Road Map to BIM Use for Infrastructure Domains: Identifying and Contextualizing Variables of Infrastructure Projects

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Abstract

Nowadays, construction activities and projects are becoming much more challenging to manage. Being involve with different stakeholders is a difficult task and information and communication technology (ICT) has been addressed as a solution. On the other hand, Building Information Modeling (BIM) has already taken first steps towards this big revolution and gained a place in the sector. By inspiration from modality of BIM, there can be an adoption to other sub-branch of construction industry such as infrastructure domain. Since BIM has proven benefits in buildings, infrastructure projects might gain similar advantages through proper implementation. The authors of this paper are suggesting the use of a new describing for the purpose of BIM adoption for infrastructure projects, namely; Infrastructure Building Information Modeling (I-BIM). The main aim of conducting this research is to identify and prove the lack of using BIM for infrastructure projects. Within this context, questionnaire survey designed and distributed among 187 participants. These respondents were mostly located at United States of America and Turkey. As a finding of this research, authors clarify the preponderance and impediment components in the path of I-BIM utilization and discuss five main categories to clustered selected 26 variables as benefit or barrier of I-BIM.

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1. **Introduction**

The Architecture, Engineering, and Construction (AEC) are one of the largest industries in the world [1]. Construction projects are specially made by a municipal agency as public property or privately by a property owner. Construction is the process of building any structure that may result in the remodeling or completion of it. All construction projects involve strong financial parties and manpower to make the project done. The labors risk their lives by using dangerous materials, construction equipment, and gears and working at various types of conditions. Minor neglect may result in too dangerous and costly circumstances. There is multiple types of construction projects and it can be divided into four main categories:

1. Residential Building
2. Commercial and Organizational Building
3. Specialized Construction
4. Heavy Construction and Infrastructure

Infrastructure is defined by the Oxford Dictionary as the basic physical and organizational structures and facilities needed for the operation of a society or enterprise. Therefore, infrastructure assets can be broken down into five main domains as illustrated in figure 1 [2].

**Figure 1.**

To deliver any construction project including infrastructure, there should be a financial benefit ahead of doing it but nothing can be done to guarantee a profit is going to be made out of a project. There are three main objectives to complete a project successfully which is time, budget and doing it according to requirements but the main barriers to overcome these objectives is project
environment. Project management is an effective approach to anticipate the probability of project success and effective time and cost control could be an important key to any construction projects. To achieve aforementioned parameter and in order to resolve related lack of management information issue, establish a strong link among different related parties and accomplish progressive practices, Information and communication technologies (ICT) has been developed and get use by construction industry [3].

In 1997, a researcher claims that the information technology and construction (ITC) is as a synonym to ICT [4]. Furthermore, ITC has been considered as domain of study in information technology and defined as a collective reference to the integration of computing technology and information processing [5]. The original belief behind this philosophy was to prove that ITC is not a stand-alone technology, on the other hand it is wide range of technical approaches in order to resolve different type of issues. Therefore, any type of artifact that has the ability to store or retrieve and transmits or receives data electronically can be defined as ICT.

Adwan [6] identified 21 sets of ICT technologies, including Web-Based, BIM-based technologies, Computer-based training and learning, Virtual Reality, Knowledge and information management, wireless and Mobile technology, Information Systems, Decision-based, tracking technologies, Optical recognition, simulation analysis and etc. These ICT technologies have been compared base on different construction task and among all technologies, BIM-based has been identified as one of the most frequent technologies compare to more than 30 other ICT technologies. So amongst different sort of ICTs, Building Information Modeling (BIM) provide a model-based cooperative approach which let the teams manage projects in better condition [7]. According to ISO 29481-1, Building information modelling provides a digital technology for describing and displaying information of a built object (including buildings, bridges road process plants, etc.) to facilitate design, construction and operation processes to form a reliable basis for decisions making process of any construction works [8]. Also, Azhar [9] introduce BIM as a process to stimulate the planning, design, construction
and operation of any facility by a computer-generated model that could be used for different construction stages such as design, modeling, energy analysis, clash detection, project scheduling, health and safety and cost estimate and BOQ plans. There are several division of BIM technology and these subsets are commonly described as a dimensions such as – 3D modeling, 4th dimension as project scheduling, 5th dimension as cost estimating, 6th dimension as sustainability and green energy and last but not least is 7th dimension as facility management.

