Integration of Building Information Modeling and Laser Scanning in Construction Industry

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ABSTRACT

Building Information Modeling (BIM) and Laser Scanning tools and applications have established their footing in different sectors such as engineering, architecture, and construction due to their capabilities and potentials in enhancing the quality, as they are accurate in collecting and analyzing the data, and reducing the time and cost of a project during different phases of design, construction and maintenance. The purpose of this study was to raise awareness and understanding concerning the use and promotion of these applications, especially in their integrated forms, in construction industry. Furthermore, the effort was made to investigate the use, purposes, benefits, and future of these novel technological means among academics, construction firms and their managers, engineers, architects etc on the individual and integrated bases.

This study includes two parts: the first part consists of administering a questionnaire to a sample of 48 participants from different contexts and companies in order to investigate their perceptions on the employing of BIM and Laser Scanning in their workplace. The results of this survey instrument indicated positive and significant results as to the awareness, information and optimism towards the use and capabilities of these two applications. The respondents were almost cognizant of the benefits and purposes of both BIM and Laser Scanning in the lifecycle of a project from the bidding to the maintenance of a construction project in general and enhancing the time, cost, quality, health and safety in particular.

The second part of this study addresses conducting a case study in order to practically examine the application of Laser Scanning tools and BIM software in construction sector. This was a study of Technology Development Center, Technopark, in Famagusta located in North Cyprus. A CADeyes camera was exploited to capture spatial and visual data within three different coordinates and from various angles from the building of this center. Then Point cloud data was analyzed by Revit, which is one of the BIM software, in order to generate a 3D model. The details of conducting the application of Laser Scanning and BIM tools were followed and displayed graphically and the outcomes revealed the efficient and effective use of these tools. This study therefore recommends utilizing these game-changing technological means by all stockholders ranging from the designers to end-users so that they can meet the basic requirements of construction projects as well as to deal the challenges of a construction project including errors, risks, and costs.

Keywords: Building Information Modeling (BIM), 3D Laser Scanner, 3D Modeling, Construction Management

ÖZ

Yapı bilgi sistemi ve 3D Lazer tarayıcı araçları ve uygulamaları bilgi toplayıp analiz etmedeki kesinliği ve dizayn, inşaat, ve bakım süreçlerinin farklı aşamalarında projenin süresini ve maliyetini azaltmak gibi kaliteyi artıran yetenek ve potansiyellerinden dolayı mühendislik, mimarlık ve inşaat gibi farklı sektörlerde temelini oluşturmuştur. Bu çalışmanın amacı, bu uygulamaların özellikle bütünleşmiş biçimde ve inşaat sektöründe uygulanmasına ve yükselmesine ilişkin bilinçliliği ve anlayışı artırmaktır.

Ayrıca, bu teknolojik değişikliklerin akademiler, inşaat firmaları ve bunların yöneticileri, mühendisleri ve mimarları arasında kişisel yada bütünleşmiş biçimde kullanımını, amaçlarını, faydalarını ve geleceğini araştırmak için çaba sarf edilmiştir.

Bu çalışma 2 kısımdan oluşur: birinci kısım işyerlerinde BIM ve 3D Lazer tarayıcı kullanımındaki algıları araştırmak için farklı bağlamlar ve şirketlerden oluşan 48 kişi ile yapılmış anketi içerir. Bu anketin sonucunda bu iki uygulamanın kullanımı ve yetenekleri yönünde haberdarlık, bilgi ve optimizm ile ilgili olumlu ve önemli sonuçlar elde edildi. Anketi yanıtlayan kişilerin çoğu, BIM ve 3D Lazer tarayıcı inşaat projesinin genel anlamda fiyat biçme aşamasından bakımına kadar olan sürecinde ve süre, maliyet, kalite ve iş sağlığı ve güvenliğini artırmasındaki faydalarından ve amaçlarından haberdardılar.

Bu çalışmanın ikinci kısmı 3D Lazer tarayıcı araçlarının ve BIM programının inşaat sektöründeki uygulanışını pratik olarak incelemek için bir tane örnek çalışmayı ele aldı. Bu çalışma Kuzey Kıbrıs'ın Magosa bölgesinde olan Teknoloji Geliştirme Merkezi, Teknoparkdı. Bu merkezin binasından çeşitli açılardan ve 3 farklı koordinat içinden uzaysal ve görsel bilgi elde etmek için CADeyes kamerası kullanıldı ve sonra 3 boyutlu model oluşturmak için bir BIM programı olan Revit ile Point cloud bilgisi analiz edildi.3D Lazer tarayıcı ve BIM araçlarının uygulanışının yürütülmesiyle ilgili olan detaylar takip edildi ve grafiksel olarak gösterildi ve sonuçlar bu araçların etkili ve verimli kullanışını ortaya çıkardı. Bu çalışma dizaynerlerden en son kullanıcıya kadar olan bütün hissedarların game-changing teknolojilerinden faydalanmasını önerir böylece hem inşaat projelerinin esas ihtiyaçlarını karşılarlar hem de inşaat projelerinin hata, risk ve maliyet gibi sorunlarıyla ilgilenirler.

Anahtar Kelmeler: Building Information Modeling (BIM), 3D Laser scanner, 3D Modeling, Construction Management

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ABBREVIATIONS

2D	2 Dimentional
3D	3 Dimentional
4D	3 Dimantional
5D	4D plus forecast cost analysis over the life span of the building
AEC	Architecture / Engineering / Construction
BIM	Building Information Modeling
CAD	Computer Aided Drafting
CM	Construction Management
CCD	Charging-Coupled Device
IEEE	Institute of Electrical and Electronics and Engineering
LIDAR	Light Detection and Ranging
MEP	Mechanical, Electronical, Plumbing
NBIMS	National BIM Standard
NIST	National Institute of Standards and Technology

Chapter 1

INTRODUCTION

This chapter introduces two new technologies, BIM and Laser Scanning tools, used in the construction industry as the main focus of this study. After a brief history regarding the development of these innovative applications, the rationale and purpose of the study are also presented towards the end of this chapter.

Traditionally, construction projects had been designed, constructed and operated by expert and non-expert teams through a time-consuming, costly, and fragmented stages. During this lengthy process, collaboration and cooperation among these different parties was usually a challenging and arduous job on or off the construction sites. This was partly due to the lack of technological developments in the past, when most of plans and documentation were prepared separately in 2D formats by separate programs or by hand, which were unable to prop up the necessary communication or integration among different groups responsible for carrying out a project. Later designers adopted other applications such as CAD (Eastman et al., 2008), but these applications again were short of storing the data or information electronically and they still needed some sheets of paper to deal with the calculations, as well as visual and special designs.

The above-mentioned drawbacks and chores, therefore, made experts develop new applications that can share or convert various type of data into digital information.

However, this did not happen until mid-1980s, when Graphisoft produced the first virtual technology called ArchiCAD in architecture (Kmethy, 2008). This new tool had the potential to create 3D models of projects and soon replaced the traditional 2D presentations. Furthermore, it had the benefit of saving huge volumes of spatial and geometric data for designing architectural projects. In addition, the introduction of 3D technology, especially 3D modeling, in the construction industry revolutionized the whole enterprise owing to the fact that this technology could reduce the cost and resources effectively.

Among the most famous 3D technological tools, engineers and architects have enthusiastically embraced different types of Building Information Modeling applications in the construction industry over the last two decades (Eastman, 2008). These applications are a series of software that have been created and used that could communicate, coordinate and calculate information easily in a building project, allowing decision makers at various stages of a project to use this data for construction of high quality projects in terms of cost-effectiveness, operation and performance as well as smooth planning.

There has also been evidence that generating a 3D model can mitigate risks, reduce errors, and save time and cost of the project significantly while it can enhance the quality of a construction project (Eastman et al., 2008). Since Building Information Modeling applications and Laser Scanning tools as 3D-making technologies can easily cater for the needs of designers, engineers, architects, etc due to their efficacy, accuracy and efficiency, they have become more popular in construction industry than others.

Thus, understanding the dynamics of these two technologies would simply be the first step in using or encouraging their use in design and construction of projects. This study, therefore, aims to introduce, promote and investigate the use of BIM and Laser Scanning technologies in the construction industry. In other words, it seeks out to look into the most conspicuous applications of these new technologies in the lifecycle of a construction project as perceived by those who have an insider look or are engaged with these applications at workplaces and on construction sites. Furthermore, through a case study the separate as well as integration of these tools in the real world situations are demonstrated.

The first section of this study goes over a brief history and definitions of BIM and Laser Scanning tools and presents an overview of their main purposes and uses in construction projects. The second part investigates the perceptions of people who have had the chance to work with these technologies in order to find out about the advantages, disadvantages, challenges and the development of these tools in the future. For this purpose, a questionnaire was developed and administrated to a group of participants, followed by the analysis of data and presenting the related tables and figures under the results section. The final section, however, illustrates the use and procedure of working with these applications in a real-world situation in a Middle Eastern context.

Chapter 2

BUILDING INFORMATION MODELING (BIM)

This chappter deals with emloying BIM applications in different sectors such as architecture, construction and management. After a short intriduction, the history, use and advantegs of BIM software are elaborated for the mentioned sectors. At the end, Revit, as one of the most efficient applications of BIM is descrbibed in details and the rationale behind its use is given briefly.

2.1 Introduction

The main propose of this chapter is to introduce the BIM system for architects and engineers and show the abilities of the software associated with the BIM system, especially as its integrated form with the laser scanning technologies that will be discussed in the next chapter. In 2004, the National Institute of Standards and Technology (NIST) published a report stating that poor interoperability and data management costs the construction industry approximately $15.8 billion a year, or approximately 3-4% of the total industry (Michael P. Gallaher, 2004). Since the publishing of this report, the focus on Building Information Modeling (BIM) has intensified and many professionals have labeled BIM as the answer to the above-mentioned problem. According to National BIM Standard (NBIMS), a BIM (i.e. a single Building Information Model) is defined as “a digital representation of physical and functional characteristics of a facility” (Floyd, 2010). Furthermore, a BIM represents a shared knowledge resource, or process for sharing information about a facility, forming a reliable basis for decisions during a facility's lifecycle from inception onward (Suermann, 2009).

BIM is the innovative attainment method, which has been developed for Architecture, Engineering and Construction (AEC) industries. It is an advanced system to simulate the construction process and production before construction. Every architect and engineer can simulate the progression of their project on the virtual screen and perceive how they can optimize the result of their work. This is a possibility, which did not exist until the digital age. BIM technology constructs a model of building that is digitally fabricated. According to this simulation, the system creates the data, which supports the construction and the development of construction.

Azhar et al., (2008) refer to a Building Information Model as a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and to improve the process of delivering the facility.

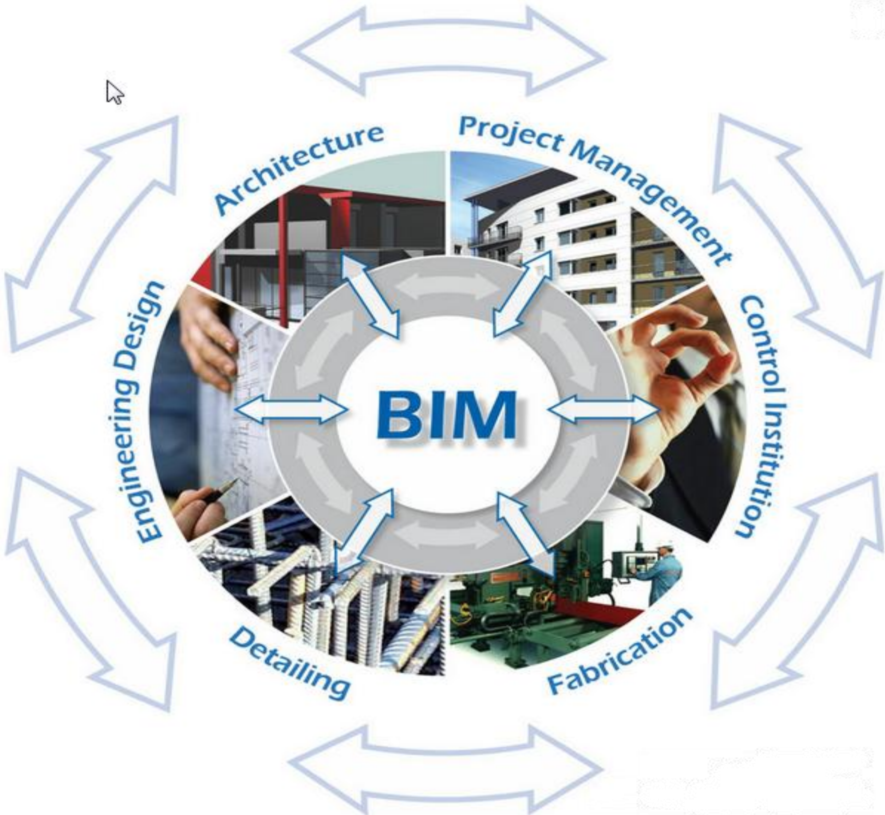

Figure 1: BIM connects all parts of project and personnel together

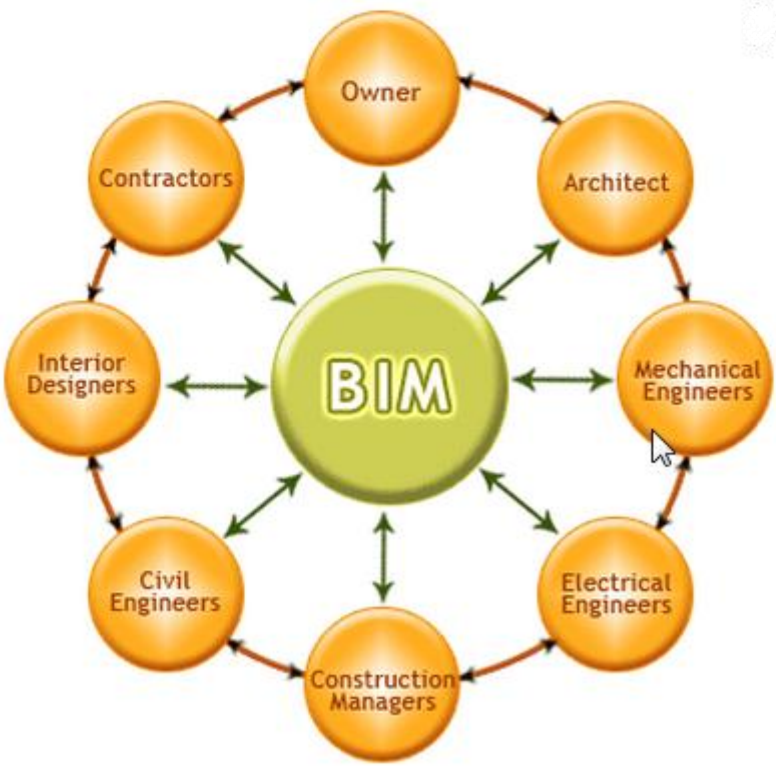

Figure 2: Relationships between various parties with BIM

Building Information Modeling as a now technology in construction industry has changed the techniques and strategies professional use to design, construct and manage buildings. This type of technology offers a constant and instant support system by coordinating and sharing objectives, schedules, costs etc through a reliable, effective and fast approach. This can offer advantages to the industry and all the professionals involved. Some of them are saving the time of delivery, mitigating errors, reducing costs, boosting productivity, and offering new business, commercial as well as job opportunities. BIM also provides accessibility to different phases of design, construction and maintenance or management of a project. For example, it can offer information on the design, timetable and the budget of a building project. As to the construction phase, it can also cover schedule, costs and expenses, and the issue of quality. As far as the last phase is concerned, BIM can also supervise the operation and maintenance of a project.

Therefore, as one of the major characteristics on BIM applications,this accessibility to the latest data and information through highly efficient digital environments would give all stockholders a better view concerning the decisions they want to make and the measures they want to take as to having a better picture to increase the quality and efficiency of the projects.

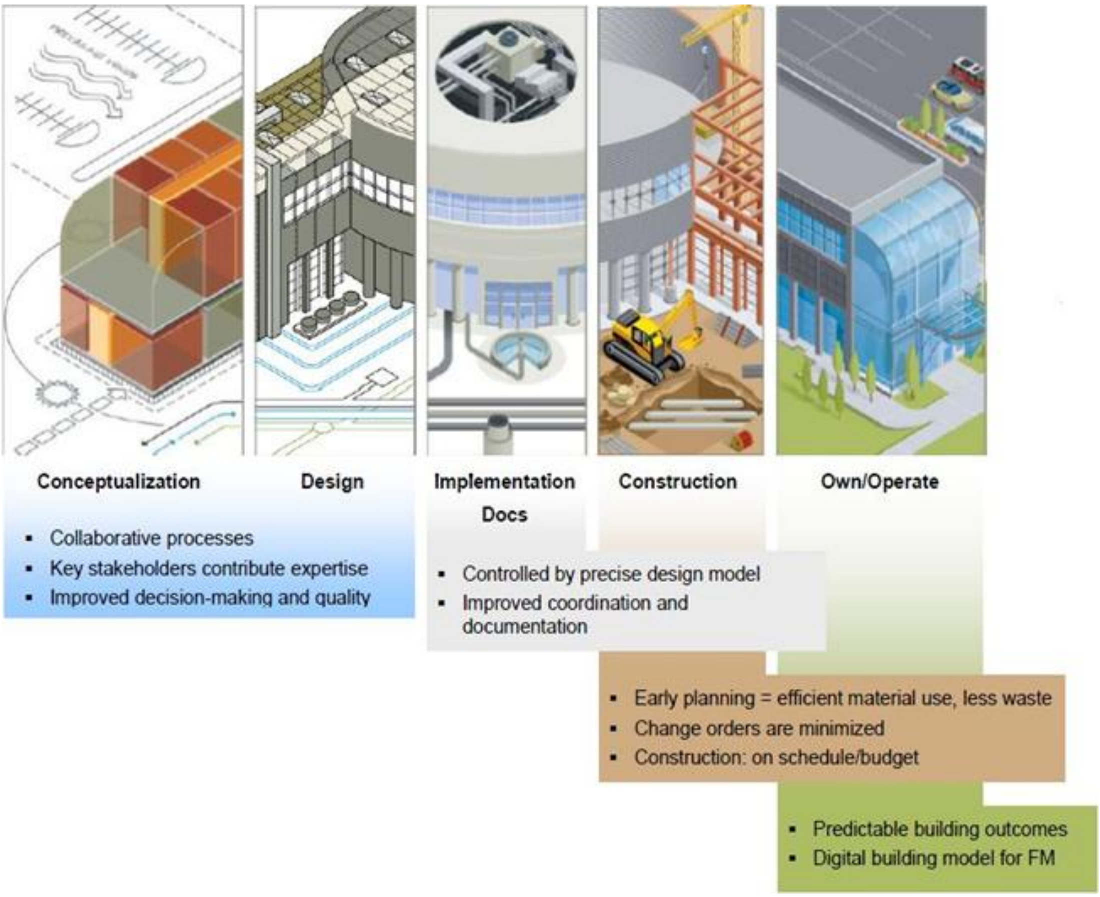

Figure 3: BIM representation of the project

The main difference between BIM system and conventional 3D CAD is the adaptability of all information plans, sections and details together in a normal 3D CAD, which can simulate the documents independent from each other and try to simulate the 3D views according to the plans, sections and elevations. Any possible change or editing in one of these documents is completely independent from others. Azhar et al. (2008) stated that 3D drawings contain data which are “graphical entities only, such as lines, arcs and circles, in contrast to the intelligent contextual semantic of BIM models, where objects are defined in terms of building elements and systems such as spaces, walls, beams and columns”.

Azhar et al. (2008) who reviewed factors of BIM found out that a building information model carries all information related to the building, including its physical and functional characteristics and project life cycle information, in a series of smart objects". (Azhar Salman, 2008)All the information generated in the BIM system is connected and adapted to all of the principles which cooperate the parts with each other to construct the building.

