified syllabuses can be helpful to adopt BIM culture. College students should learn using 3D design software, and academicians should give responsibilities to encourage it. At this point, design competitions can be organized with the collaboration of universities and software companies as an incentive factor for students. For example; in Turkey 'Design Together' competition aims to make the design effectively using BIM system with project design teams which consist of at least 1 architecture, 1 civil engineering and 1 mechanical engineering students. In this way, college students may learn to work collaboratively with different disciplines together. Thus, graduate engineers and architects will be informed about BIM implementations. In business life, integrated way of working should be maintained between BIM experienced young engineers and professional experienced engineers. This will result in efficient work environment for BIM implementations.

Implementing BIM technology in construction projects will be inevitable soon, thereby companies should invest in BIM technologies. BIM system is like an orchestra; when all the participants are working together coordinately it gives effective results.

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APPENDIX

BIM Questionnaire

1) What is your position in the company?
   a) Managing director
   b) Project manager
   c) BIM supervisor
   d) Architect / Engineer
   e) Other

2) What is your profession?
   a) Architect
   b) Engineer
   c) Technician
   d) Other

3) How many years are you working in the construction industry?
   a) 0-3 years
   b) 4-6 years
   c) 7-10 years
   d) 11-20 years
   e) 20+ yrs

Information of the analyzed project…

4) What is your company's role in the project?
   a) Employer
   b) Contractor
   c) Sub-contractor
   d) Supplier
   e) Project manager / Adviser
   f) Other

5) What is the type of the project?
   a) Residential building
   b) Office building
   c) Industrial building
   d) Tourism complex
   e) Infrastructure
   f) Dam-road-bridge
   g) Other

6) What is the budget of the project?
   a) < $500,000

b) $500,000 - $2,000,000
c) $2,000,000 - $5,000,000
d) $5,000,000 - $20,000,000
e) $20,000,000 - $50,000,000
f) > $50,000,000

7) How and in which phases of the project BIM was used?
   A) In the pre-construction phases
      a) Design phase
      b) Contractual arrangements
      c) Strategic planning
      d) Planning (time schedule)
      e) Mobilization
   B) During construction
      f) Schedule updates
      g) Budget control
      h) Contract administration
      i) Site management
      j) Construction site waste management
      k) Occupational health and safety
   C) In the post-construction phases
      l) Repair & maintenance
      m) Monitoring energy consumption
      n) Controlling the performance of the certification of sustainable buildings (LEED, BREEAM etc.)
      o) Demobilization
      p) Facilities management
      q) Other

8) What were the difficulties experienced in the use of BIM?
   (Multiple options can be marked.)
   a) The lack of contractual arrangements about the BIM
   b) The lack of in-house organizational arrangements about the BIM
   c) The lack of organizational arrangements in supply chain
   d) Lack of education
   e) Employee resistance
   f) Initial investment cost
   g) The lack of a widespread demand at sector in Turkey
   h) The lack of the necessary infrastructure for the implementation of BIM
   i) The lack of experience within the company regarding to BIM
   j) Difficulties in adaptation of subcontractors and suppliers
   k) Difficulties in preparation of EIR (Employer's Information Requirements) documents
   l) Difficulties in preparation of BEP (BIM Execution Plan) documents

m) Difficulties in preparation of PIP (Project Implementation Plan) documents
n) Difficulties in preparation of MIDP (Master Information Delivery Plan) documents
o) Difficulties of identifying of LOD (Level of model definition)
p) Difficulties in preparation of "Supplier BIM assessment form"
q) Other

9) Which way was followed in the use of BIM?
   a) In-house resources
   b) Outsourcing or taking consultancy

10) What were the administrative and organizational changes that have been made for the implementation of BIM?
    (Multiple options can be marked.)
    a) Invested in information technologies.
    b) Provide training to the employees.
    c) New employees were hired (experts in BIM, as BIM information manager etc.).
    d) Different project teams were created.
    e) The communication was strengthened between project participants.
    f) Authority allocation of decisions and sharing of information were provided in more innovative forms.
    g) Changes were made in the organizational roles and responsibilities.
    h) Other

11) What are your observations about the supply chains' / subcontractors' adaptation of BIM and experiences about BIM?
    (Multiple options can be marked.)
a) Lack of experience
b) Lack of information
c) They are not being able to prepare documents such as; BEP or PIP
d) They can not afford the initial investment cost
e) They adapt to the demands of the construction sector in Turkey

12) Did any disputes arise between the parties during the analyzed project?
    (Multiple options can be marked.)
a) No, there was not any dispute.
b) Disputes emerged between the parties at a very low level.
c) The use of BIM reduced the disputes.
d) There were great disputes between parties.
e) The use of BIM increased the disputes.

13) How did BIM affect the COST performance of the construction project?

(Multiple options can be marked.)

a) It reduced costs.
b) It made cost analysis easier. It made easier to stay within the planned budget.
c) It increased cost.
d) BIM did not change the cost.

14) How did BIM affect the TIME performance of the construction project?
    a) It shortened the construction period.
    b) The effective implementation and control of the planned construction schedule prevented the extension of construction time.
    c) There was not a significant impact to shorten the construction time. The average delay occurred.
    d) It extended the construction period.

15) How did BIM affect the QUALİTY performance of the construction project?
    a) It made easier to reach the targeted quality.
    b) It had no effect on enhancing quality.
    c) It lowered the quality.

16) How did BIM affect the SUSTAINABILITY performance of the construction project?
    a) BIM made easier to monitor of buildings' sustainability performance, thus the control was increased.
    b) There was no significant effect on the sustainability performance.