The main aim of conducting this research is to identify and prove the existing lack of BIM utilization for infrastructure projects. In order to justify this issue, a questionnaire survey is selected as the major data collection tool. Within this context, respondents of the conducted questionnaire are selected from USA and Turkey / North Cyprus considering the fact that, these two countries represent good cases of being an advance country (USA) and developing country (Turkey / North Cyprus). This questionnaire seeks to determine and prioritize the concerns of professionals for not adopting BIM utilization for infrastructure projects within the context of 5 main categories namely; managerial concerns, contractual relations, public authority, financial and educational reasons. For this purpose, 26 variables are obtained subject to critical review of existing body of knowledge, and these are correlated with aforementioned 5 categories and diverted as questions for review of the professionals. Performed analysis and obtained results are critically discussed and necessary reliability analysis, data mining of all variables necessary charts for compared countries are presented in the upcoming sections of the paper.

Figure 2.

As depicted in figure 2, this research is composed of 5 sequential processes. Research process starts by selecting two different countries that are in different leagues in terms of adoption of latest trends, technology, and processes in construction. Therefore, United States of America is chosen as an advanced country in terms of existing construction practices and Turkey is selected as a developing country for the same purpose. Determination and evaluation of the difficulties for very
little or no use of BIM adoption in infrastructure projects in these two countries, observing similarities / dissimilarities, analyzing the reasons that lay under the difficulties will light the way for proposing an action plan to mitigate those difficulties if it cannot be eliminated. In this way, authors of this paper strongly believes that theoretical proof and finding will create the necessary motive for industry professionals to adopt BIM for infrastructure projects.

2. Building Information Modeling (BIM)

By the previous decade BIM has been considered as one of the most important technological improvements in the structure design and construction industry. Architecture, engineering, and construction (AEC) industry have been attracted by this significant technology. The road map of this technology can be map out back to the 1960s by computing applications and also appearance of need to have solid modeling programs in order to achieve more proper design[10]. The establishment of BIM has been started by the development of the ArchiCAD and furthermore Revit software played an important role on BIM utilization in construction industry. This technology was introduced to figure out the potential problem of construction project in order to analyze and simulate any effected influences. To achieve this goal BIM presents the building process of a construction project virtually in preliminary stage and before even construction tasks get started. Generally, BIM is more than just a simple application of 2D and 3D techniques. It is more descriptive as a system to help companies in order to organize the right people with accurate information together, efficiently and effectively. So as a highlight, BIM is the combination of information, technology, people, and processes.

By the mid-1990s and decreasing of construction projects demand and other obstacles which construction industry has been faced, BIM is been introduced as a solution to overcome these obstacles. The variety of direct and indirect of BIM’s benefits were undeniable and construction phases such as prefabricated buildings is also going to adopt BIM within a new frameworks [11]. In the past two decades, the AEC industry owes its reinvention to BIM. As mentioned, the main
concept of BIM was 3D modeling but by the time it’s expanded and improved to 4D programming connected with the construction process. Later on, it got even more developed by 5D modeling integrated with cost data. According to Jung [12] and Biancardo [13], the effectiveness and benefits obtained by implementing the BIM can lead to reduction in terms of construction times and costs and in some cases decrease the delivery time of projects by 7% or eliminate unbudgeted change of projects by 40% and make the process of cost estimation faster up to 80%. Furthermore, it can merge different phase of any construction projects such as demolition, maintenance, design, and construction information into a solid and single higher level phase, and assist all participants with improvements in costs reduction, monitoring risks, and waste management, as well as carbon emissions and generally by efficient performance.

BIM contains rich structured data which is represented by an easily visualized 3D-object database. Moreover, it can be functional in order to analyze building costs, schedules, sustainability, and performance [14]. This technology initially has been applied only for construction phase of building projects, but nowadays, it known as a tool can be contribute at operation or maintenance phase for most of the construction projects such as airports, stadiums or even bridges and more generally for most of well-known infrastructure domains to advance and expand it and it sometimes referred to as civil information modeling (CIM) [15].

Basicly, CIM is a term commonly used to refer to the application of BIM for civil infrastructure like tunnels and bridges but there are other terms like construction information modeling, civil information management or civil integrated management which is use by various institutions to define CIM. This variety on definition of CIM can led any users to errors while working on a project with other members who work for different companies and it make it difficult to collaborate. Furthermore, by moving from paper-based of workflow to a computer aided workflow, there are other terms in infrastructure domains such as Bridge Information Modeling (BrIM) that makes thing more complicated to gather all infrastructure project such as bridges, roads, railways, tunnels,
airports, harbors and other infrastructure domains within a single framework. To solve this issue, authors of this paper are suggesting the use of a new describing for the purpose of BIM adoption for infrastructure projects, namely; Infrastructure Building Information Modeling (I-BIM).