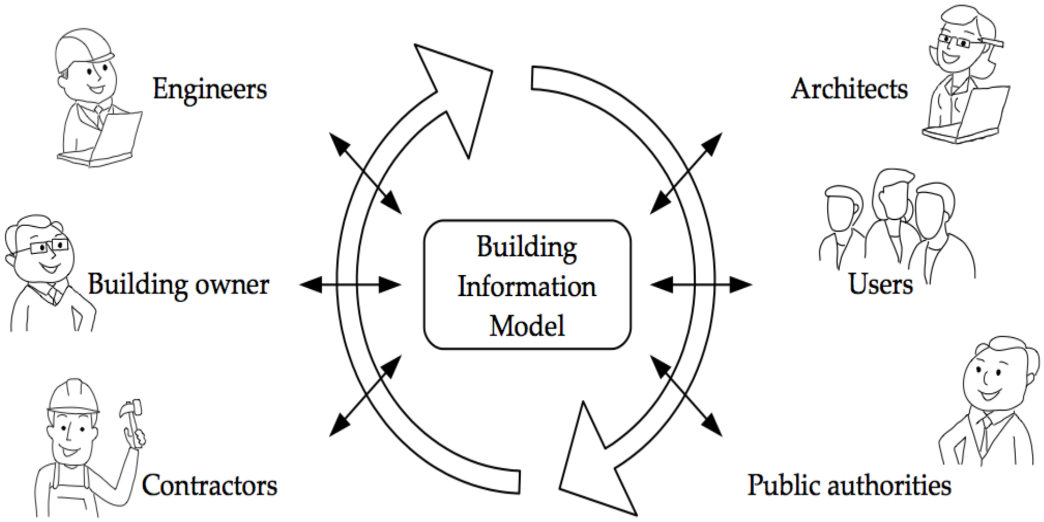

Figure 4: The BIM (model) and some of the participants of the building process

2.2 BIM for Architects and Engineers

BIM is a paradigm change for architects and engineers. In order to achieve a greater effort in designing and construction, BIM system gives more importance to conceptual design. This is one of the benefits of the BIM for architects who can design more accurate and realistic plans without any need to change the design. The possibility of misinterpreting the design in the construction period is also decreased. On the other hand, its benefits include easy methods ensuring reliability across all documents and reports and presetting spatial intervention checking. Thus, it is a great achievement to have a strong center of data, which are acceptable to submissions of analysis, simulation, cost and can improve visualization communication at all scales and levels of the assignment (Eastman, 2011)

There is another viewpoint, which advocates the use of BIM system procedure for design and analysis of building systems. “Analysis in this respect may be thought of as operations to measure the fluctuations of physical parameters that can be expected in the real building” (Eastman, 2011) The analysis covers several functional features of a building implementation like structural integrity, temperature control and even other aspects, which may be related more to architects like ventilation or airflows, lighting and acoustics. The BIM system also covers the energy efficiency of building. These aspects could become more analytical and predictable with BIM applications. There are several features, such as energy distribution and consumption, water supply and waste disposal that can be controlled by BIM as well.

BIM also has the potential to generate design layouts, which are used to plan and harmonize the various procedures of designs. In this level all of the documents are provided with absolute coherence. This is an association during all period of assignments from final concept design until the establishing in construction level. In all aspects and levels BIM system could be used as a contribution to the design and construction of projects. In addition, this system is also helpful for the refurbishment project. That is, BIM system can work as coherent database to harmonize all fragmented data in one reliable source in order to be utilized for renovation of the old and valuable buildings. However, all of these abilities have a certain prerequisite, which is selecting the appropriate software.

In BIM Handbook, Eastman (2011) stated that an operational way to border between a BIM authoring device and an analysis application has at least three aspects, which are listed as follows:

1. Assignment of specific attributes and relations in the BIM authoring tool

2. Methods for compiling an analytical data model

3. A mutually supported exchange format for data transfers

(Chuck Eastman, 2011)

These characteristics that are at the core of BIM could make an ability to sort and analyze multiple data entry for various analysis applications; it is just consent to the design virtual model to be analyzed straight within precise short time. Practically, all-current building analysis software features necessitate widespread preprocessing of the model geometry (Babič, 2010). This processing contributes to defining material properties and applying loads. BIM software could cover these three abilities, geometrical issues could be resulting directly from the corporate model; material assets can be appointed automatically for every analysis. The appropriate conditions, which are achieved in the analysis could be stored, modified, and applied.

2.3 Advantages of BIM

2.3.1 Benefits of BIM in the Design Part

When conducting a project, an architect should make sure to make a trade-off between the scope, cost and schedule of the project because any change in each of these key factors may bring about some unwanted impacts on the process of the project. In this regard, then, Building Information Modeling can effectively give an estimate of the cost and schedule of the project and this can help make critical and informed decisions immediately and efficiently, which was almost absent in the traditional methods of design.

Building Information Modeling also lends itself to automatic and quick changes to the project by a project team during different stages of documentation or design. This gives the members more time and opportunity to attend to the issues and problems at a higher level and value. Another advantage could be that the work of design and documentation of the building, which can be carried out concurrently rather than in a leaner or serial approach when the design is made and it is documented at another time. In this way, when the designer makes any change in the design, this change is instantly documented and matched to other parts of the project (Autodesk, 2002).

2.3.2 Benefits of BIM in the construction part

As far as the construction of a buiding is concerned, BIM creates and makes the data on the attributes of quality, scheduling and cost available for the building lifecycle of the project. By doing so, the constructor would be able to accelerate the calculations to estimate the cost and time as well as the planning of the project required to do engineering work. The constructor then can make this information and calculations accessaible for the engineers and even the owner to make plans ready and communicate easily by sharing the products and information among the team members. Furthermore, BIM technology is able to save time and cost on the part of adminstration because it can paln better due to having quality documents at its disposal.

2.3.3 Benefits of BIM in the management part

With regard to the management part, BIM provides the personnel with information for the building performance, the contents and occupants, its lifecycle, as well as the maintenance or financial issues. BIM makes a database saved digitally on the maintenance issues like renovations and later management or any modification or adoption in planning, which could include adapting some standard prototypes for business plans that need to construct other buildings in other places. This database also contains information on the physical properties of the building like finishes, occupants - tenant or business sections – the list of inventory and the contract or lease documents, the income and costs etc. Such information is expected to facilitate the management of the building effectively.

2.3.4 Potential for new services and revenue sources

The efficient exploitation of the information extracted from BIM can also provide architects with the required data to generate new sources of income as well as offering new services. For example, there are owners who are ready to pay for this data or other calculations or estimations. Therefore, architects can analyze, estimate and measure the likely services like energy analysis, renovation and refurbishing projects, etc for obtaining further income and making more money (Autodesk, 2007).

Parametric modeling, which is associated with the design and construction database, is a challenging one to observe from practice and insurance cover perspectives. Engineering firms will have increasing contests, as they understand that they are passing from a hard-copy plans and physical models to the primary data generators for a digital database (Guidelines for Improving Practice, 2007). Some difficulties with BIM will be interconnected to obligation. With the exposed access to the simulation model from all facets, (anyone elaborate in the construction project) how can architects and engineers be expected to sign a set of documents, placing their obligation on the line? This main matter could have possibly massive detrimental effects on output.

As the Architectural and Engineering firms transfer from an analog system, where creative construction designs are easy to classify and supervise, to a current "semiintegrated” system, this transformation is a step to achieve what should be called “super-integrated” future. These firms will have the new challenge with new rules and probably unfamiliar liability experiences. This occurs because of the owners, the subcontractors and suppliers put all the data to the BIM. The cohesion in the data and the timetable could afford to do the project through less time and more accuracy. In this method the budget of every project could be precisely defined with a minimum possible waste, which is the most desirable for a project.

Missing information in construction documents becomes the main cause to understand the importance of BIM. The main idea to design and approve the BIM system is to match all of the information of the project and check possible conflicts and problems between the documents and design in all majors, which are related to the project design. In this way all parties could be coordinated by BIM. Therefore, all documents and designs, information and details could be checked before the construction. When all parties involved approve these documents, the construction phase should begin.

All the parties can get together and coordinate the use of BIM model to achieve all construction information with the BIM simulation model. That is, they are connected to each other in this complicated network.

2.4 BIM Software

Architectural design applications do not have the capability to generate or represent structural associates, who should be appropriate for presenting structural analyses. Software companies propose individual versions of their BIM software to offer these capabilities. Revit Structures is the example that offers the simple objects and relations generally used by structural engineers. These features are an advantage for the engineers to design the structure of the project more accurate and easier. The features that are used for design purposes are columns, beams, walls, and slabs. The other ability of this software is that forms could entirely exchange the data and analysis with the same objects in their architectural BIM software (Chuck Eastman, 2011).

However, the BIM software applications have a dual representation in the structural options, which make the engineers to run the structural applications fluently. The first one is the “Stick and node” structural system to analyze the data and the structure of the project. The second option is a capability to analyze and make data about structural load, load combination and abstract behavior of connections, which is a contribution to the engineers to calculate and analyze the structure of project.

2.4.1 Object-based parametric modeling

In ordinary CAD systems objects are defined by fixed geometries and properties. However, in BIM software as well as other software, which are object-based, parametric the forming objects are geometry and its assets are definite by guidelines and parameters. By defining distinctive guidelines and parameters the modeling form could be controlled as to how objects act and relate to each other depending on the framework.

The objects form a hierarchy that can be defined by users. Object-based parametric modeling has a possibility for the users to outline a model family or element class. These families follow the relationships and the rules, where objects are defined by parameters. These parameters could be length, height and angles; all of these parameters are restricted by the family rules. It could be explained in this way that objects defined in a class or family vary based on their parameters and framework. However, rules and guideline could be set up following the necessities on the design.

2.4.2 Parametric modeling of civil structures

Engineers who want to work with the BIM models and simulations should consider that BIM features are object-based parametric models, which have a regulation of object families. The regulation of object families in BIM model approaches from both software designer and an independent company, which advances object families for the user of the BIM model, should be taken into consideration. This firm actually created an objective family and developed it for BIM users. Both these paths developed BIM capabilities in civil structures. BIM software converted the modeling process from geometric design features to a multi-layered creation of forms and data, which could be intelligent demonstration of a structure. There are great capabilities and a selection of these abilities is mentioned below:

Topological structures: With the capability of intelligent models BIM users could design as well as describe connections and relations between objects. These objects could be considered as any building element used to build and develop a building like walls and windows and even the direction of pipes. These relations and connections are used to cover three types of data: what objects can connect together; what are the connections made of; and at last what connection is appropriate for the environment. Therefore, BIM users could transport the necessary information to a model in BIM software that can be capable to mechanize the level design.

Property and attribute handling: when an engineer wants to analyze a part of a structure, should have enough information about the part and structure. So it seems to be necessary in the simulation that part has enough information and properties in the model. These properties could be recognized as: material specifications and assemble method, instructions and environmental impression. In a BIM model these characteristics can be arranged which make this capability for the users of BIM to analyze parts of construction. The comparison between 2D plan, BIM software simulation and real structure shown below:

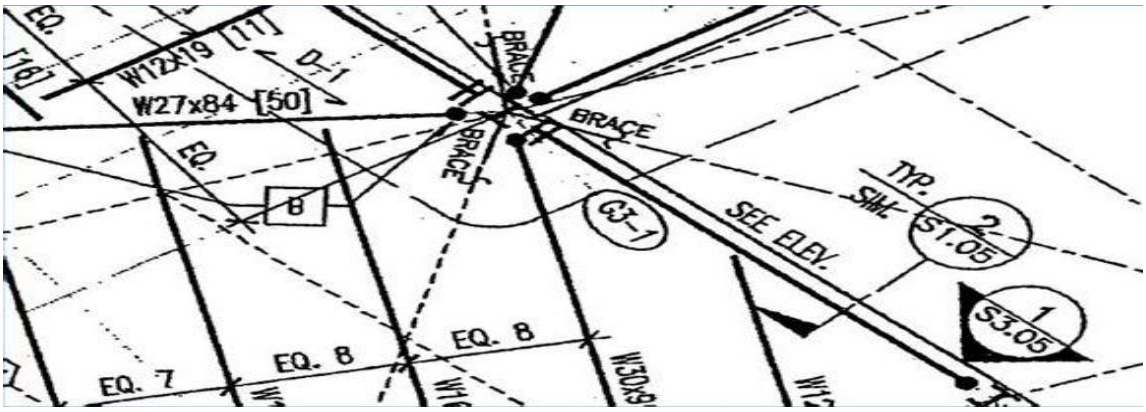

Figure 5: Pre BIM

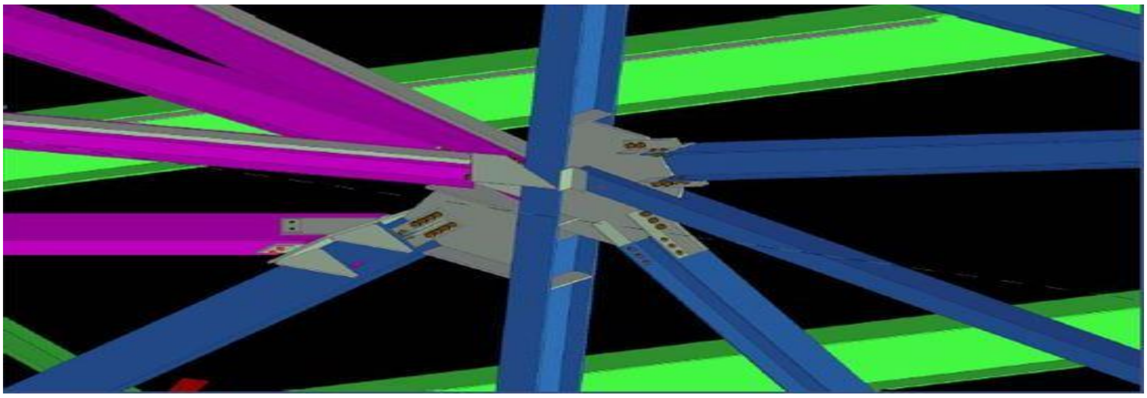

Figure 6: BIM

Figure 7: Part of structure

Drawing generation: BIM software applications have the capability for the users to extract a 2D drawing to 3D and from vertical or horizontal section they could add details in any level to the BIM model. If in design any possible changes occur for an object all of the relations will change automatically and will be updated. With this method all of the changes occur to all parts of documents and all of the plans and sections can match together.

2.4.3 Revit

The main challenge in the use of BIM is the issue of duality. The first one is Building Information Model that is digital building model and covers parametric knowledge and data. The second one concentrates more on Building Information Modeling, which tries to achieve concept and philosophy of a progression that may have usage in digital 3D parametric models to produce and analyze the building documents through its life cycle (Lee, 2006).

BIM needs software features to apprehend the philosophy. There are several software, which are used in the BIM system to optimize the result of the system such as ArchiCAD, Revit, Tekla structure and Bentley. The section below gives an introduction to the Revit software which will be used for the analytical and simulation of the data in the case study as a practical part of this research.

Revit is object-oriented parametric software, which was primary announced by the Revit Technology Corporation in 1997. In April of 2002 the Autodesk announced Revit software as one of its own properties. Revit is different from AutoCAD software since users have the capability to design with both parametric 3D simulation modeling and 2D drafting basics. In Revit software, every document, which exists in 2D and 3D, as well as the schedules, is an object or presentation of data from the same simulation of building model database. By using Revit software the designer can work on drawing and schedule views, and at the same time collect data about the project and organize this information through all other illustrations of the project. The Autodesk Revit software parametric changes engine repeatedly to organize variations, which occur anywhere, in model views, documents sheets, schedules, plans, and sections (Autodesk, 2009). Simulation of an object in Revit is a minor representation of the project. It associates with the parametric information and the environment factors. For example, users can move a sidewall in the simulation, the windows, which are located in the wall, in order to move them together.

The appearance of Revit is user friendly and understandable. Revit is designed and developed for the Microsoft Windows operating systems. The toolbars, which include the command icons, is very similar to Windows Office; therefore people can use Revit more quickly and conveniently. The users can use the command bar and find the commands and functions easily; the other way that is helpful for using Revit commands is the Project Browser panel to have a complete view of the plans, schedules, etc. Every year, the Revit interface changes eventually through the newer versions of Revit.

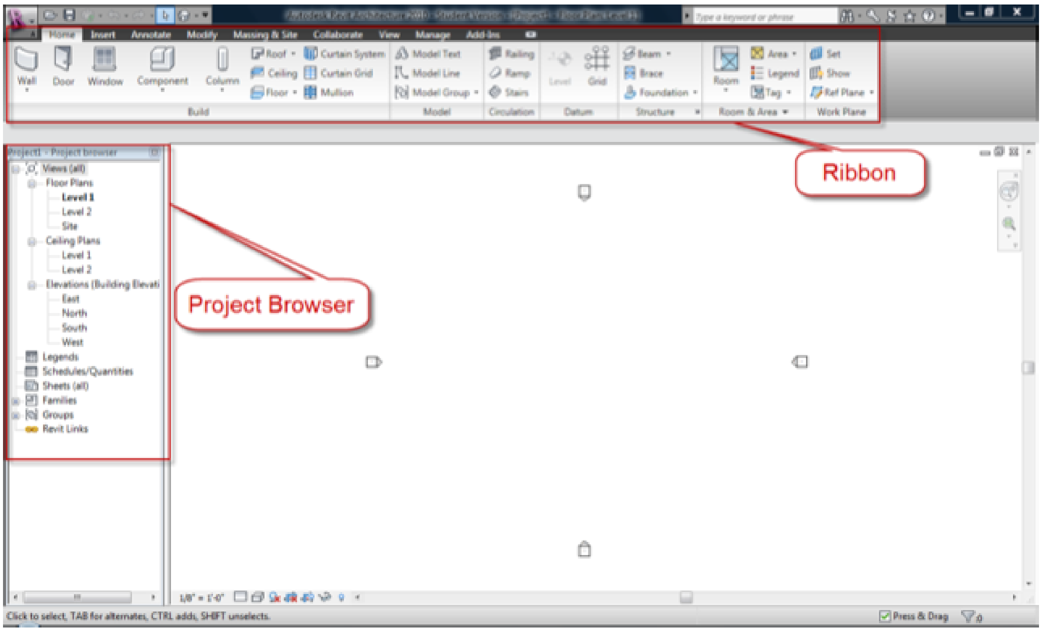

Figure 8: Revit 2013

2.4.3.1 Revit parametric system

In every project, Revit software uses 3 types of features or objects (Autodesk 2009). First one could be introduced as “Model features represent the virtual 3D geometry”. This feature presents the 3D simulation of the building components. They are displayed in related views of the simulation like doors, walls, pipes, and beams. These are the model elements, which complete the simulation more accurate. The second one is the “Datum elements assistance to designate project context”. For example, guidelines, levels, and reference planes are distinguished from the datum elements. The third one is ”View-specific elements display”, which help to define or document the model. This part includes dimensions, tags, and 2D detail components, which are considered as view-specific elements (Autodesk, 2011).

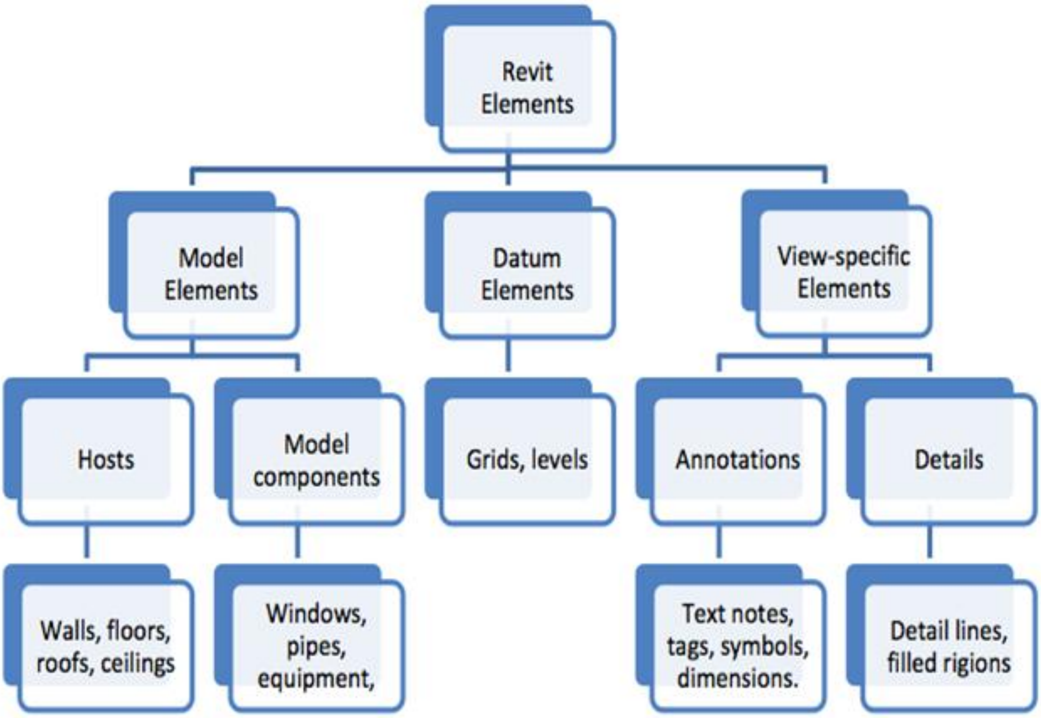

Figure 9: Revit parametric modeler (Autodesk 2009)

There are 2 categories for model elements: the first one is Hosts (or host elements) that are commonly built in the location of the construction site such as walls and roofs. Model components are entirely the added types of features in the building model. For example, windows, doors, desks, chairs and lamps are model components, which are hosted by host elements (Autodesk, 2011).

There are 2 types of view-specific elements: annotation elements are 2D components, which document the simulation and preserve scale on paper. Dimensions, tags, and keynotes are annotation elements. The Details, which are 2D items, are affording details for the building simulation in a particular view. Examples could be introduced as 2D detail components, filled regions and detail lines. (Autodesk, 2011)

2.4.3.2 Interoperability

The IEEE (Institute of Electrical and Electronics Engineers) described the term interoperability as the capability of two or further systems or components to interchange information and to practice on the information, which has been changed. (Institute of Electrical and Electronics Engineers, 1999).