17) How did BIM affect de 'Variation Order' demand of construction projects?
    a) Working together of all participants provided identifying requirments and needs completely; so VO demand reduced in the project.
    b) There was no significant effect on the amount of VO demand.
    c) Monitoring the construction project by all the participants and the client, increased the amount of VO demand.

18) How did BIM affect the WASTE MANAGEMENT (in terms of sustainability) of the construction project?
    a) Building material waste was decreased. Effective waste management helped gain environmental and social benefits (such as waste disposal and reducing health risks).
    b) It did not provide a benefit for waste management.

19) How did BIM affect the WASTE MANAGEMENT (in terms of lean management) of the construction project?
    a) BIM reduced events that cause to loss of production, storage space. It reduced the error amount.

b) BIM did not reduced the waste in accordance the principles of lean management.

20) How did BIM affect the BIDDING PROCESS of the construction process? (Multiple options can be marked.)
   a) Because the proposals were prepared more rigorous, there were more realistic bid prices.
   b) BIM provided to make certain list of material and precise amount of material.
   c) Applicability of e-procurement method shortens the procurement process.
   d) There was no impact on procurement process.

21) How did BIM affect the DESIGN PROCESS of the construction process? (Multiple options can be marked.)
   a) Shareable 3D data based system made easier to design.
   b) As it improves and eases the communication, design was made according to client's requirements and demands.
   c) As all disciplines work together and coordinated in the design process, revisions were reduced.
   d) BIM had not a positive impact on the design process.
   e) It extended the design process.

22) Evaluate the performance of following factors in terms of the effect of BIM.

   a) Cost
   b) Time
   c) Quality
   d) Sustainability
   e) Variation Order
   f) Waste management (in terms of sustainability)
   g) Waste management (in terms of lean management)

23) In which field the BIM use reduced the construction waste? (Multiple options can be marked.)
   a) Construction material waste during the construction (steel, concrete, timber etc.)
   b) Demolition waste (rubble, gravel, soil, destruction etc.)
   c) Building renovation wastes (maintenance and repair)
   d) Other

24) Which of the following was saved through BIM use, in terms of the wastes during the all events that led to waste in the construction process? (Multiple options can be marked.)
   a) Delays and the waiting times

b) Storage space and overstock
c) Amount of error
d) Excess transport
e) Spent brainpower
f) Other

25) Which do you think is the motivating factor for a company to the use BIM? (Multiple options can be marked.)
a) Having an innovative role in the sector
b) Reduction of tax payments due to the environmental friendliness of the buildings that produced by BIM
c) It is mandatory for some of the projects (particularly for companies doing business abroad)
d) Gain global competitiveness among other construction companies
e) Other

General opinions about BIM;
Mark each option according to its importance level.

26) The advantages of the use of BIM in construction projects;
(Score the factors; 5 for the factor that provide biggest advantage, and 1 for the minimum benefits that you think.)

a) BIM increased to cooperation and concordance among the project participants.
b) Creating a shareable 3D data media simplified the design process.
c) Due to richness of shareable data media, problems were solved more quickly.
d) Error rate was reduced.
e) Re-works were decreased. (This directly reduced the waste of time and cost.)
f) A new concept of serving occurred for clients.
g) Delivery times were shortened.
h) BIM has increased the lean performance.
i) BIM has increased the sustainability performance.
j) The construction site was used more efficiently through visualization techniques.
k) At the end of the construction, facility portfolio was developed, which contains space planning and maintenance records.
l) More realistic proposals were occurred in the bidding process.

27) Do you want to specify advantages that brought by the use of BIM in construction process?

28) The disadvantages encountered by the use of BIM in construction projects; (Score factors; 5 for the factor that cause the biggest disadvantage and 1 for the minimum disadvantage that you think.)

a) Contractual arrangements related to BIM was not sufficiently defined.
b) In-house experience was lacking about BIM.
c) The necessary infrastructure was not prepared about BIM.
d) Subcontractors and suppliers had difficulties in BIM adaptation.
e) The high initial investment cost of the new software and information technologies was a deterrent.
f) Preparation of documents that are required to use of BIM (such as; BEP, PIP etc.) was a time-consuming and laborious process.
g) Preparation process extended because of the detailed bidding process.

29) Do you want to specify disadvantages that encountered by the use of BIM in construction process?

30) Which factors do you think will be effective for widespread use of BIM in Turkish construction industry?

(Multiple options can be marked.)

a) Mandatory use of BIM in government tenders
b) Increased tax benefits of buildings which are constructed by BIM technology
c) Increased organization of seminars, panels and conferences that help to introduce of BIM in construction sector.
d) Increased and widespread use of softwares which are compatible to BIM technology, such as; Revit, Bentley, Allplan
e) Increasing training about BIM in academic institutions; thus graduated architects and engineers have more technical capability.
f) Other

CV - Curriculum Vitae

Profile Summary

Name: İmge Kıvırcık

Nationality: Turkey

Date of Birth: 07/11/1991

Education:

2014-2016: Istanbul Tecnical University – Master of Project Management

2011-2014: University at Buffalo – Civil Engineering

2009-2013: Istanbul Technical University – SUNY Civil Engineering

2005-2009: Özel Çamlıca Bilfen Lisesi

Internships and Experience:

IMS Project Management (Office intern) – June 2014 – July 2014

Zorlu Levent Office and Trade Center (Field construction intern) – August 2012

Sinpas GYO Bursa Modern Residance Project (Field construction intern) – June2012 – July 2012

Gained experience as an intern in construction field. In office internship gained experience on project management techniques and drawed many residance plans on Autocad.