2.1. BIM Implementation

2.1.1. North America

According to Wong [16], the North America region is leading the construction industry in BIM implementation and development. McGraw Hill Construction [17] found that by the end of 2007 the rate of BIM adoption was only 17% in the North American industry and later on, in 2012, it has been increased to 71% by project team professionals which it provided data including satisfaction of more than %60 of BIM users on companies turn over through the investments in BIM and this proves that BIM is playing a key role in development of construction industry. This increment proves the fact that this region is on the top of BIM ladder in global scale. The improvement of BIM went back to 2003 when the General Services Administration established a new 3D and 4D BIM based program to contribute as an accelerator of Public Buildings Service Office and because of huge number of building for this public sector across the United States, this program has had its own influence on BIM adoption. Consequently this fact, demonstrating the importance of major government and client leadership for the construction industry. In the United States, there were two significant publication reports by the National Institute of Standards and Technology which quantified the cost subsequences of insufficient interoperability in the capital facilities sector of the U.S. construction industry.

2.1.2. Turkey

One of the leading industry in Turkey is construction and it needs access to its success in the long term by increasing the awareness on green building, energy efficiency, and sustainability [18]. Since 2007, the legislations and law about energy efficiency have been implemented in the Turkish construction industry by energy efficiency Law no. 5627 and regulation of energy performance of
building. Therefore, many contractors realize that using BIM can promote collaboration of different working parties, computation of material qualities, improve visualization of project to stakeholders, positive impact on green design in term of daylight analysis and energy saving, LEED documentation, reducing the carbon emission of projects. It can also be applied for different purposes such as lifecycle asset management, condition monitoring and sustainability [19].

2.2. BIM Benefits

The way that any building is designed, constructed and maintained has been changed by the introduction of BIM technologies to the construction industry. According to Eastman [20], owners have better visualization over the sequence of construction activities of the base of their project on anticipated duration. An innovative framework has been proposed by Schade [21] based on decision-making system which is used based on the design performance in design phase stage. This method has been developed in order to inform decision-maker by making a best choice regarding to life cycle performance of building. This BIM-based model includes a variety of information such as building geometry, materials, structure, functional and installation which lead the project to reduce time and cost for the analysis of energy performance [22].

BIM is also using by contractors to support several construction management tasks [23-24] and furthermore, Farnsworth [25] investigated that BIM is part of commercial construction processes in recent years. Also scholar found that the advantages of using BIM include variables such as better communication systems among different involved parties, provide more accurate scheduling, improving coordination of project teams, improving visualization and accurate clash detection, providing cost estimation in short time and increasing on quantity takeoffs performance accuracy. Weygant [26] agreed that both clients and contractors have the benefit of 4D and 5D modeling of BIM by increasing the awareness of coordinating, estimating and scheduling of any project aspects.

Managing existing facilities of any project can be categorized as another advantage of BIM which would be achieved by fully linking and modeling of any structure to the computer-generated model.
In this manner, all operational error and energy consumption can be monitored by selected team members as a management purpose [27]. Likewise, other potential benefits of BIM implementation such as: Increase productivity through cost and time saving, Improve information sharing, improved quality management, support decision making and increase sustainability. Similarly, researchers through a quantity survey in Australia has been found that the time saving factor is the most significant perceived benefit of using BIM and gather benefits associated with BIM implementation data through questionnaire survey and the highest-ranking benefits went to reduced clashes, improved visualization and productivity.

By increase of BIM software interoperability among team members, more than %65 of the overall annual cost paid by clients, operators and building users has been saved. Also, different parties like software vendors had large benefit on their investment for BIM [28-30]. Furthermore BIM is capable of making multiple parties, and other benefits could be bring to the project by team member such as: 3D visualization, full understanding of project requirements, time saving, reduction of construction activities period and reduction of design problems [31-33]. Even so, to gain these benefits on any projects, there are various factors which play a significant role in the success of BIM implementation of any projects. These factors are collaboration among different teams member, experts team members legal contractual related issues of projects which involving BIM usage, project budget and project type and geographical location. It is noteworthy that if any of these components doesn’t handle properly in a BIM project, they certainly turn as barriers to BIM adoption of any projects. [34-39].

2.3. BIM Barriers

BIM implementation require the development of national strategy and standardize the BIM process. In order to obtain this goal, related organization need to provide guidance and set out national priorities for the whole industry. Moreover, there is a need to classifying all types of work in construction industry accordingly. However, there is no clear general agreement regarding BIM
implementation and use but during the previous decade some guidelines have been developed, but then again still there is no formal standard to organize industry practice. However there are some standards which are applying throughout AEC industry but development of new standards for implementation of BIM is a must to industry.

The inconsistency of data and the data compatibility for exchange and sharing are the most noticeable data related problems [40]. Also, the inclination of information sharing among project parties is considered as a critical factor and this shows the fact of BIM needs include the capability of transmitting the embedded information in the graphical model and consequently a lack of information sharing could be considered as BIM implementation barrier.