This research achieved results, which showed that Revit software has the capability of interoperable with many other BIM features. These features also include software like Bentley Architecture, Digital Project and ArchiCAD (Georgia Institute of Technology, 2009). Revit is also designed to be interoperable with products of Autodesk, which included all versions of Revit: Architecture, Structure, and Mechanical, Electrical, Plumbing (MEP).

Revit Architecture : Building Information Modeling software developed by Autodesk often referred to as Revit. It allows the user to design with both parametric 3D modeling and 2D drafting elements.

Figure 10: Revit Architecture

Revit Structure: Similar to Revit Architecture but with additional tools and functionality specifically aimed at structural engineers.

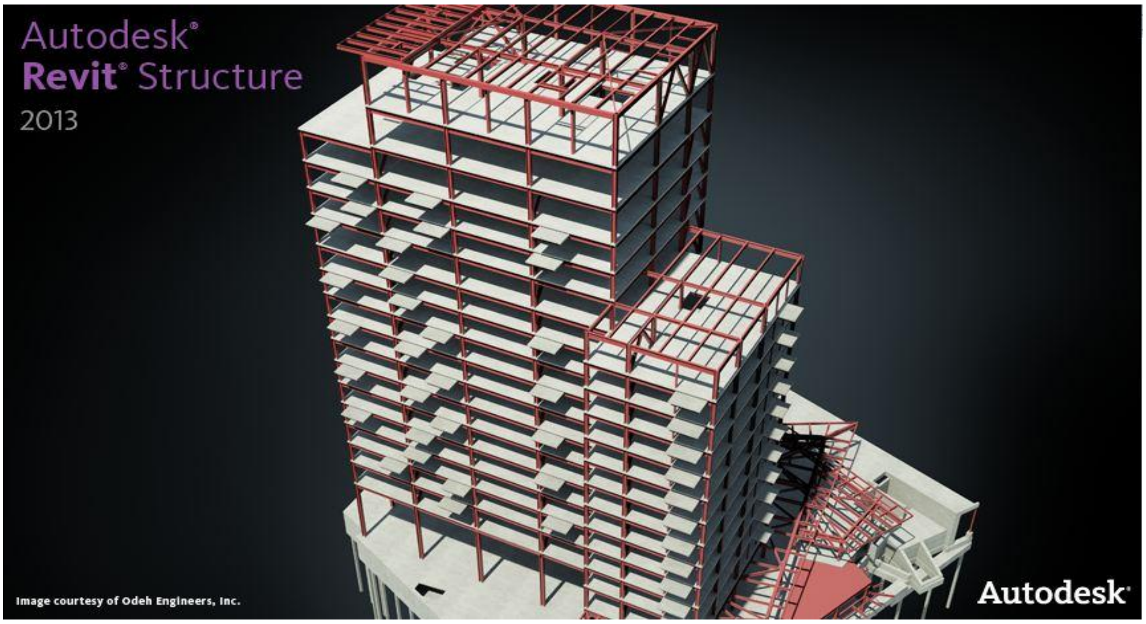

Figure 11: Revit Structure

Revit MEP: Similar to Revit Architecture but with additional tools and functionality specifically aimed at mechanical, electrical and plumbing engineers.

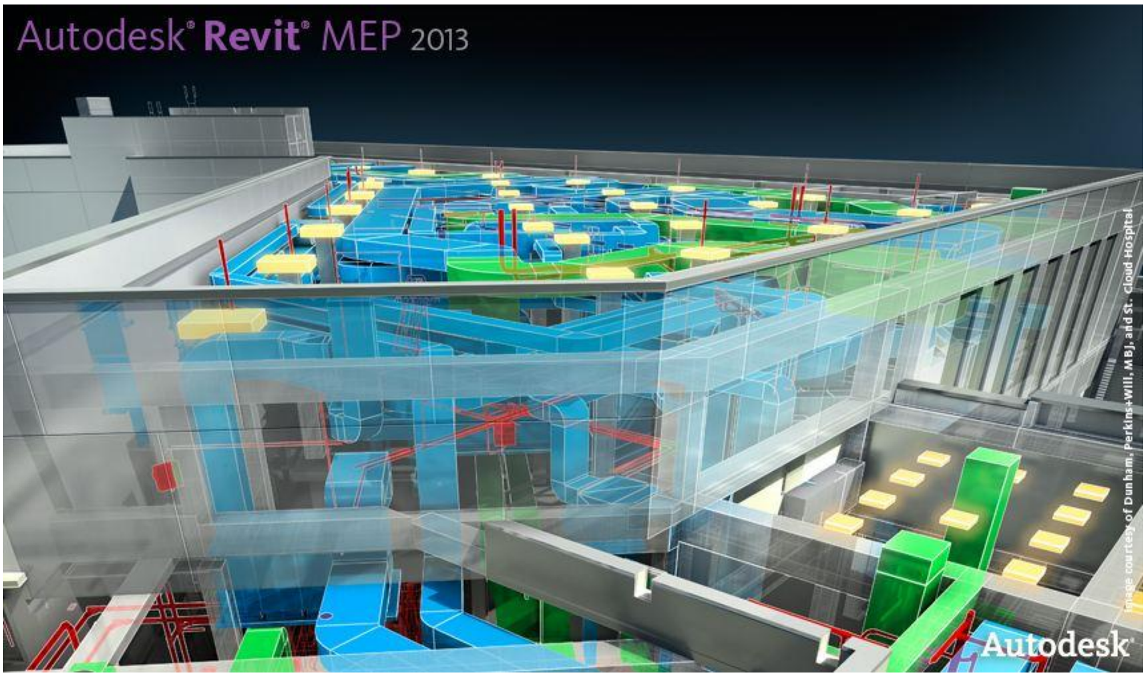

Figure 12: Revit MEP

Autodesk had formed Revit into three main styles for the variable building design disciplines. Revit Architecture is software, which was created for architects and designers; Revit Structure is deliberate for structural engineers; Revit MEP is for electrical, mechanical, and plumbing engineers. All these three versions share the same interface of the software and also have the same parameter systems, but with diverse uses (Innovation, 2007).

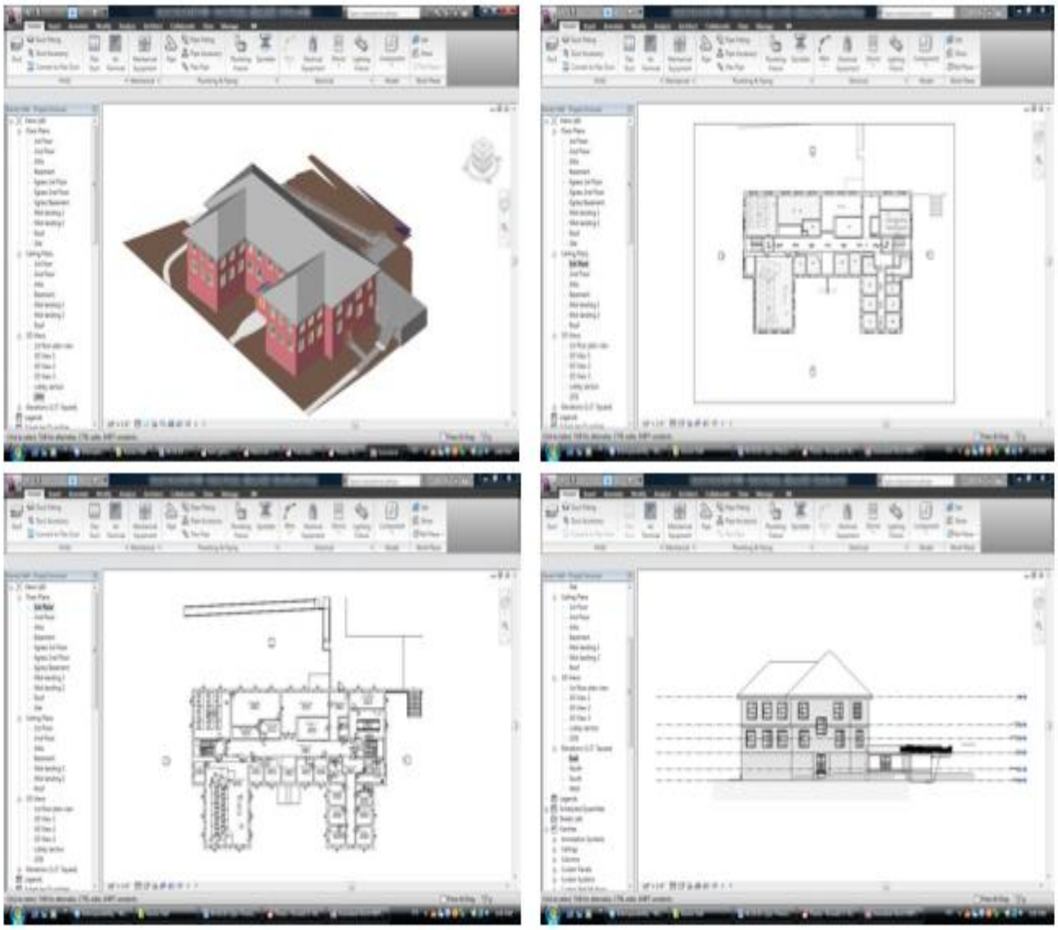

Figure 13: All these three versions share the same interface of the software

Chapter 3

Laser Scanning

This chapter begins with an overview of Laser Scanning as the second technology under investigation in this study. Then, the methods of 3D scanning are explained in details along with a visual presentation of different components of the most popular laser scanning tools which are used these days. In addition, different types of scanning are descibed and at the end a short literature on the usages of laser scanning tools in different fields as well as in construction industry is provided.

3.1 Laser Scanning Overview

3D Laser Scanning captures data within three coordinates of longitude, latitude and elevation of different objects. This equipment, which works by laser light, records this spatial data by millions of points (Jones, et al., 2008). In most cases, a lot of scans from various angles are performed in order to obtain enough data for an object or a location such as an architectural or construction site or a historical building. These types of scans, which are formed by plenty of point clouds (A point cloud is a set of vertices in a three-dimensional coordinate system. These vertices are usually defined by X, Y, and Z, and typically are intended to be representative of the external surface of an object. Point clouds are most often created by 3D scanners. Point Cloud tools in Autodesk Revit Architecture software connect laser scans directly into the Building Information Modelling process, helping to accelerate renovation and retrofit projects. By visualizing point clouds directly within the Revit software environment, it is easier to create an as-built model with more confidence and accuracy), are processed and saved to form a special model of an object or to be registered for later use. In other words, 3D scanner is a device that analyzes a real-world object or environment to collect data on its shape and possibly its appearance. The collected data can then be used to construct digital, three-dimensional models useful for a wide variety of applications (Georgopoulos et al., 2010, p. 250).

It is worth mentioning that this technology has been developed only to enhance accuracy of measurements that are used for various purposes worldwide. The new 3D scanners have outperformed 2D scanners, which were previously used for producing 2D maps and drawings. Not only do these 3D scanners help researchers produce more accurate and faster models and maps, they also deal with an object under study by points. This would bring efficiency and efficacy for this technology, which is being used in medical sciences, geography, reverse engineering, construction etc.

Based on the data, which is acquired from laser range finder plus vision's data in a solo representation, 3D model is created. This model then makes our distant observations easier and our scene overview faster. Another advantage of this procedure is that when we process an image the view of construction like doors and windows are clearer than 2D model. In 2D models these constructions are invisible and are not shown. So the 3D model is more appropriate than 2D models for different tasks.

In comparison to the 3D scanners with cameras, we found out that these two have a lot of similarities. However, when we compare these in capturing the surface of a certain object, the camera gathers color information and 3D scanners gathers distance information. Range of the data that we acquired from the 3D scanners defines the distance to the every certain point of the object surface. Another advantage of 3D scanners is that when the direction of an object is changed, for example rotation or in a rotatory mirror mode, the range finder has that capability to be changed. The mirror method is commonly used because it is lighter in weight compared with that of the entire system. So in the rotation mode you can rotate it easier, faster, and more accurate. Information and data that is necessary for making the model is acquired from several scans of different sides of a certain object. The alignment and registration is a name that is given to this method. After this process, the scans are combined to make the whole 3D model.

Figure 14: Laser Scanning

3.2 3D Scanning Methods

For the last two decades robots have been used to map the indoor environment, which have become one of the major problems scientists have to deal with. Nevertheless, the procedure which used for indoor environment is not completely useful to map the outdoor environment. This means that for different purposes and environments we need different scanners. Types of the scanners that are used for this task are very important and vital. There are various procedures used to collect range data to make a 3D model of an object. They are classified in two main groups: non-contact scanners, which are categorized in two sub groups: active and passive, and contact scanners. These groups will be discussed in details in the following section.

3.2.1 Contact Scanners

These scanners represent a 3D model of the object surface and during this process scanners should have a direct contact with the item, which becomes the major disadvantage of this device. This disadvantage becomes more visible and important when it comes to scanning the surface of a fragile object or when the object is expensive, because of the probable damage to the object during this process.

Another deficit of this 3D scanning procedure is that it is slower than other similar techniques. Because, in order to scan a certain object the probe should be attached, so there is a necessity of changing arm position several times to scan the whole object. This will affect the quick movement of the system and decreases the system operating speed.

Figure 15: Contact Scanner

Figure 16: Contact Laser Scanning (coordinate measuring machines with rigid perpendicular arms)

3.2.2 Non-Contact Active Scanners

These scanners fundamentally rely on radiation and reflection of the light. In addition to the light, they can produce ultra sound and x-ray. They can be used in both indoor and outdoor environments. The scan range ability of these scanners is wide and they can make a 3D model from a tiny object to the huge elements such as trees and buildings.

3.2.2.1 Hand held Laser Scanners

These scanners by the triangulation technique produces a 3D image. This device transmits the laser onto the subject surface in order to evaluate the distance. After collecting data, they are stored in computer. Then these data become range data in a system called 3D coordinate system. This scanner also can combine these range data with textures and subject surface colors to make the 3D model.

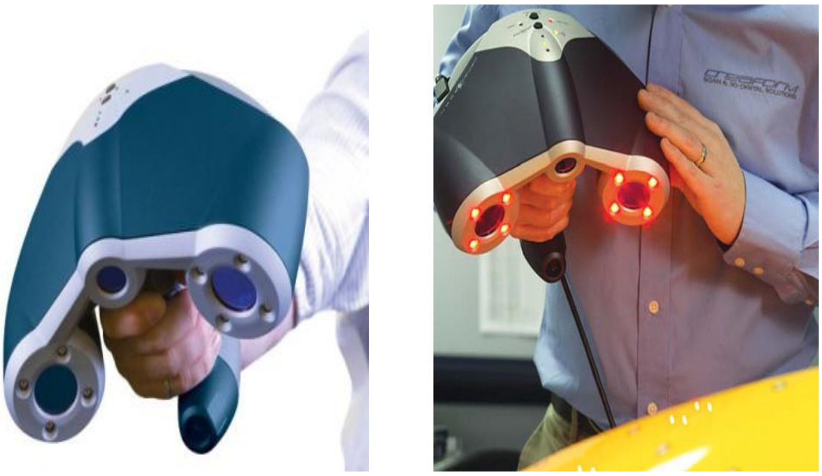

Figure 17: Hand-held scanners

3.2.2.2 Light Detection and Ranging (LIDAR) Scanners

Light Detection and Ranging (LIDAR) and SONAR belong to the same types of technology (Cai, 2003). LIDAR consists of a process that starts with sending out laser light at an object and then dealing with analyzing the data through calculating the time the beam flies. Both static and moving objects could be laser scanned in less than a second with the least amount of money.

This 3D Imaging and LIDAR are developing fast in the related areas such as engineering and surveying, where these technologies determine the production of the detailed maps and drawings of objects. In addition, compared with those conventional means of measurement that produce single points with a larger 3D coordinates from10-50 feet apart, LIDAR produces point coordinates within less than an inch apart. LIDAR also has the potential to retrieve the details of coordinates for countless number of points and this is another characteristic that has made it useful for different clients. All these tasks are done within a millisecond and are very cost-effective for the purposes of collecting data.

These scanners can produce laser beam at different ranges and in different directions. The main part of these scanners rotate horizontally and in order to support the vertically movement, there is a mirror inside it to flip vertically, and if the main part rotates vertically, the mirror flips horizontally. By the laser beam this scanner has that capability to measure distance to the first item on its way.

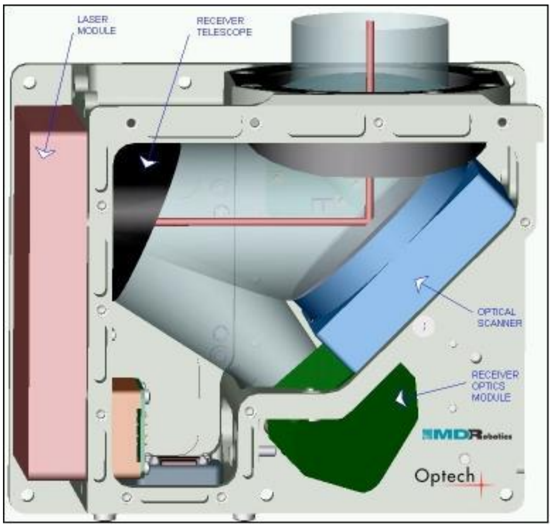

Figure 18: Internal system of LIDAR scanners

3.2.3 Non-Contact Passive Scanning

In contrast with the above-mentioned scanners, passive scanners do not give out radiation and depend mostly on the detection of reflected radiation from the surrounding environment. For example, they rely on the visible light, as it is already accessible from the ambient radiation, though some other types of radiation like infrared could also be used. This then would make the use of these passive methods cheap because they do not need very sophisticated hardware to do the job (Yu et al., 2011).

3.3 Scanning Principles

LIDAR scanners are active type scanners that use beam light of laser to investigate the object. The main feature of this type of technology is based on the time of flight laser range finder. Laser range finder is a feature that processes the detachment of object surface by timing the pulse of light around the object. By calculating the propagate of a pulse of the laser light and the time between this pulse and the reflection of it which detected from the surface of the object the scanner, it can deliver a point by point data collection from the surface object. The accuracy of every scanner device depends on the accuracy measurement of the time between each reflex of the laser beam. Generally, scanners capture the range data based on spherical coordinates.

3.4 Operating and Monitoring Vehicle

As was mentioned before, a 3D simulation gives more detailed and data rather than a classic 2D map. The combination of the laser range data, or what is called vision data in a model, forms a digital textured in 3D simulation. Conversely, in several cases, a scan shot is not enough for form to create a complete simulation of the object. Mobile robots, which are used in indoor scanning, could not be a considerable method to be used in outdoor scanning of environments straight.

The scale of environment is one of the considerable factors in outdoor scanning. The indoor scanning simply deals with the rooms and corridors, which are completely different, compared to the outdoor scanning. In the outdoor scanning, the approached map should be scaled to square kilometers. In environmental scanning the user should travel kilometers to take enough rang of information to set it for suitable simulation. In this scale the small details like rocks or facade details become problems for computer vision. To overcome this problem in outdoor scanning, the laser scanner uses an additional device to Operating and Monitoring as a Vehicle System. This vehicle is planned to transport the laser scanner through the indoor and outdoor operation process.

3.5 Alignment or Registration

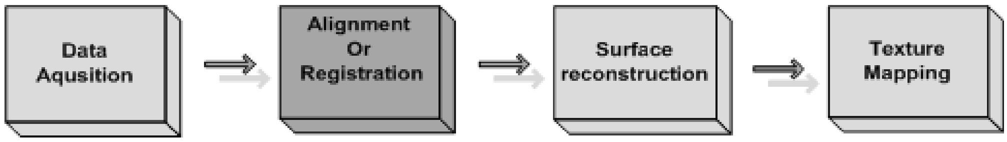

Figure 19: Forming the Point Cloud Model (Alignment or Registrations)

Every point, which is scanned with the laser scanner device, has three dimensions of X, Y, Z. With these three dimensions every point is located in the final result of the simulation. However, this data is just the raw data of simulation and with this information the final model of the objects could not be achieved. There are several methods to form a simulation according to the data, which is collected from the field. The famous and widely used method of the graphical simulation is the point cloud presentation.

Point cloud presentation method forms the 3D graphic simulation from an object or scanned environment area by ordering all data matching to their scanned space. This method presented the data as particular dots, which are collected from all dots, or points that form a point cloud simulation from the scanned environment or object. Therefore, creating a point cloud simulation or a range data is a basic aim to achieve.

The software and the usage of this data have become critical and important in this process.

In several cases, one-scan shot could not be sufficient for progression of a complete simulation or object. Many scans have to be taken from several different angels and directions to capture information and data about all sides of an item. All these scans have to be assigned to a unique and common reference coordinate system. This process is not only used to form a unique and complete model of the scanned object or environment but also to approximately create a seamless point cloud model. This procedure is commonly called alignment or registration.

However, in several situations the attached point cloud simulation has the weakness of sparse noisy data, which are overlapping with the other data. The main cause of this phenomenon is the inapplicable merging process. To prevent such problems there are algorithms and techniques such as using variety type of noise redundant or different method of merging. This is an important step on the pre-processing phase of the surface reconstruction process. This phase is a basic step of the modeling sequences of laser scanning. Alignment methods are categories in three main groups: manual, semi-automatic and automatic.

Manual method is based on adjust and align a various rang of data (two or more) from an object or environmental target. This rang of data could be produced in different angels or different viewpoints. The achieved point cloud has this capability to be rotated, shifted or scaled by the user. The simulation that is created with this ability and the data match together and the user could find the best position to merge, align or stitch the point cloud situation.

Automatic methods do not need any contribution from the user in the working process period. These methods have the ability to find the common attributes and objective points in every point cloud, which could be achieved separately such as edges, curves, corners, and sharp sides. Therefore, to achieve this attribution in this method the alignment are estimated on the prominent and from that step the software could detect all the other points and match these point clouds together. Matching the several point clouds is the final step of this regulation, which could be occurred by transforming and translation methods.

Semi-Automatic methods are based on a partially manual method and automatic method. In the first step of this alignment user should specify the similar points in several ranges of data manually afterwards the software match all the other points automatically according to the selected points by detecting methods.

One of the samples, which should be mentioned as a semi-automatic method, is the laser scanning simulation from the EMU Techno-park building, which is located in the North Cyprus. This simulation is achieved by several scans from several points. The main target of these scans is the main entrance of the Techno-park building (Figure 19). In this Figure, the photo simply shows the scans of the: a) front angle, b) left corner, c) right corner, and d) merge data.

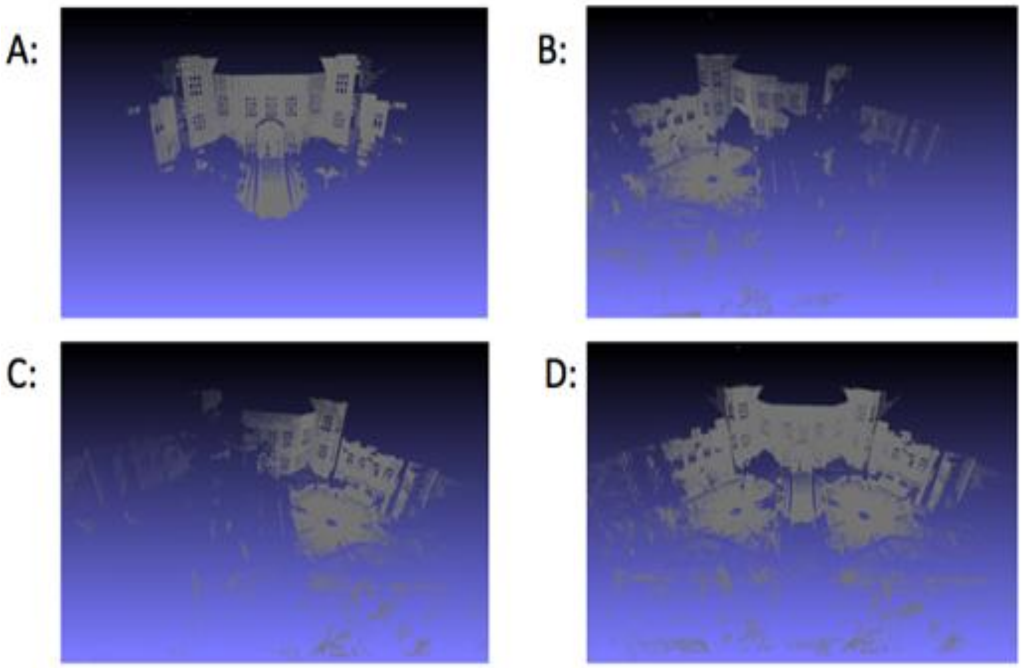

Figure 20: Point clouds merging sequence (EMU, Techno-park, front entrance)

The last part of every scan is the surface reconstruction to make a high-resolution simulation, as a result. The surface reconstruction mainly estimates the arbitrary surface from the topology of an object to the point cloud simulation.

3.6 Laser Scanning Applications

A 3D modeling that uses Laser scanning tools is very effective for many applications in terms of their speed and cost.

3.6.1 Mechanical Engineering

One of the applications of Laser scanning is in mechanical engineering where these types of software convert point data into other software like Revit fast and accurate.

Figure 21: Laser scanning in Mechanical Engineering

3.6.2 Construction design

Another field in which 3D modeling is utilized is in construction design where designers need to develop designs of roadways, highways, bridges, or use this type of modeling for other purposes like rehabilitation or renovation. These projects can offer many advantages such as minimizing coordination problems, generating multiple views and bills as well as integrating this data into software that are usually used for analysis and interpretation.

3.6.3 Transportation

In this area, Laser scanning applications can be used in designing highways because they can cater for surveying the highway when the traffic is heavy without the need to put surveyors at different positions or even closing the highway. They also could be made use of in generating as-built drawings for bridges in case of any renovation or change. In addition, Laser scanning can be employed for simulation purposes like storm simulations in order to assess the volume of water and its pounding impact as well as the drainage systems of these structures. They can also be used as the invaluable applications to inspect rebar, potholes, and rutting in the roads.

Figure 22: Laser Scanning in Transportation

Figure 23: Use of Laser Scanning in Transportation

3.6.4 Surveys

There are cases when a traditional survey cannot be used because they are not accessible or safe. In such places, therefore, Laser scanning applications are the best choice. They are used to execute as-built surveys accurately and efficiently in areas, in which access is an issue, arrangements are complex or there is a sense of danger or risk.

Figure 24: Laser scanning for surveing

3.6.5 Historical modeling

Recently, laser scanning has become a standard tool for 3D data collection for the generation of high quality 3D models of cultural heritage sites and historical buildings. This system allows for the fast and reliable generation of millions of 3D points based data on the run-time of reflected light pulses, which will result in a very effective and dense measurement of surface geometry.

Figure 25: Scanning the historical place with Laser Scan

Figure 26: Scanning historical place

3.6.6 Accident investigation

Another area where Laser scanning can provide valuable 3D model data and documentation is in forensics and investigations of an accident site on the roads or streets.

Figure 27: Laser Scanning in Accident Investigation

3.6.7 Planning, logistics, and management

Laser scanning can also provide scans of existing buildings. For instance, 3D modeling can be used in cases where the owners or designers want to install new buildings or any other additional planning or change. This scanning is shown by hologram that illustrates the location of everything in the building, which can help the designer see or inspect walls, studs and any other components. Then, this modeling can give an overview of the quantity and quality of the work to be done. Besides attending to the quantity of the work, Laser scanning could also be applied to improve as well as control the quality of the work such as measuring the location of different components, scanning them and evaluating their performance.

3.7 Research on Laser Scanning in the AEC Industry

Laser scanning has also been used besides conventional means of recording data and information only to help this process. However, the investigation and research in this field is going on, which is mainly focusing on ways concerning the exploration of methods to make the scanning more accurate, to do research on analyzing approaches for the comparison of the collected data from scanning to the models designed for quality control, and finally to conduct research on producing as-built BIM based on laser scans (Huber et al., 2010).

However, Laser scanning technology could have some limits to be identified and making sense of these restrictions might help use this technology in a more efficient and effective way. Some of these issues were voiced by Huber et al., (2010), while referring to the use of mixed pixel detection and modeling edge loss at certain depth conditions. Bosche (2009) also proposed an approach to verify dimensional compliance control and progress monitoring to track the status of 3D during the construction timeline. Some researchers used a robotic total station as well as a Laser rangefinder system to gather coordinates of the end and center line of different parts of buildings and then used Revit to feed the data in and to place essential modeling components (see Goedert & Meadati, 2008). This process proved to be cheaper than a full Laser scanning. In addition, Laser scanners were used to monitor construction sites in order to make a comparison of as-built conditions and identify the possible faulty spots (Huber et al., 2010).

There is evidence that little has been done to generate as-built BIMs from Laser scans in their complete automation. The process, which is at work these days, is to generate point clouds from LIDAR and then use different types of algorithms to convert them to a 3D surface. Some of these algorithms have been developed so far (see Brilakis et al., 2010; Huber et al., 2010; Maas & Vosselman, 1999; Tang et al., 2010). The next step in this process would be replacing a group of points by objects from a standard pile of components. The final step involves attaching a detailed set of attributes to each object so that they show level of the needed as-built (Brilakis et al., 2010). However, this process could be expensive and laborious and therefore many owners and developers still prefer to use more conventional methods for constructing their buildings.

3.7.1 Laser Scanning in Construction

Following the geometry of the objects that do not fall within the category of apparatus is one of the challenges at a construction site, which is of crucial importance because this data does not have a special form to be used in the work method. This type of information or formless data could be found in workspace surfaces, highways, interior and exterior spaces, etc. In addition, the approach or form of capturing this data on the construction site is another challenge because the project managers and engineers should be able to explain this procedure besides the way they offer or obtain feedback on it. Without this data it might be difficult to give a description of the construction site. Therefore, Laser scanning and ranging seems to be considered the proper tool not only to provide data but also to conduct a 3D analysis of the data.

This, thus, requires the study of three main areas of registration of the data, sensor calibration and classification of the objects. The registration methods are to be used in order to verify the data. Sensor calibration is used to check on the precision of the measurement though this is not an easy job and it needs a complex procedure, which is beyond the remit of this section. Regarding the surfaces whose data is unclear, their calibration should involve developing certain algorithms. Although establishing measurement metrics is not easy for such surfaces, making a comparison of the results from the model and the ground can be a solution. This algorithm can be assessed if the shape and the volume of the surface could be obtained. Lastly, object classification ensures that objects that are not parts of the land can be removed from the data.

Chapter 4

METHODOLOGY

The purpose of this chaper is to touch upon the description of the instrument exploited in this study. First, the process of design, development and precedure of applying the questionnaire is given. Then, the case study project is described as a practical miniature project in which the application of BIM and Laser Scanning tools are going to be displayed.

This study aims at investigating the stand and use of Building Information Modeling applications along with Laser Scanning tools among different teams and specialists in the field of construction industry. First, the perceptions of a sample of participants were sought using a survey questionnaire in order to realize if these technologies were common and, if so, what areas in construction they would be helpful. Secondly, the actual application of these technologies was reviewed in a case study, which was carried out on the mapping of Technopark building located in Famagusta, North Cyprus. This case study was included to give an example of how BIM and Laser Scanning tools can be effectively and efficiently integrated to serve different parties and groups in this field. The following section presents an overview of the so-called instruments and components of this study; namely, the questionnaire and case study. Then the results section is provided, which is followed by the discussion of results and the details of carrying out the case study. At the end, a list of references is given for further research and information.

4.1 Questionnaire

A survey was administered to 48 participants selected mainly from people such as designers, architects, civil engineers, managers, etc. who were working in different areas of construction industry. This questionnaire consisted of 22 questions, which could be broken down into three categories covering some related tasks these applications might be expected to carry out. For example, the first set of questions, 1 to 12, addressed the use, advantages and challenges of BIM at workplace. The second set, questions 13 to 17, covered the applications of Laser Scanning tools, their benefits and potential. Finally, the last set of questions, 18-22, targeted the integration of these technologies and their future use through the eyes of the respondents. This questionnaire was designed by the researcher in an electronic format and was sent to as many as hundred Email addresses of those working in important construction companies in some selected countries. However, only 48 people filled in this survey and returned them later. The analysis of the data was conducted automatically using MonkeySurvey (surveymonkey, 2011) application, where the survey was designed.

4.2 Case Study

The case study project focused on the integration of Building Information Models and Laser Scanning tools while mapping a building site. In addition, this was a real-life case where the results of questionnaire could be evaluated, hence confirmed or refuted. For this purpose, the building of Technology Development Center (Technopark) was selected due to easy access to different mappings and plans of the building as it is owned by Eastern Mediterranean University and the goal of establishment of such a center was then to provide students and academics of this university with the materials and technological instruments they need for the research purposes. Furthermore, the building was located in a place where taking photos and getting information from different angles was easy because of the surrounding open spaces.

Different 2D and 3D plans of this building were collected and then a CADeyes Laser Scan, used as one of the Laser Scanning technologies, was used to gather Point cloud data from different parts of this building. This data was taken using different applications of Laser Scanning such as registration of data as well as its calibration and classification by several sensors. This data was based on three coordinates and algorithms capable of being deciphered by BIM software such as Revit, which was exploited to convert Point cloud data into 3D models to be used for design and construction purposes.

Chapter 5

QUESTIONNAIRE

This chapter provides information on different parts of the questionnaire, its administration and analysis of participants' perceptions on the items of this survey. The results are then tabulated and presented according to the order of the items on the questionnaire.

The survey included two parts: the first three questions addressed demographic information while the second part, which was made up of 22 questions, covered the issues related to the application, use and the future of the integration of Building Information Modeling and Laser Scanning in construction. The results of the geographical distribution of the participants' workplace are given in Table 1.

Table 1: The geographical distribution of participants' workplace

Workplace	Number	Percentage (%)
Iran	18	37.5
USA	12	25
Cyprus	9	18.75
Canada	6	12.5
UK	3	6.25
Others	0	0

Participants were also asked as to their field of specialization and majority of them reported that they were working in civil engineering and project management fields.

Table 2: The distribution of participants based on their field of specialization

Field of specialization	Number	Percentage (%)
Civil engineering	18	37.5
Project management	15	31.5
Architecture	9	18.8
Building surveying	6	12.5
Others	0	0

In addition, more than half of the participants reported that they had 1 to 10 years of experience working or teaching in the field of construction.

Table 3: Participants' profile based on their years of experience

Years of experience	Number	Percentage (%)
1-5	15	31.25
5-10	12	25
10-15	3	6.25
15-20	9	18.75
20+	9	18.75

The participants' responses to the second part of the questionnaire indicated several results. It was assumed that most of these respondents had information about the field as well as BIM software, and they were working with this software. This helped the researcher to investigate their attitudes towards using this software and how it helped them in their work and how they would see the future of this application. In addition, the aim was to see the effect of this application on time, cost, quality and health and safety. For example, respondents' opinion about the level of their awareness about BIM showed that 31.25% were 'somewhat' aware, while the same percentage (25%) had 'very much' or 'just a little' and the rest had no information about this application.

Table 4: Participants' responses on their information about BIM

1. How much are you informed about BIM?		
Options	**Response Percent**	**Response Count**
Very much	25.0%	12
Somewhat	31.25%	15
Just a little	25.0%	12
Not at all	18.75%	9

Furthermore, 68.75% indicated that they were aware of using of BIM while 31.25% simply said no to this question.

Table 5: Participants' responses on their level of awareness about BIM

2. Are you aware of any BIM software?		
Answer Options	**Response Percent**	**Response Count**
Yes	68.75%	33
No	31.25%	15

They were also asked as to the reason they were using BIM in their company. Exactly half of the respondents used it for design coordination. Others, however, used it because the owners demanded it (31.3%), used it to sequence construction (12.5%) or employed it for other purposes (6.3%).

Table 6: Participants' responses on their reasons for using BIM

3. What is your reason for using BIM in your firm?		
Answer Options	**Response Percent**	**Response Count**
Design Coordination	50.0%	24
Owners demand	31.25%	15
Construction Sequencing	12.5%	6
Clash Detection	0.0%	0
Extract bill of quantities	0.0%	0
Competitors using it	0.0%	0
For efficiency process improvement	0.0%	0
Others	6.25%	3

Regarding the type of software used in the firms where they were working, almost half of the participants were using Revit, while the same percentage (18.75%) were using Tekla or no software and 12.5% were working with other types of software.

Table 7: Participants' responses on the type of software they were using

4. Which software do you use in your firm?		
Answer Options	**Response Percent**	**Response Count**
Revit	43.75%	21
Tekla	18.75%	9
Allplan	0.0%	0
Archicad	6.25%	3
Navisworks	0.0%	0
None	18.75%	9
Other (please specify)	12.5%	6

Concerning their opinions on the items that might have been affected by BIM application, participants rated better design tool as the leading item benefited from using BIM followed by other items in the order of the most important to the least important from client demand, competitive advantage, saving costs and energy analysis purpose.

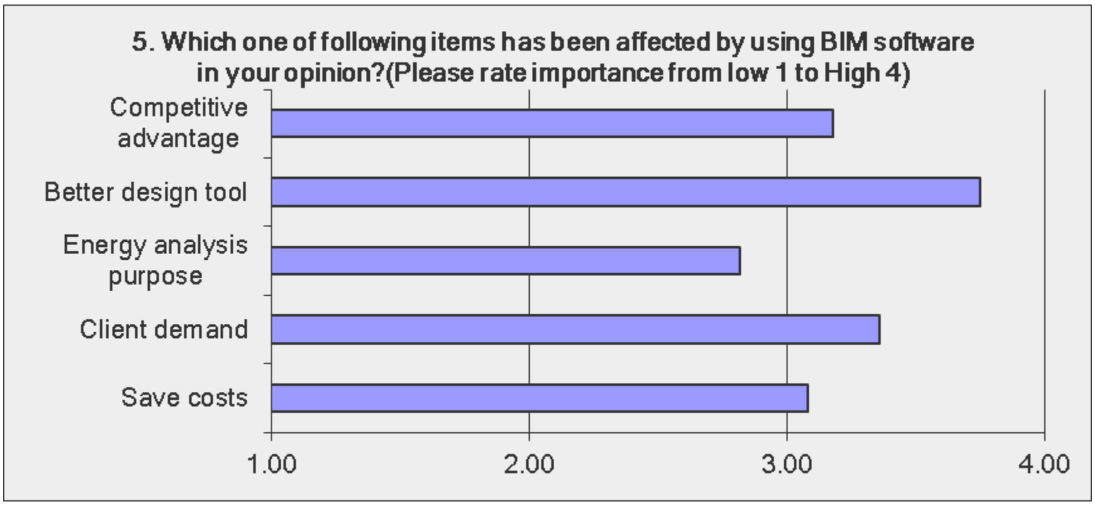

Figure 28: Participants' perceptions on the effect of BIM on different aspects of their job

Table 8 shows the participants' opinions concerning the different parties that could use BIM more efficiently in their workplace. The results indicated that they rated construction management team and architects as the main two parties involved in using this application more efficiently than other parties like contractors (10.4%), subcontractors and MEP (6.3% each) as well as other parties (12.5%).

Table 8: Participants' perceptions on the party using BIM more efficiently

6. Which party in construction industry could use BIM more efficiently?		
Answer Options	**Response Percent**	**Response Count**
Architectures	33.3%	15
Construction management team	31.3%	16
Contractors	10.4%	5
Subcontractors	6.3%	3
MEP	6.3%	3
Suppliers	0.0%	0
Others	12.5%	6

Question 7 asked participants whether adopting BIM could result in greater efficiency. The results showed that an overwhelming majority (91.7%) agreed or strongly agreed with the idea of correlation between BIM adoption and its effect on efficiency while 6.3% were not sure the rest disagreed.

Table 9: Participants' opinions on the efficiency of BIM

7. Do you think BIM adoption leads to greater efficiency?		
Answer Options	**Response Percent**	**Response Count**
Strongly agree	66.7%	32
somewhat agree	25.0%	12
Not sure	6.3%	3
Somewhat disagree	2.1%	1
Strongly disagree	0.0%	0

In addition, an overwhelming majority of respondents believed that BIM software is not so easy to use or user-friendly. Although there was no negative answer, 16.7% were not sure about the complexity of this application.

Table 10: Participants' perceptions on the complexity of BIM software

8. Do you think BIM software is complicated and should be easier?		
Answer Options	**Response Percent**	**Response Count**
Strongly agree	52.1%	25
somewhat agree	31.3%	15
Not sure	16.7%	8
Somewhat disagree	0.0%	0
Strongly disagree	0.0%	0

However, participants' opinions on the effect of time on the success of construction projects varied on a scale of 'very much' to 'not at all'. For instance, while 41.7% ticked 'very much', a quarter perceived the effect of time as 'somewhat' and others rated its impact as 'just a little' (20.8%) and 'not at all' (4.2%).

Table 10: Participants' opinions on the effect of BIM on the timing of construction projects

9. How much would BIM affect the time of construction projects?		
Answer Options	**Response Percent**	**Response Count**
Very much	41.7%	20
Somewhat	33.3%	16
Just a little	20.8%	10
Not at all	4.2%	2

As far as the relationship between BIM and the cost of construction projects is concerned, almost half of the participants rated this effect as 'very much', followed by 'somewhat' (31.3%), 'just a little' (18.8%), and 'not at all' (4.2%).

Table 11: Participants' opinions on the effect of BIM on the cost of construction projects

10. How much would BIM affect the cost of construction projects?		
Answer Options	**Response Percent**	**Response Count**
Very much	45.8%	22
Somewhat	31.3%	15
Just a little	18.8%	9
Not at all	4.2%	2

Also concerning the relationship between BIM and the quality of construction projects, over half of the participants rated its effect as high, and the rest of the opinions scattered on the continuum of 'somewhat' (31.3%), 'just a little' (12.5%), and 'not at all' (4.2%).

Table 12: Participants' opinions on the effect of BIM on the quality of construction projects

11. How much would BIM affect the quality of construction projects?		
Answer Options	**Response Percent**	**Response Count**
Very much	52.1%	25
Somewhat	31.3%	15
Just a little	12.5%	6
Not at all	4.2%	2

Furthermore, participants perceived the relationship between BIM and health and safety of construction projects almost the same as its relationship with the cost. Here again over half of the respondents rated this relationship as 'very much', while 35.4% ticked 'somewhat' and the remaining ticked it as 'just a little'.

Table 13: Participants' opinions on the effect of BIM on the health and safety of construction projects

12. How much would BIM affect health and safety of construction projects?		
Answer Options	**Response Percent**	**Response Count**
Very much	52.1%	25
Somewhat	35.4%	17
Just a little	12.5%	6
Not at all	0.0%	0

As the first question on the participants' use of Laser Scanning, majority of the respondents (60.4%) stated that they had used it before whereas the rest of them reported that they had never used it.

Table 14: Participants' responses on their use of Laser Scanning

13. Have you used Laser Scanning in any projects before?		
Answer Options	**Response Percent**	**Response Count**
Yes	60.4%	29
No	39.6%	19

Also, those who employed Laser Scanning reported that they mostly used it in the order of importance for drawing plans for buildings, historical documentation, reconstruction of old buildings, controlling after implementation, controlling after natural disasters and finally for redesigning freeways.

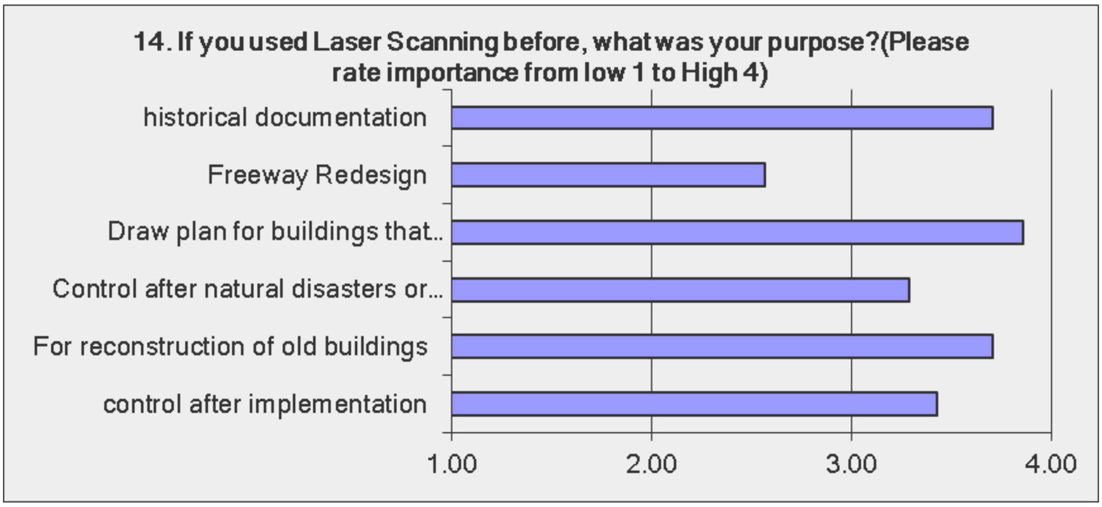

Figure 29: Participants' reasons for using Laser Scanning

Participants also reported that they had employed several types of software and hardware in their projects. For example, the most popular type they used was Scan to Revit. The second most common was Cyclone-SCAN, and the same number reported the use of Leica CloudWOrx for AutoCAD and SurvTech.

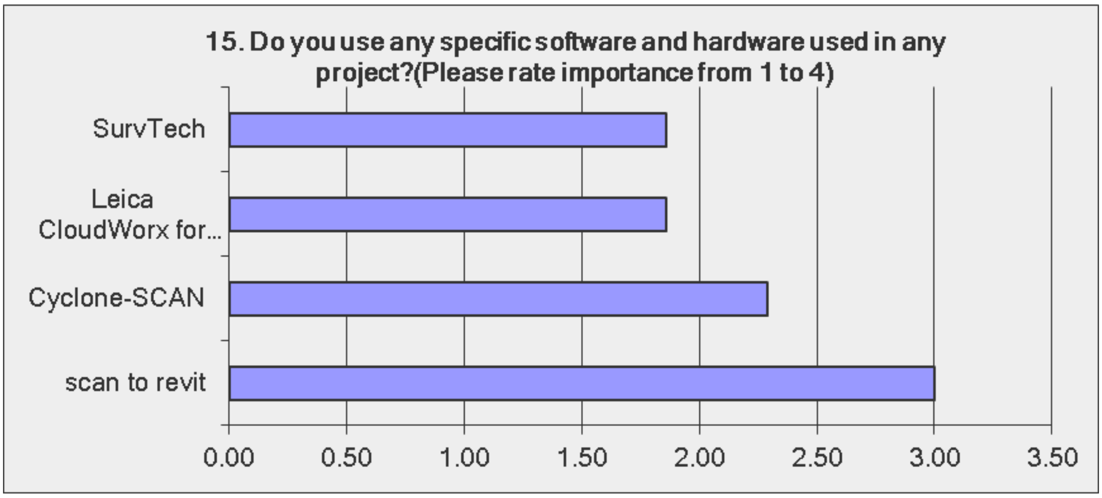

Figure 30: Participants' responses on the type of software or hardware used in projects

Regarding the benefits of using Laser Scanning in projects, the participants rated its fast and accurate capturing of data as the first benefit; increasing the design quality as the second and reducing the time and cost of project design as its third and fourth benefits.

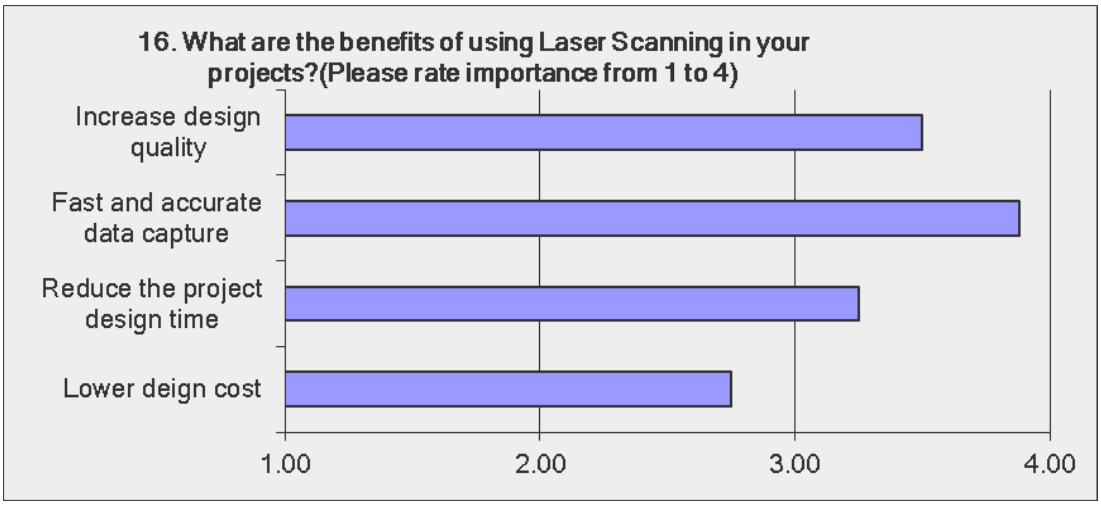

Figure 31: Participants' responses on the benefits of using Laser Scanning in projects

In addition, the question regarding the usage of Laser Scanning in construction elicited three important uses for this application: creating a three dimensional model from buildings was ranked the most important usage while its usage as a quality control tool for new projects and reducing the crew time for data collection and verification processes ranked as the second and third usages respectively.

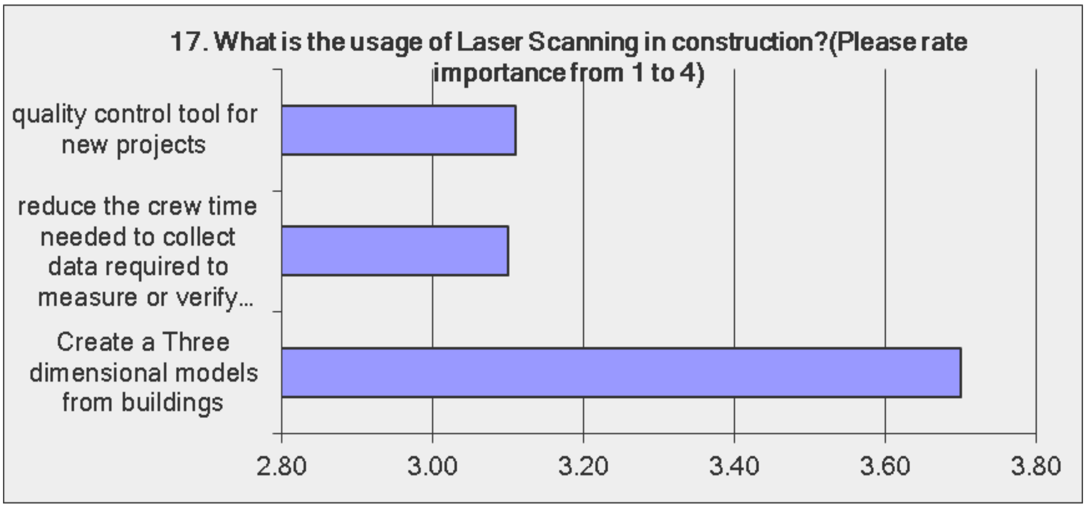

Figure 32: Participants' responses on the usage of Laser Scanning in construction

Concerning the integration of both BIM and Laser Scanning software in the future, an overwhelming majority of participants (72.9%) were optimistic while 27.1 % responded negatively to this idea.

Table 15: Participants' responses on their information about BIM

18. Do you think the integration of BIM and Laser Scanning is possible?		
Answer Options	**Response Percent**	**Response Count**
Yes	72.9%	35
No	27.1%	13

Those who felt optimistic about the integration of these two software in the future mentioned three advantages for this merge in the construction industry. For example, as the most important advantage they believed that Laser Scanning would be able to create fast and accurate three-dimensional BIM models. They also viewed this importance for space coordination in renovation projects and lastly for monitoring the progress of the designed buildings.

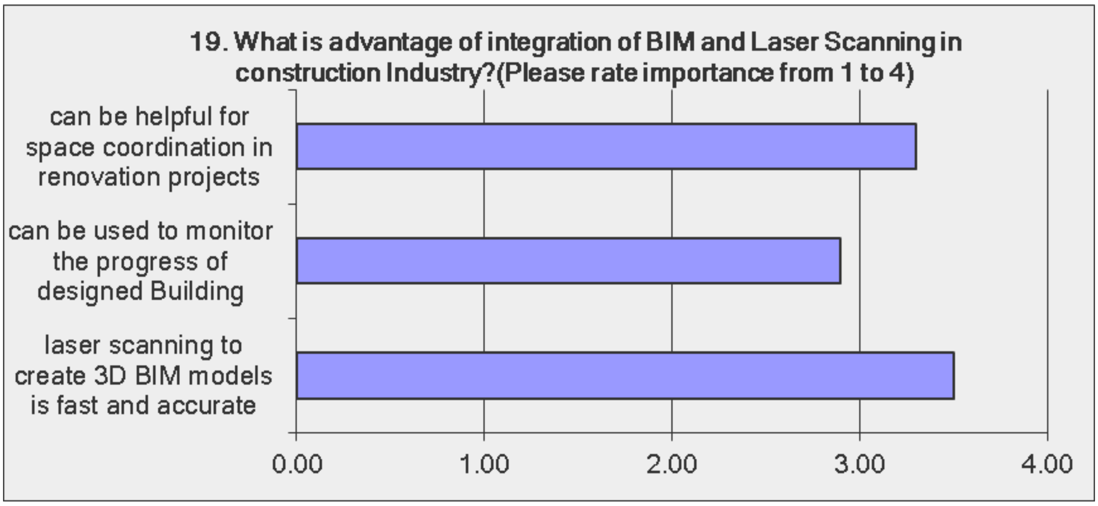

Figure 33: Participants' opinions on the advantages of integrating BIM and Laser Scanning

Over 90% of participants also opined that BIM will be used and developed in the future while 6.3% had no idea and only 2.1% responded the other way around.

Table 16: Participants' opinions about the development and use of BIM in the future

20. What is your opinion about the development and use of BIM in the future?		
Answer Options	**Response Percent**	**Response Count**
Definitely no	0.0%	0
Maybe no	2.1%	1
No idea	6.3%	3
Maybe yes	25.0%	12
Definitely yes	66.7%	32

However, the participants' opinions on the development and use of Laser Scanning in the future were a little bit different from those about BIM. Almost over 70% reported that it will definitely or possibly develop in the future while 16.7% had no idea and the rest answered the other way around.

Table 17: Participants' opinions about the development and use of Laser Scanning in the future

21. What is your opinion about development and use of Laser Scanning in the future?		
Answer Options	**Response Percent**	**Response Count**
Definitely no	6.3%	3
Maybe no	6.3%	3
No idea	16.7%	8
Maybe yes	22.9%	11
Definitely yes	47.9%	23

Finally, the participants' perceptions as for the development and use of these two applications together in the future followed almost the same trend as two tables before with some minor differences so that while 66.7% stated that these software will definitely or probably develop in the future, 12.5% remained neutral and 20.8% were of the opinions that they will or may not develop or be used in the future.

Table 18: Participants' opinions about the development and use of Laser Scanning in the future

22. What is your opinion about development and use of BIM and Laser Scanning together in the future?		
Answer Options	**Response Percent**	**Response Count**
Definitely no	10.4%	5
Maybe no	10.4%	5
No idea	12.5%	6
Maybe yes	22.9%	11
Definitely yes	43.8%	21

Chapter 6

CASE STUDY

The purpose of this chapter is to give the details of conducting a case study in which the way the BIM and Laser Scanning tools are applied on their own as well as in their integrated format is displayed. The main focus is on applying 3D mobile systems like CADeyes and also on BIM software such as Revit to the data collection and palnning phases of Technopark buidling as a construction site.

6.1 Technopark

The idea behind opening a Technopark in Northern Cyprus was to stay current with the latest state of art industrial as well as scientific breakthroughs in the science, technology and research areas. The aim was to bring together the different parties such as producers, researchers and entrepreneurs to help boost the institutions in higher education with the top-notch products and production methods, which in return, will help boost the thriving economy of this country. This could also help build and provide technological infrastructure, which will be of high importance in the international arena due to the geopolitical and sociopolitical position of this island in the region.

Famagusta Technopark was founded in 2006 by Eastern Mediterranean University, Lefke European University and Turkish Cypriot Chamber of Industry and since then it has been the hub of cooperation and collaboration among different groups such as faculty members of different institutions of higher education, innovators and young entrepreneurs, university graduates and businesspeople in this country not only to share their ideas and experiences but also to undertake developing and introducing some technological innovations and projects aiming at promoting these innovative ideas and technological means through training and publicizing their applications. Some of these developed software and hardware like those uses in telecommunications section, transportation and traffic, renewable energy and other design technologies have found their ways into the local and international markets and institutions. Among the laboratory equipments used in this center we can name Zcorp 450 3D Laser Printer, Circuit Board Constructor, CNC 3 Axes Milling Machine, 3D Laser Scanner and 3D Mobile Mapping System, which are at the disposal of young graduates and entrepreneurs of different universities, especially those studying at Eastern Mediterranean University.

Figure 34: Famagusta Technopark

6.2 3D mobile mapping system (3D MMS)

A 3D mobile mapping system (3D MMS), as one of the most sophisticated equipments in this center, has the potential to help engineers and scholars make 3D models of locations and even towns and cities for design, construction as well as other urban and development decisions made by authorities or experts. This application is made up of a scanner with a 3D high resolution that has the capability of scanning a diameter of 100 m. In addition to that, it also has a video camera that can catch a 360 degrees picture of the location with the help of the subsidiary instruments or tools enabling it to perform at various angles. This system also can offer coordinates to be used on computers and can be navigated by a click of a mouse in order to add or calculate the distances to the views captured by its camera. The situations in which this system might be employed could include GIS systems for planning, navigation and management of various buildings or other similar geographical locations in a three-dimensional environment.

Figure 35: CADeyes Laser Scanner

Although originally this system was used in road infrastructure and building facades, such as making 3D modeling of railways, highways and cities, nowadays big corporate like Google and Microsoft are making use of this application on a very huge scale which has resulted in the advancement and development of this system due to its high demand for carrying out a variety of tasks (Petrie, 2010).

There have been researches done to use this application for different purposes and in different fields such as in gathering data about locating road and traffic signals and boundaries and other road objects. Through a combination and integration of a navigation system, GPS receivers, and cameras which capture high quality 3D images as well as laser scanners for scanning these images, this system has proved to be efficient and effective in cases where it has been so far used. Some of the 3D Point Cloud scanned data has clearly provided the geographical and spatial information as well as 3D images of the environment under the study (see Ishikawa et al. 2006; Shi 2008). Compared with some other sophisticated methods like aerial photogrammetry used for the similar purposes, this system has proved to be 8 times more efficient in terms of saving time and labor as far as human resources are concerned (Shi, 20012).

The main components of this system consist of the digital imaging devices; the laser ranging and scanning devices; and the positioning (or geo-referencing) devices. The first component captures the geometrical and 3D topological vector data automatically from, for instance, construction and architectural sites. The second part creates and offers the optimum path in a 3D modelled building and provides 3D visualization and simulation while the last component generates the images and provides the information to the output devices. Mobile Mapping System (MMS) is usually set up on a platform or a stand so that its sensors can detect the location and position of the surrounding environment using the imaging sensors along with some laser sensors, which capture and convert images in a frame of so-called mapping co-ordinate (Figure 36).

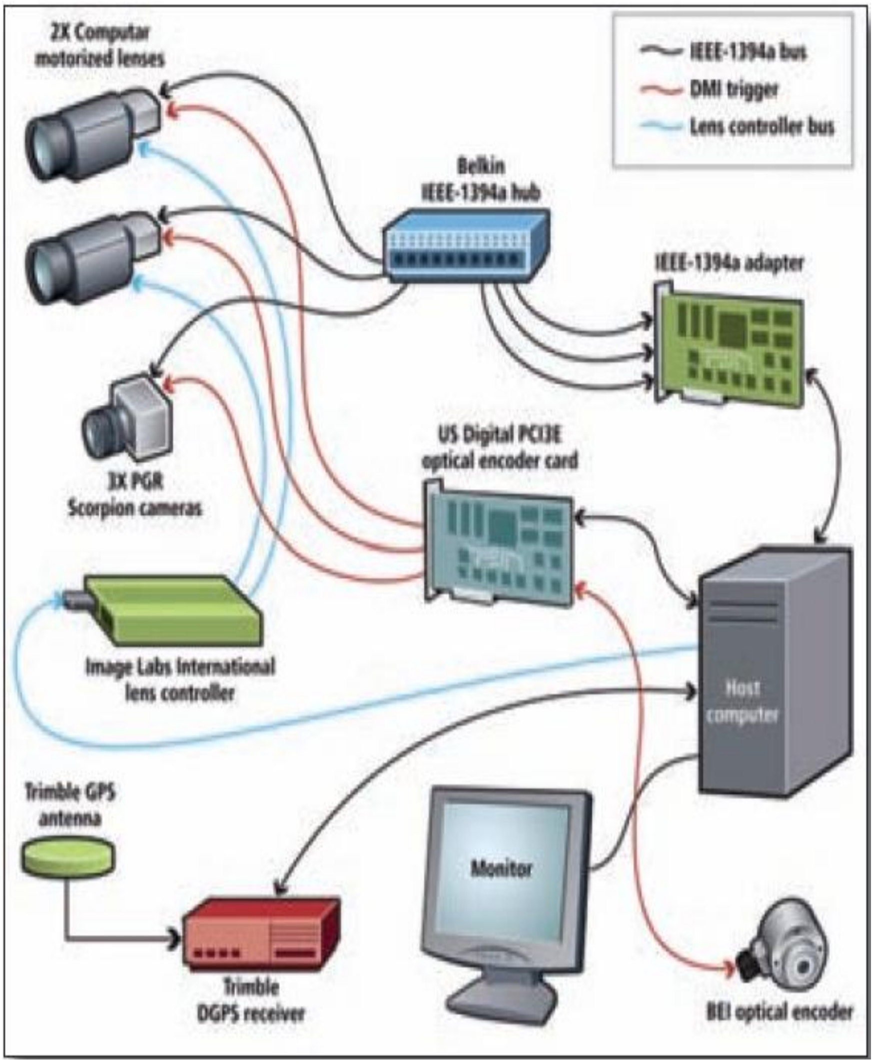

Figure 36: A diagram showing the main components of 3D mobile mapping system (3D MMS)

Since the introduction of 3D mobile mapping system (3D MMS), various types of this kind of technology have been manufactured and used in different contexts for different purposes. However, the brand of application used in this case study was

CADeyes, which was originally developed by a team of researchers, students and professors in Stevens Institute of Technology through a program called Stevens Entrepreneur and Enterprise Development (SEED). CADeyes can create and convert scan images such as those drawings of constructions and buildings into two and three-dimensional maps with a remarkable accuracy and speed. Due to the importance of 3D-oriented products and technology, a market worth million dollars worldwide, in areas such as visualization, broadcasting, game manufacturing etc., these maps and simulations can be employed in different industries and sectors where engineers, architects and companies are engaged in construction business like real states. Another advantage of CADeyes is that this avant-garde technological means can also reduce the cost of drawing and mapping and help bridge the gap between the world of business and that of the technology or scientific innovation due to its capability in reducing the labor of monitoring and scheduling big constructions, which were executed by lots of errors and omissions in the conventional approaches of measurement and scanning. As a matter of fact, this is a hybrid measurement technology that has some spectacular characteristics like portability, mobility, and affordability, which altogether would push for productivity of this product. High definition mapping of underground pipes, using point cloud to show the different aspects of a place like the trees, roads, and other geographical and geological variables are just some of its potentials (Figure 37). Therefore, the market need has pushed the innovation of this type of application. Also, there is a large market doing the position and services related to this technology for the users.

Figure 37: CADeyes Laser Scanner

As to the way this technology works, it is worth mentioning that the data that comes from CADeyes are transferred to Revit software that has the ability to turn these data into 3D mapping by Point cloud. The laser scan data coming from various stations are defined in a space that is called Point cloud. Hundreds of thousands of these data points in 3D space are collected using an imaging application. However, the spaces or distances between points are not homogeneous, and this application can define their coordinates as well. These sample points then can be referred to by Revit model in case it needs to perform any designing or other displays as it sometimes uses a limited number of them. While feeding Revit with these sample points, we insert the related file to be converted from these points to the .pcg indexed format. To do so, first of all, the 'Revit Project' should be opened by going through 'Start-up Menu' and then selecting 'Revit Architecture 2013'. Then the New icon is selected as follows:

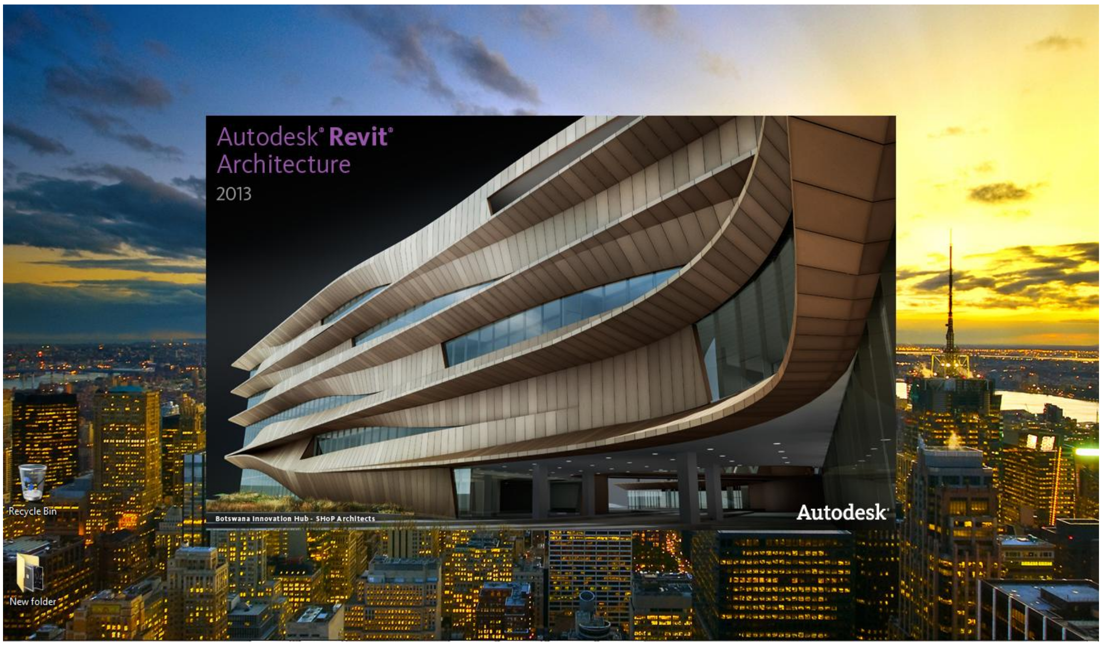

Figure 38: The first step in running Point cloud

The next step is to go to reach Project icon through 'new' icon under Projects category.

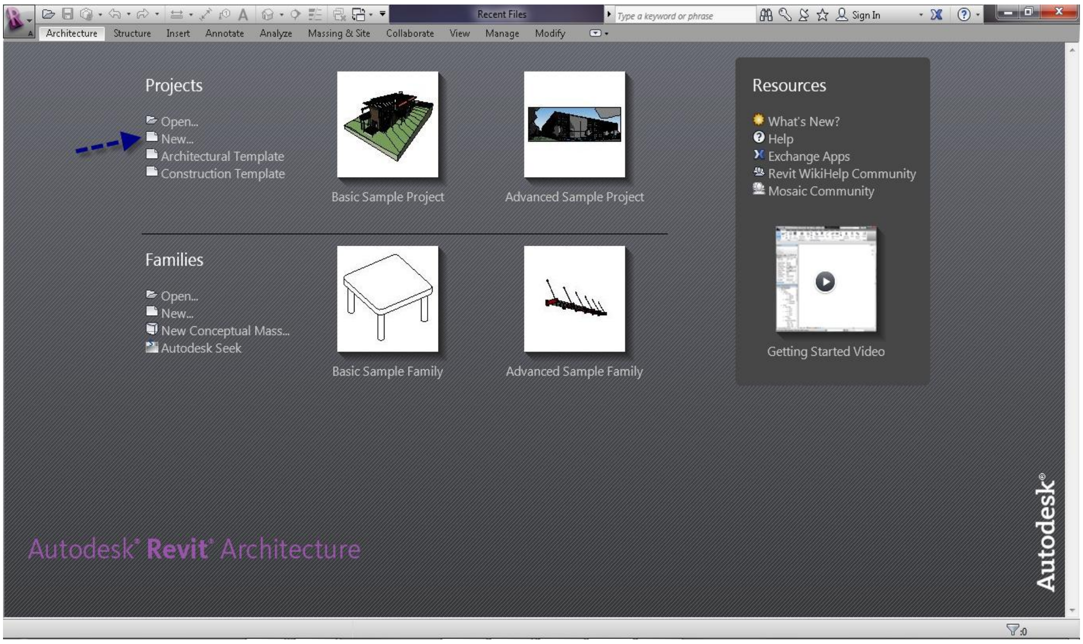

Figure 39: The second step in running Point cloud

Through New menu, the Project icon is clicked to open the main page.

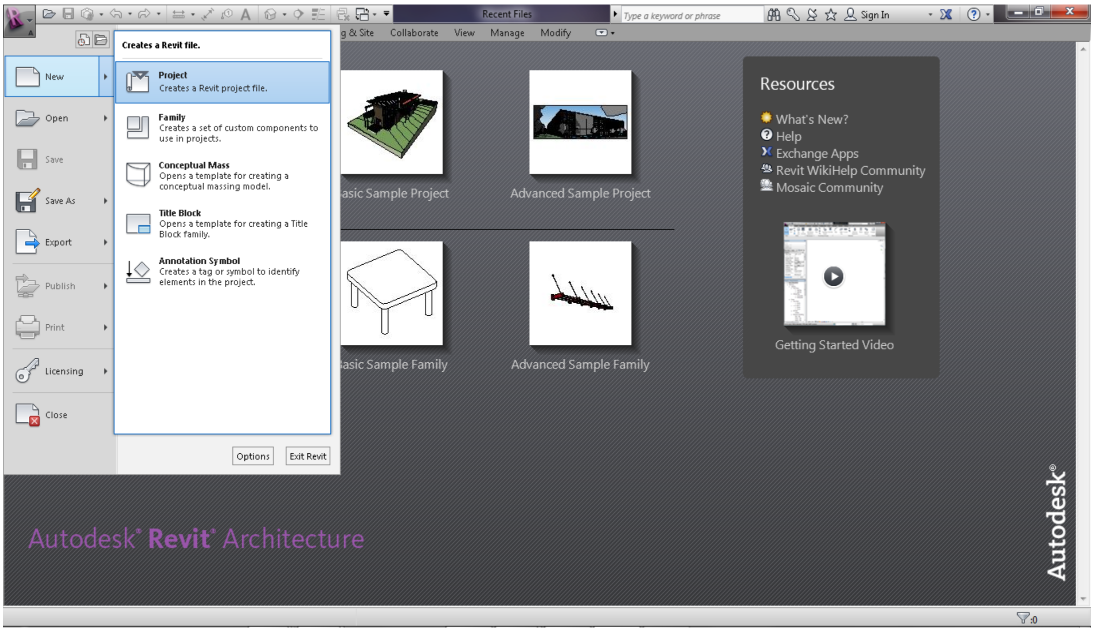

Figure 40: The third step in running Point cloud

Then the main page is accessed and opened as shown in figure 41, showing different menu bars on the top and left of the page.

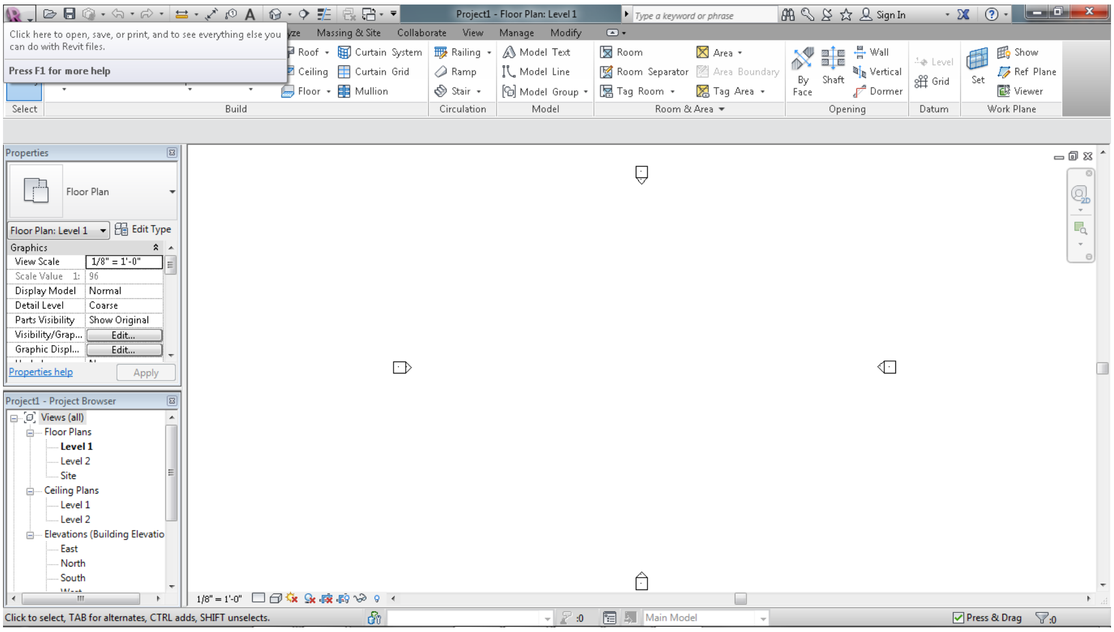

Figure 41: The fourth step in running Point cloud

The next stage is to click Insert Tab and select Point cloud  from Link panel on the menu bar at the top.

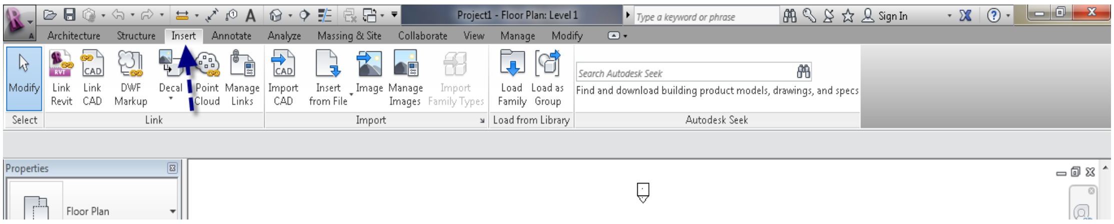

Figure 42: The fifth step in running Point cloud

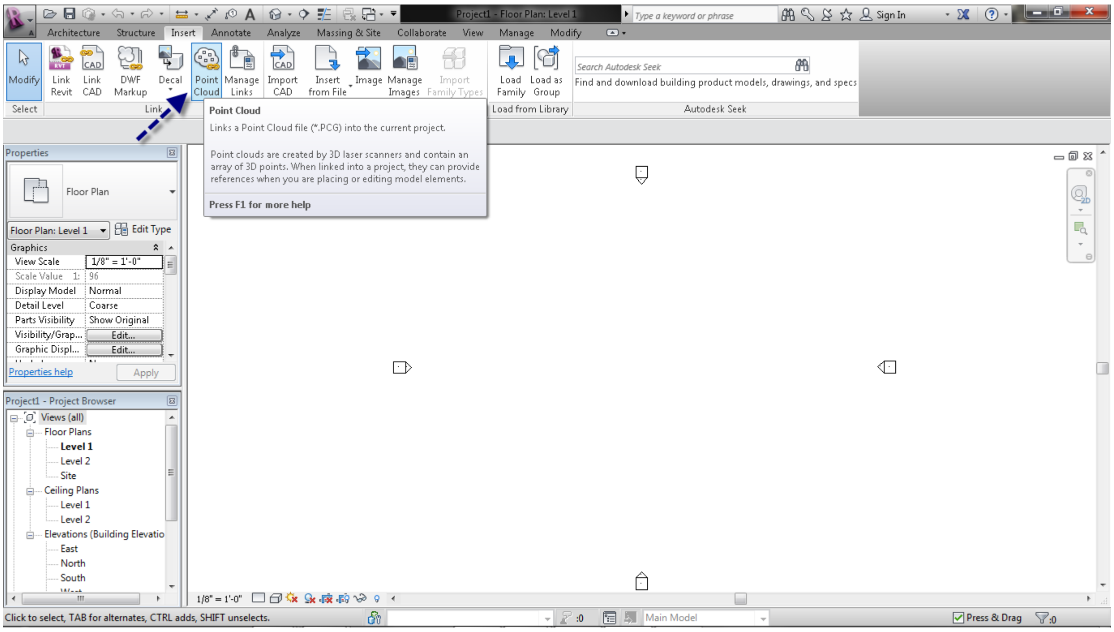

Figure 43: The sixth step in running Point cloud

Now Point cloud is ready to deal with points. In order to specify a file, we should navigate its location as follows:

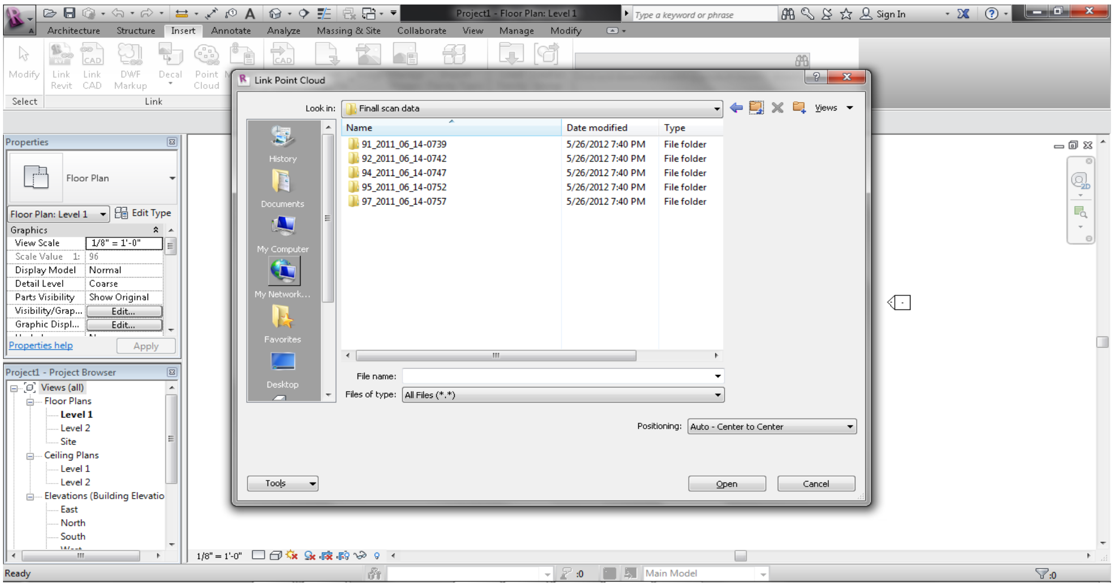

Figure 44: Navigation to locate a Point cloud file

Since types of files used by Point cloud vary, Autodesk Indexed Point clouds file with .pcg, extension could be selected or we can select files with raw formats such as fls, .fws, .las, .ptg, .pts, .ptx, .xyb, or .xyz, which can then be converted to .pcg format automatically.

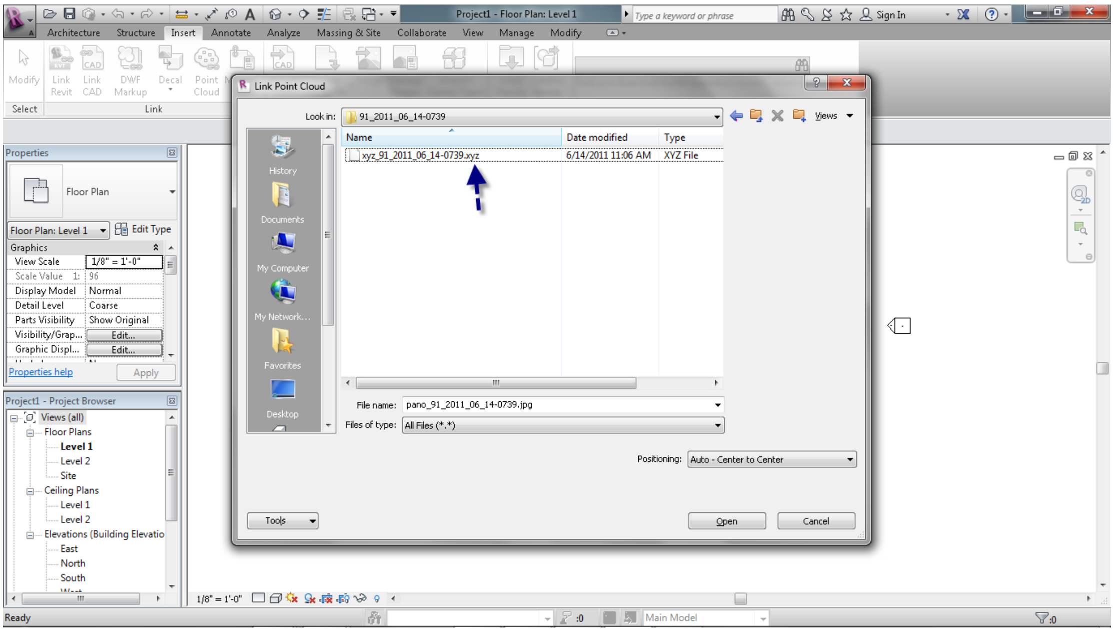

Figure 45: Converting xyz. files into files with pcg. Extension

Therefore, any type of file could be used with any extension, and in case of selecting any file without index, the Revit itself can give a new index to the file automatically as follows:

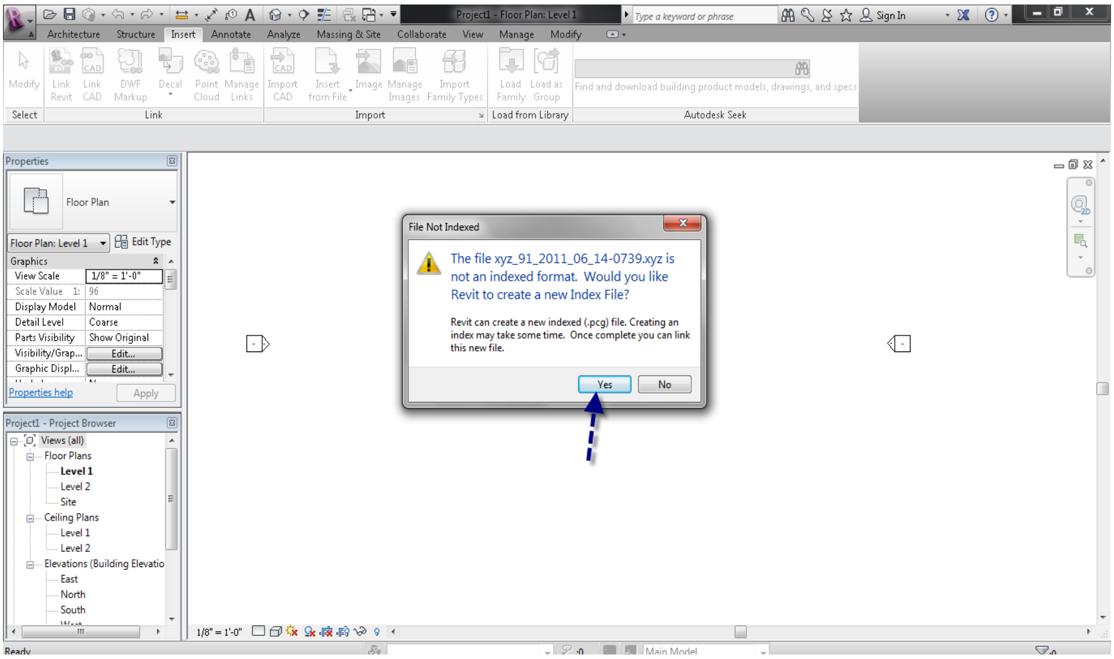

Figure 46: Assigning an index to a file without an index automatically

Then the file is converted after indexing process.

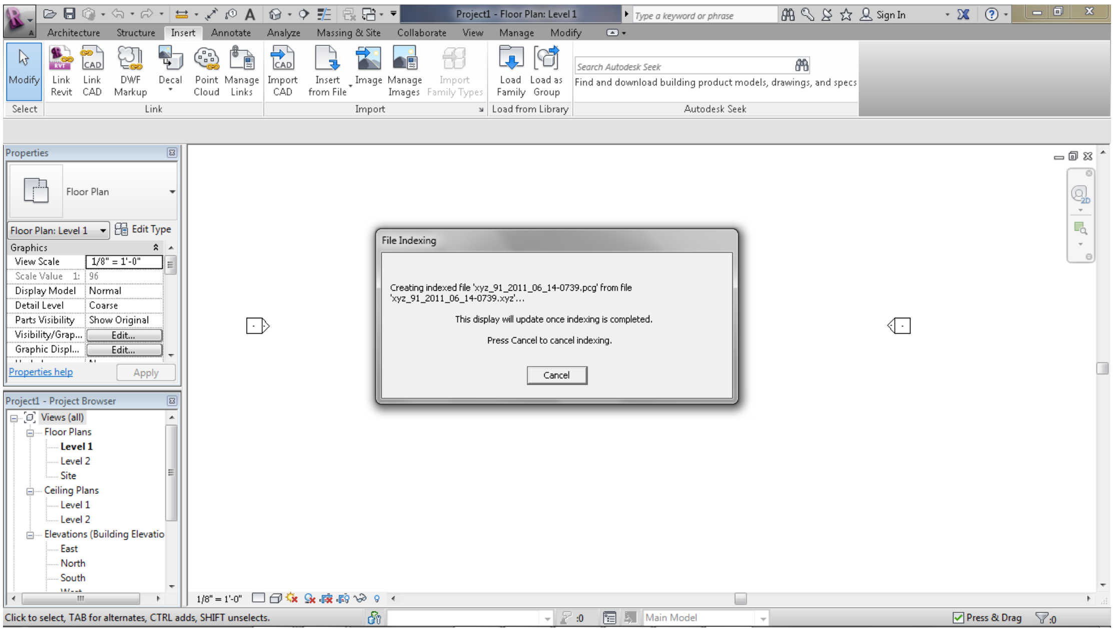

Figure 47: Converting the file after indexing

After this stage is completed, Revit will give us a feedback if the process is successful or not.

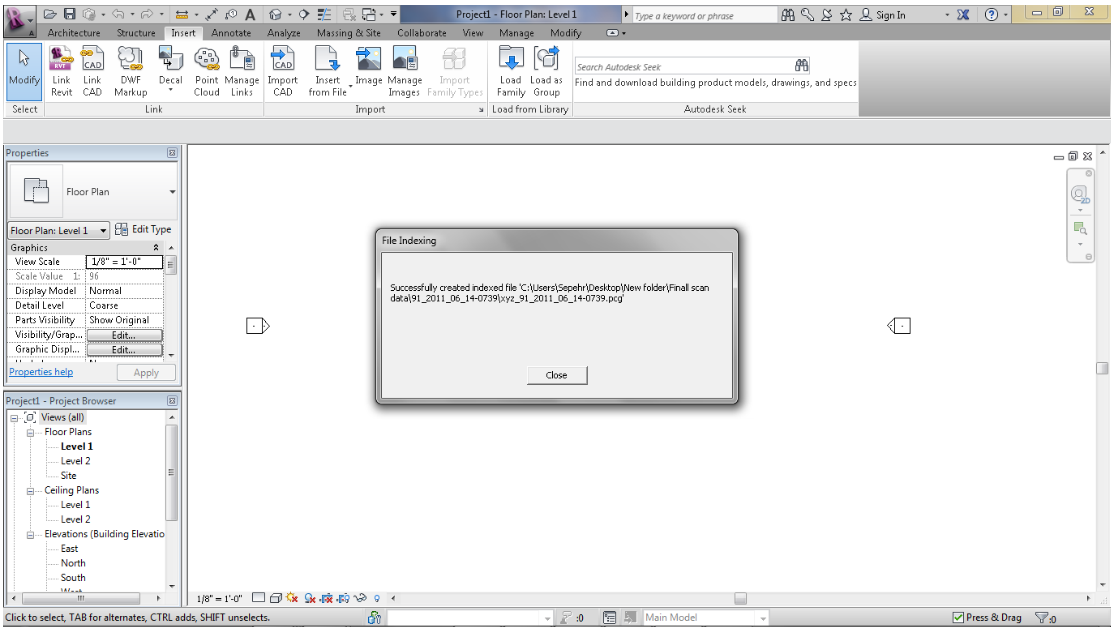

Figure 48: The last stage of converting the file

Now, the file is changed into a .pcg format and can be used for the later use by Point cloud. This file is reached by clicking on Open icon.

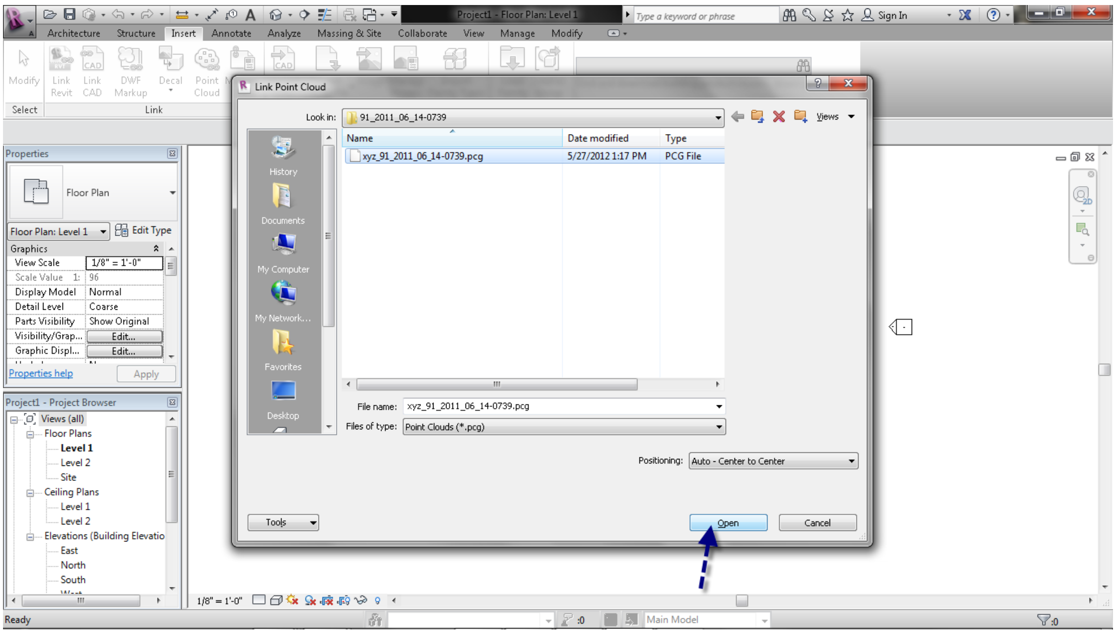

Figure 49: Open the file with new format

This file is then depicted as a 2D Point cloud

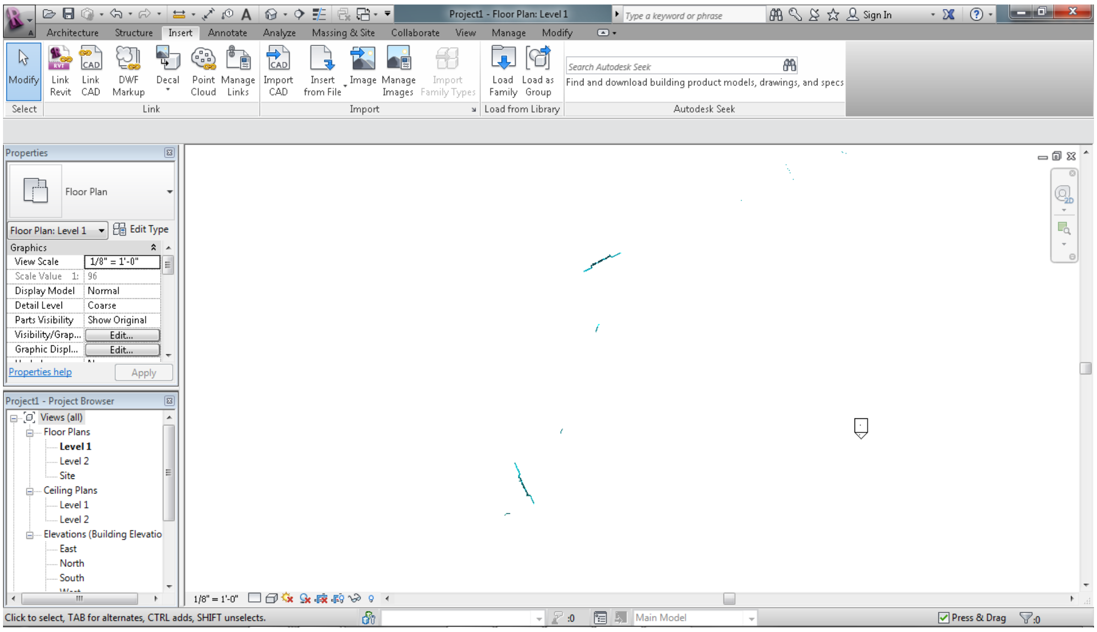

Figure 50: Opening the file after converting to a pcg. Extension

However, for viewing this file to a 3D point cloud, we should click on Default 3D view on the main tool bar menu as follows:

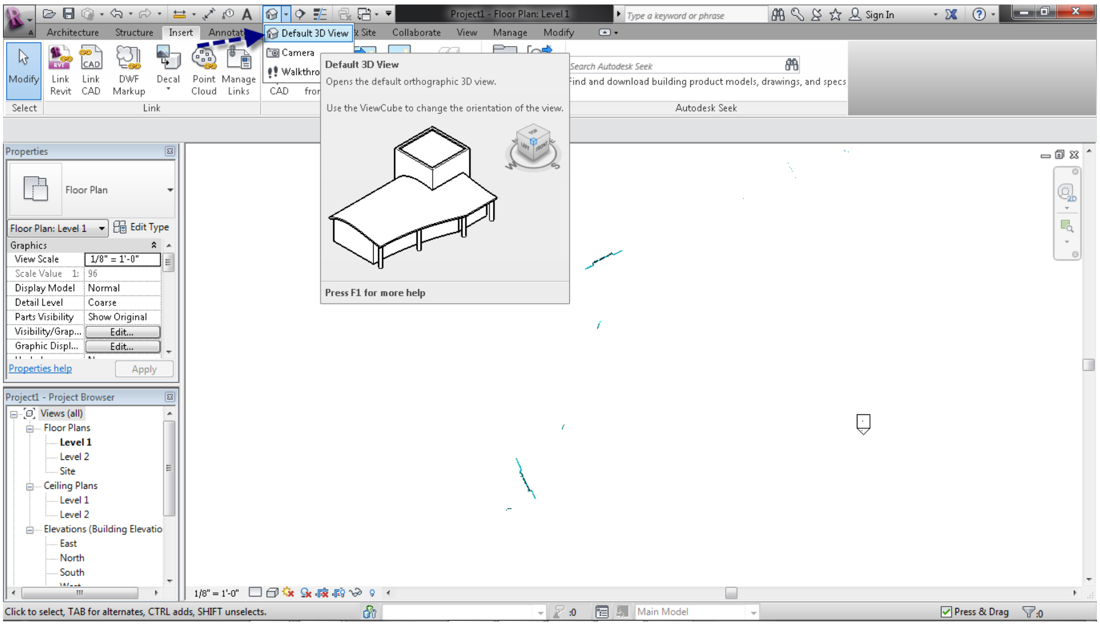

Figure 51: Viewing a 2 D as a default 3D format

Now, the file is illustrated as a 3D Point cloud, and there is a possibility of modifying this file using various icons of this page.

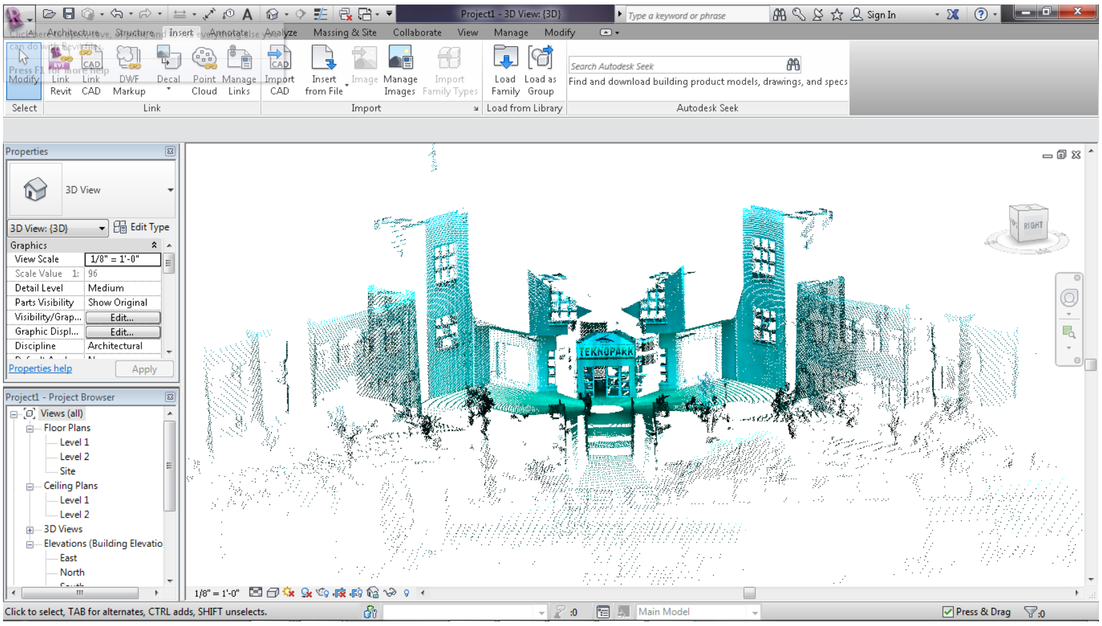

Figure 52: Viewing a final stage of a Point cloud file

In this case study, approximately 16 positions were taken for gathering the data by Laser scanning. However, three positions were used specifically: 1) in front of the entrance door 2) on the western side of the entrance door and 3) on the eastern side of the entrance door. First 2D aerial photo of Technopark was taken to compare it with those taken at the later stages by CADeyes later on.

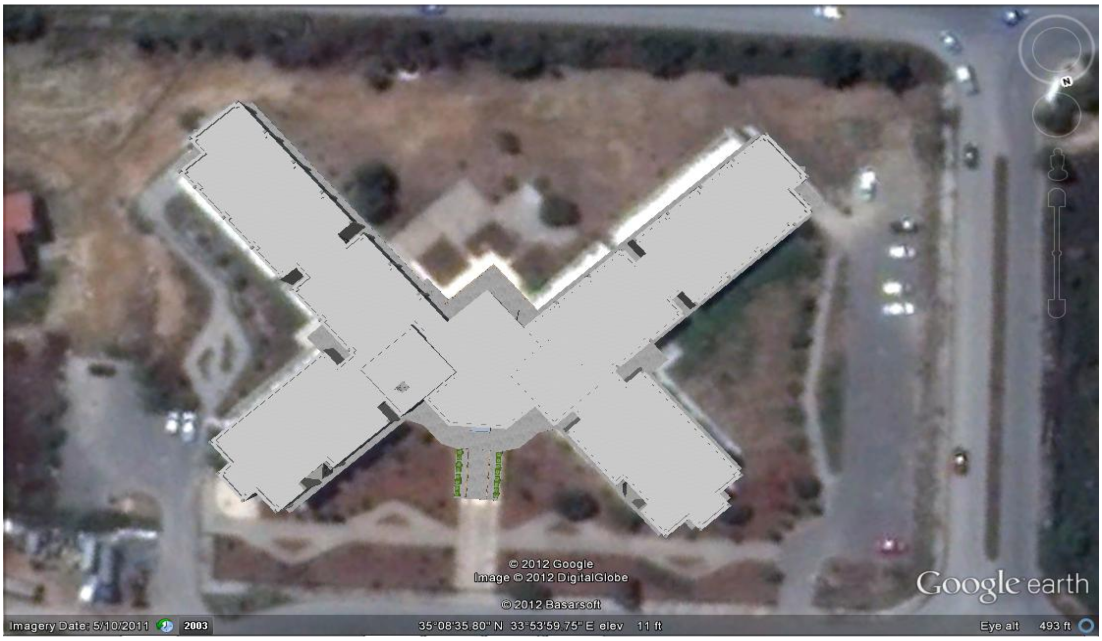

Figure 53: An aerial photo of Technopark from Google Earth

Figure 54 shows a 3D ground-based view of the western side of the entrance gate of Technopark obtained from Google Earth.

Figure 54: A 3D view of the western side of the entrance gate

The view in figure 55 is also taken from Google Earth and it shows a 3D view of the eastern side of the entrance gate.

Figure 55: A 3D view of the eastern side of the entrance gate

The next view in figure 56, which is also taken from Google earth, shows the front view of Technopark.

Figure 56: A 3D front view of Technopark

Now, the Point cloud views are given to see the accuracy and efficiency of different parts of this construction. This is a profile of the western side of the entrance gate. The white circle in front of the building shows the exact location of the camera and its position.

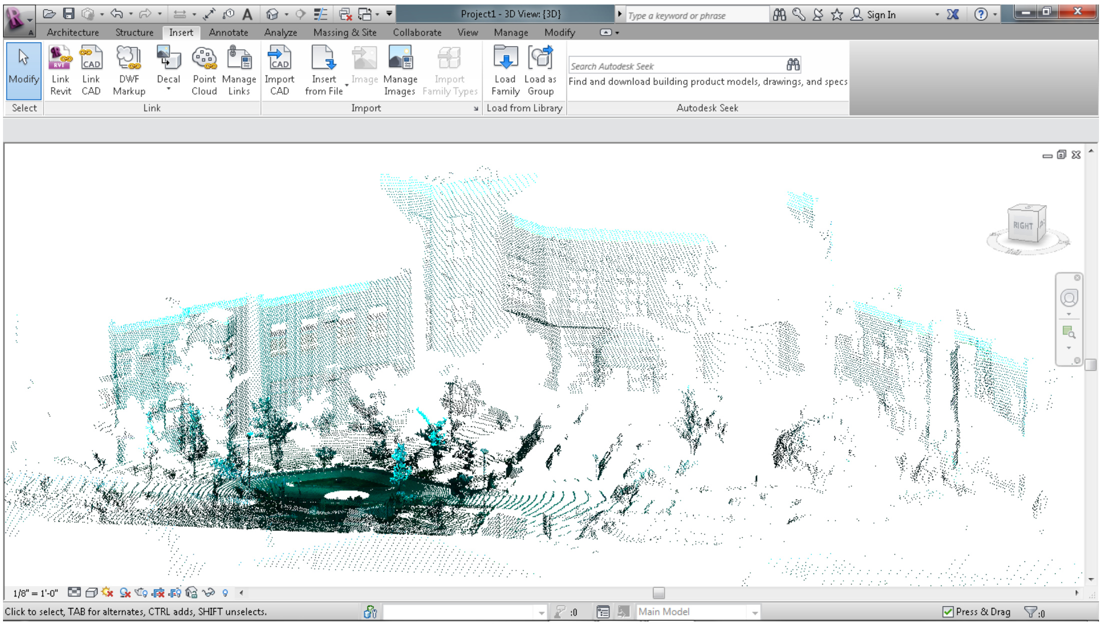

Figure 57: A Point cloud view of the western side of the entrance gate

The view in figure 58 is taken from the eastern side while changing the position of the camera.

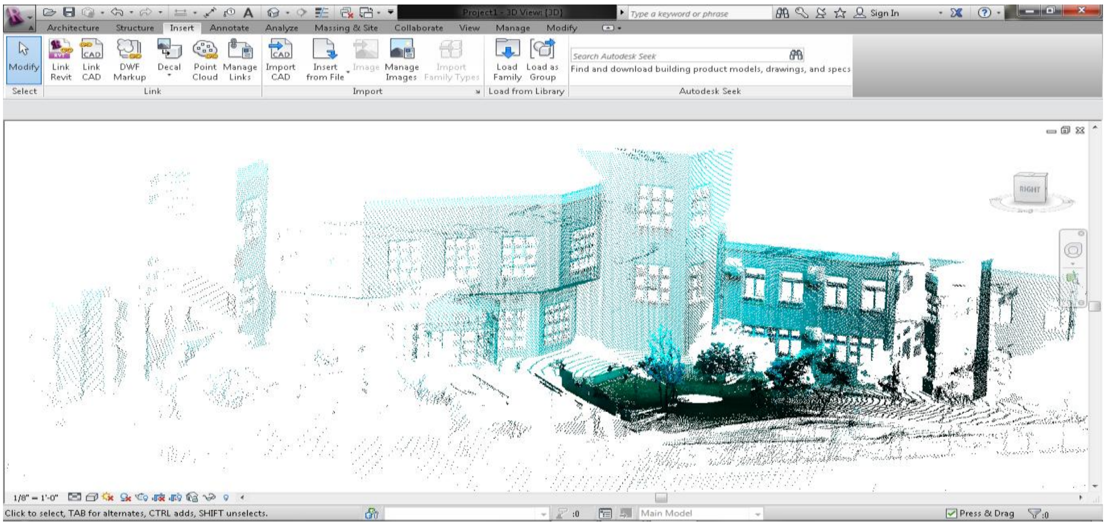

Figure 58: Another Point cloud view of the eastern side of the entrance gate

The view in figure 59 is also a front view of the main entrance gate.

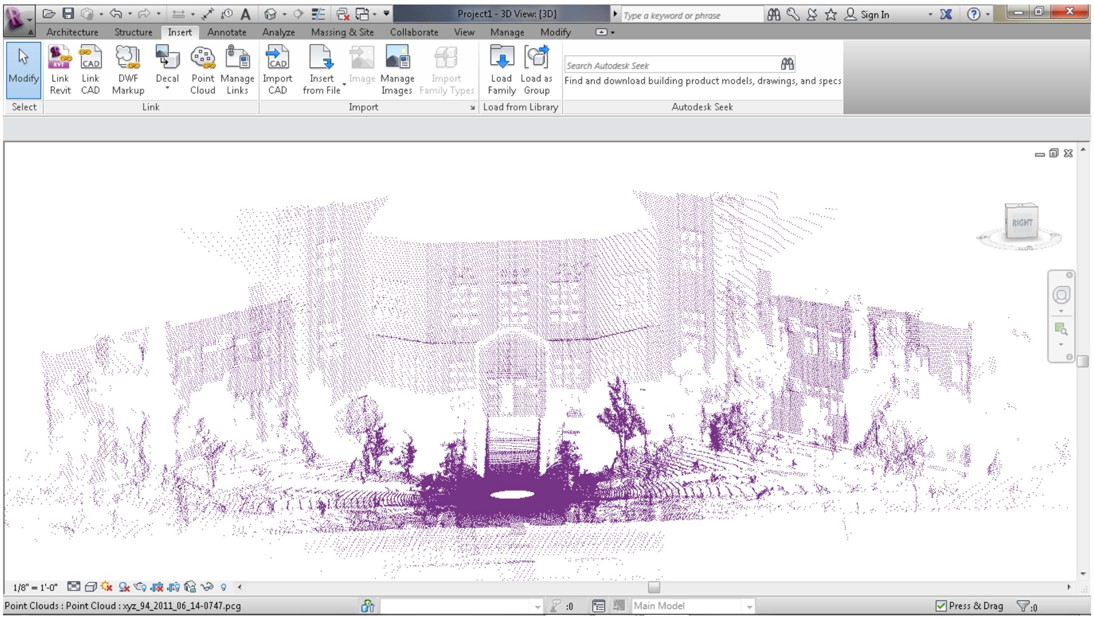

Figure 59: A Point cloud view of the main entrance gate

The last Point cloud image shows another front view of the main entrance gate but with a different position of the camera.

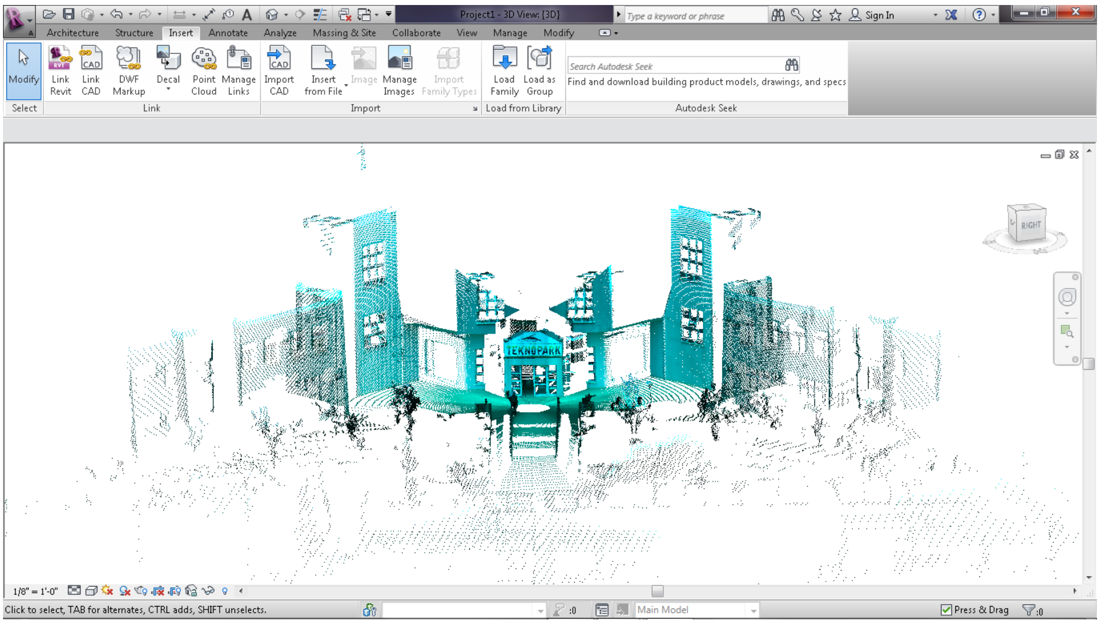

Figure 60: Another Point cloud view of the main entrance gate

Chapter 7

DISCUSSIONS

This chapter presents the discussion of results and findings with reference to the brief literature on BIM and Laser Scanning tools as the theoretical backbone of the study. First, the quantitative findings of the questionnaire are discussed and then the findings of the case study, which could illuminate different parties involved in construction industry, are presented.

This study documented the effectiveness of Building Information Modeling software and Laser Scanning tools and their integration in construction industry. The results of this study reported some significant findings. First of all, the results coming from analyzing the questionnaire data show that different groups are inclined to use these applications because of several reasons such as the amount of support they can grant from the design to implementation, construction and operation phases. This could be even before conceptualization the maintenance many years after the implementation of the project, which might engage contractors, sub-contractors, engineers, designers, architects, civil engineers, site managers, suppliers and so on. The different people in this survey also endorsed their familiarity with both BIM and Laser Scanning tools and software and their capability in design, specifically in making 3D, 4D, 5D models and plans, and in offering the better overview of the different parts of the project in architecture, structure and installations. As it was expected, they all predicted that their applications would become more popular among these professionals in the future.

Furthermore, it was found that one of the main applications of BIM models in architecture and design was the vital role they play in converting 2D to 3D plans. Owners also demanded this application in order to determine the different aspects of a project before making any decision or taking any measure in project construction, which is not a new phenomenon as they have been using it for the last 20 years (Coates, et al, 2010). That is, they can find out about the shape, cost and expenses, quality and all other aspects of a project they want to undertake more effectively and efficiently. Among the various software in Building Information Modeling system, Revit and Tekla were reported to be the most common and used by different specialists in the addressed fields. This denotes that Revit, as one of the most popular software that is nowadays being used in many famous companies, has become a strong substitute for more conventional software such as Autocad and 2D-making software. Likewise, this was the reason that this software was used in this case study as well.

Although BIM software has many advantages such as client demand, cost effectiveness, competitiveness potential, energy analysis purpose, etc., it was found out that the ability to design was the main benefit of this software. This was also predictable as this software has been developed and used for designing purposes because of possessing abilities and tools where Building Information Modeling is used. For example, it can revise and edit the project effectively; something that was very costly and time-consuming with more traditional software and applications. However, this can be performed by doing a small edition and revision and make a larger scale change on the overall project, which could save a lot of time, money and resources. By using some tools or software, BIM also can help design teams to evaluate the ideas and strategies that result in saving energy even earlier than design process. This will help designers and decision-makers to figure out, for example, what materials they should use for insulation in roofs or other parts of the buildings because the traditional software tools used to assess energy-saving policies when many phases of the design had been carried out.

In addition, the findings indicate that different respondents were quite sure that BIM adaption would lead to a greater efficiency. This finding is in line with the conducted research, for instance, in architecture where the architects are being pushed to adopt and turn to the exploration of BIM tools in different cycles of design and implementation in European as well as American contexts (Mihindu and Arayici, 2008; Arayici et al, 2009; Arayici et al, 2011). Because BIM enables architects to examine the design intelligently in order to produce fast and cheap designs with better coordination, control and less repetition in a very competitive way is achievable by giving them a detailed, vivid and clear vision and strategies for the next phases (Arayici et al, 2011).

However, some respondents believed that this software is complicated due to having multiple applications and tool bars each responsible for conducting a different task. Therefore, they think it should be easier to use so that more individuals and companies can use them faster and more conveniently. Undoubtedly, as one of the benefits of BIM, time can be saved because its software make designs faster and easier for architects; make the implementation and construction easier by using 3D models and details of plan for project managers, contractors and sub-contractors and those engaged in the construction site; and make it more convenient for those involved in the sustain and maintenance.

Apart from the benefit of saving time, BIM also enhances the accuracy of different phases of a project and accordingly adds to the quality as one of the main determinants in using an application in design as well as construction stages. This refers not only to the capability of BIM in generating and managing the data, but also in sharing this data and dissemination of knowledge that could definitely lead to building up cooperation among different people involved in producing and constructing a building project. Another area that increases quality is the omission of errors and the exact details given through visualization for project teams and their members by documentation and giving them both input and output. Safety also was referred to as another benefit of BIM in construction. Ostensibly, construction sites are among the hazardous places that usually result in thousands of fatalities and incur billion dollars cost every year (Lopez del Puerto & Clevenger, 2010). Increasing safety results from advancement in communication between different teams and mitigation of errors, which has led to a rise in safety and reducing the likely risks at workplace. As a matter of fact, this communication is carried out by design-review tools or graphic applications that explicitly share information, goals and the project vision among all stakeholders, which will surely end up reducing the risks for all BIM platforms and teams as well as more effective and safer structures for the owners and occupants (Sullivan, 2007).

As far as using Laser Scanning tools in design and construction is concerned, it was also reported that these tools are popular among designers and construction teams as powerful tools with a wide range of applications for three-dimensional based models that can be combined or integrated with BIM in construction projects. This combination of BIM with Laser Scanning can lead to many benefits over more conventional approaches because of the enhanced accuracy of design and construction activities (Randall, 2011), which in turn could also result in the improvement of reliability of the project model (Goedert & Meadati, 2008). This study found out that participants used Laser Scanning for various reasons such as controlling after implementation a project, reconstructing old buildings, controlling after natural or unnatural disasters, drawing plans for buildings without plans, redesigning freeways and documenting historical buildings. However, the results indicated that laser Scanning was predominantly used to draw plans for buildings without plans, which included also those of historical buildings, places or monuments that usually need documentation or renovation. Different tools can perform many tasks such as inspecting of different pipes and cables and drawing maps for buildings that need renovation by robotic and sensor technology embedded in this application (Hajian & Becerik-Gerber, 2009).

The data that are generated by Laser Scanning are to be integrated with other tools or software and participants reported the use of Scan to Revit application as a tool integrated with Laser Scanning for dealing with their tasks in design as well as construction. All these capabilities would justify several benefits why Laser Scanning is being used in construction projects. For example, it can capture fast and accurate data by generating Point cloud model to allow designers to have a 3D model of the project, and this consequently, will save a lot of time, energy and cost of different phases of a construction project. In addition, generating 3D models and accuracy would mean enhancing the quality of the design as another key feature of any construction project.

Integrating Laser Scanning with BIM can also be used for monitoring purposes mostly done after the project is completed or during the implementation phases of a project. This was traditionally a time-consuming and highly costly job used by different people employing a variety of measurement and inspection tools and instruments. However, with this novel technology, it is a matter of some seconds to capture a map of a construction site or building and evaluate whether all steps were taken based on the initial design, estimations or calculations.

Thus, Building Information Modeling is an effective application for gathering, sharing and monitoring information and data not only among different stockholders but also between other software applications. This could include the efficient use of human, financial, and other resources, monitoring the harmony among different sections of a building, using sustainable and high quality materials and the best performance and management concerning the use of facilities. This is in conjunction with promoting the buzzword of service-oriented policy and respecting customers or users among different disciplines and businesses. As a result, then, BIM and its related tools have made a big jump in successful managing and implementing a project due to meeting the requirements of both clients and other stockholders and because of its real world and practical uses.

Although Building Information Modeling has proved to be a very helpful process, it has some limitations such as its complexity or lack of enough information on the part of design and construction companies to use it in their projects. Furthermore, the today's popularity of some old approaches might hinder the effective use or people's temptation to use these tools or even their integration. Also, while integrating these applications might seem inevitable for the future use, it might add to their complexity and hence their limitations. However, it is predicted that more accurate drawings and designs within three coordinates, more efficient and effective timing or dealing with sequencing and scheduling, and estimating the expenses, risks, and even lifecycle of the facilities could be among some of the future capabilities of Laser Scanners. Therefore, further studies and work on its abilities and limitations might offer more insight as to how to integrate this application not only in the workplaces but also in academic settings like universities and colleges.

Secondly, the conducting of the case study showed the effectiveness of the practical integration of BIM and Laser Scanning in gathering and analyzing data. The latest technological means of Laser Scanning was employed to capture the visual data and then one of the most powerful BIM software, Revit, to be fed with this data and to generate a 3D mapping of the building under the study. This case study proved the efficient and effective integration of these two applications in the construction industry.

Chapter 8

Conclusion

This chapter concludes this study by providing a short summary of the most significant findings. It also offers some implications for the practical use of BIM and Laser Scanning tools for different users. Finally, recommendations for further studies are made and a list of references and appendices are included for further readings and research.

This study has proven that Building Information Modeling is an effective application for gathering, sharing and monitoring information and data not only among different stockholders in construction industry but its software can also be employed to coordinate the work of other software applications. This could include the efficient use of human, financial, and other resources used, monitoring the harmony among different sections of a building, using sustainable and high quality materials and the best performance and management concerning the use of facilities. This is in conjunction with promoting the buzzword of service-oriented policy and respecting customers or users involved in different disciplines and businesses associated with construction projects. As a result, BIM and its related tools have made a big jump in successful managing and implementing a project due to their capabilities in meeting the requirements of both clients and other stockholders and because of their real world and practical uses.

Although Building Information Modeling tools have proved to be very helpful in the process of conducting a project, they might have some limitations including their complexity for engineers or designers or other parties involved. In addition, there seems to be scarcity of information on the popularity of these tools in many contexts, especially where people do not usually keep up with the new developments in technology. This could be even worse with today's popularity of some old approaches that might hinder the effective use or people's propensity to use these tools, let alone their integration. Also, while integrating these applications might seem inevitable for the future use, it might add to their complexity and hence their limitations.

However, it is predicted that more accurate drawings and designs within three coordinates, more efficient and effective timing or dealing with sequencing and scheduling, and estimating the expenses, risks, and even lifecycle of the facilities could be among some of the future capabilities of these technologies. Therefore, further studies and work on its abilities and limitations might offer more insight as to how to integrate this application not only in the workplaces but also in academic settings like universities and colleges.

Moreover, conducting the case study showed the effectiveness of the practical integration of BIM and Laser Scanning in gathering and analyzing data used in construction sites. Laser Scanning was employed to capture the visual data and Revit, as one of the most powerful BIM software, was exploited to be fed with this data and to generate a 3D mapping of the building under the study. The case study proved the efficient and effective integration of these two applications in the construction industry. However, further studies will be needed to shed more light on the separate as well as integration use of these technologies in the lifecycle of construction projects right from the early stages of data collection to different stages of construction, maintenance, management and so on.

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APPENDIX

Appendix A: Questionnaire

1. Information

1. Where is your workplace?

- Cyprus
- Iran
- United Kingdom
- Canada
- United State

Other (please specify)

2. What is your background or field of specialization in the construction industry?

- Architecture
- Quantity Surveying
- Project Management
- Civil Engineering
- Building Surveying
- Asset/Facilities Management

Other (please specify)

3. How many years of experience have you had working and/or teaching in construction?

- 1-5
- 5-10
- 10-15
- 15-20
- 20+

2. Building Information Modeling and Laser Scanning

1. How much are you informed about BIM?

- Very much
- Somewhat
- Just a little
- Not at all

2. Are you aware of any BIM software?

- Yes
- No

3. What is your reason for using BIM in your firm?

- For efficiency process improvement
- Owners demand
- Competitors using it
- Design Coordination
- Clash Detection
- Extract bill of quantities
- Construction Sequencing

Other (please specify)

4. Which software do you use in your firm?

- Revit
- Tekla
- Allplan
- Archicad
- Navisworks
- None

Other (please specify)

5. Which one of following items has been affected by using BIM software in your opinion?(Please rate importance from low 1 to High 4)

	1	2	3	4
Save costs	○	○	○	○
Client demand	○	○	○	○
Energy analysis purpose	○	○	○	○
Better design tool	○	○	○	○
Competitive advantage	○	○	○	○

Other (please specify)

6. Which party in construction industry could use BIM more efficient?

- ○ Architectures
- ○ Construction management team
- ○ Contractors
- ○ Subcontractors
- ○ MEP
- ○ Suppliers

Other (please specify)

7. Do you think BIM adoption leads to greater efficiency?

- ○ Strongly agree
- ○ somewhat agree
- ○ Not sure
- ○ Somewhat disagree
- ○ Strongly disagree

8. Do you think BIM software are complicated and should be easier?

- ○ Strongly agree
- ○ somewhat agree
- ○ Not sure
- ○ Somewhat disagree
- ○ Strongly disagree

9. How much would BIM affect the time of construction projects?

- Very much
- Somewhat
- Just a little
- Not at all

10. How much would BIM affect cost of construction projects?

- Very much
- Somewhat
- Just a little
- Not at all

11. How much would BIM affect the quality of construction projects?

- Very much
- Somewhat
- Just a little
- Not at all

12. How much would BIM affect health and safety of construction projects?

- Very much
- Somewhat
- Just a little
- Not at all

13. Have you used Laser Scanning in any projects before?

- Yes
- No

14. If you used Laser Scanning before, what was your purpose?(Please rate importance from low 1 to High 4)

	1	2	3	4
control after implementation				
For reconstruction of old buildings				
Control after natural disasters or unnatural				
Draw plan for buildings that haven't any plan				
Freeway Redesign				
historical documentation				

Other (please specify)

15. What are the benefits of using Laser Scanning in your projects?(Please rate importance from 1 to 4)

	1	2	3	4
Lower deign cost				
Reduce the project design time				
Fast and accurate data capture				
Increase design quality				

Other (please specify)

16. Do you use any specific software and hardware used in any project?(Please rate importance from 1 to 4)

	1	2	3	4
scan to revit				
Cyclone-SCAN				
Leica CloudWorx for AutoCAD				
SurvTech				

Other (please specify)

17. What is the usage of Laser Scanning in construction?(Please rate importance from 1 to 4)

	1	2	3	4
Create a Three dimensional models from buildings	○	○	○	○
reduce the crew time needed to collect data required to measure or verify pay quantities	○	○	○	○
quality control tool for new projects	○	○	○	○

Other (please specify)

18. Do you think integration of BIM and Laser scanning is possible?

- ○ Yes
- ○ No

19. What is advantage of integration of BIM and Laser Scanning in construction Industry?(Please rate importance from 1 to 4)

	1	2	3	4
laser scanning to create 3D BIM models is fast and accurate	○	○	○	○
can be used to monitor the progress of designed Building	○	○	○	○
can be helpful for space coordination in renovation projects	○	○	○	○

Other (please specify)

20. What is your opinion about the development and use of BIM in the future?

- ○ Definitely no
- ○ May be no
- ○ No idea
- ○ May be yes
- ○ Definitely yes

21. What is your opinion about development and use of Laser Scanning in the future?

- Definitely no
- May be no
- No idea
- May be yes
- Definitely yes

22. What is your opinion about development and use of BIM and Laser Scanning together in the future?

- Definitely no
- May be no
- No idea
- May be yes
- Definitely yes