BIM as a new technology with the all provided significant benefits to the AEC industry, requires costs for its implementation. The main common costs to BIM adoption is education and training costs as well as initial costs and development costs of this innovative technology. Generally, the implementation cost is recognized as an obstacle to BIM. According to Ganah [41], mainly the large companies which have the most resources are in charge of BIM implementation in the industry. One of the critical requirement of BIM implementation is data storage and specific software which these two factors could make a significant cost to any firms. Depends on the companies IT facility, the costs of purchasing new software could be considered as a barrier to smaller companies and this could easily force investors to reconsider the BIM options more carefully due to nature of the project and its requirements.

Generally, education and training cost have a broad influence. For instance, education is ensuring a firm has either the right personnel by retraining existing one or hiring new staff in order to integrate BIM into its operational phase. Also, retraining the majority of existing staff to support the behavioral and organizational changes required to fully adopt BIM technology within a business model. The fundamental of BIM evolution is training and education which could be considered as the best solution that can improve the BIM learning procedure. The lack of adequately trained BIM
professionals has hindered BIM implementation and use in the AEC industry. Similarly, lack of skills is another barrier to implementation of BIM in the future. This condition is going to be worse by the persistent shortage of capable BIM professional over the following decade [42].

The issues such as process problems, liability, and trust are categorized as an organizational problem on the way of BIM implementation [43]. The reluctivity of senior managers of any firm about new technology and processes of it is too low while the management system needs more support in order to adopt BIM implementation quicker. A bottom-up approach is considered more efficient in dealing with resistance to change [44]. Moreover, the lack of knowledge about the differences between conventional construction methods and using BIM by some managers are identified as one of the other obstacles on the way of BIM implementation.

Legislation aspect of BIM development is one of the concerns by scholars and governments. The primary risk about legal aspects of BIM is for data ownership because if clients pay for the design phase of construction projects, they have the right to claim ownership of the documentation. Likewise, there would be a high chance of conflict among other stakeholders than owners and architects in case that they involved in a project. Additionally, it is extremely important to determine who will access data and be responsible for any inaccuracies during the project and this point of view could bring a considerable risk. Also, stakeholder prefers to have the confidentiality of data and documents in BIM model but there is a range of legal issues which have been identified in connection with administration aspect of projects.

Table 1 provides a comprehensive assessment on critical variables of BIM implementation, such as Contractual Relations (CR), Education (E), Financial (F), Managerial (M) and Public Authority (PA). The detailed assessment of each category is added to explain their sub-factor like availability of expert personnel (E1) or responsibility for inaccuracies (CR3). Correspondingly, these variables are not uncorrelated from each other and by presenting data mining, these relation will be shown with more details.
3. Research Methodology

To demonstrate the industry professionals how they can efficiently adopt BIM for infrastructure projects, comprehensive review of existing body of knowledge from many different sources (academic journals, dissertation and conference databases, web, e-books, etc.) is performed. During this critical review, the benefits and barriers of BIM implementation are identified in terms of 26 variables, where these variables are later assessed and rated by the professionals through their involvement of the conducted questionnaire. As illustrated in Figure 3, these variables are correlated and clustered under 5 different headings as suggested by the authors.

Subsequent to identification and classification of the 26 variables, it was vitally important to obtain opinion and feedback of the professionals and benefit from their experiences of BIM adoption. This is why questionnaire survey is selected as an instrument for collecting data in this respect. After about 4 months of efforts, 187 experts working in USA and Turkey is reached. For the participants with whom the authors had personal communication, questionnaires are conducted face-to-face in an interview-based environment. Rest of the respondents are reached through newsletters, professional organizations, and academic networks and participated through online tools.

In here, our research team considered two main principles to detect and screen an invalid questionnaire. Firstly, if some answers are missing; secondly, if answers are the same score pattern from beginning to the end. Within this respect, 12 invalid questionnaires are detected and 175 respondent’s participation is considered during analysis. On the other hand, it worth to highlight in this stage that, 44% of the respondents are from USA where the remaining are from Turkey and North Cyprus.

Figure 3.

The questionnaire is comprised of two main parts. In the first part, general information about the participants concerning the type of firm they work for, their affiliation, their level of proficiency in
BIM, work experience, and knowhow in using a BIM software is investigated though 15 questions. In the second part, 26 variables identified from literature review are diverted to participants under 5 different heading for their classification of those variables either as a barrier or benefit, and participants have prioritized these variables so that a relative important index of the variables could be obtained. The final ranking of variables upon respondent opinions has been stated in Table 2.

Table 2.

4. Results and Discussion

4.1. Respondent Profiles

This questionnaire survey had 175 complete responses. Figure 4 categorized all respondents by their occupation and level of expertise in the construction industry and in this case, it has been tried to distribute survey among the infrastructure experts firms. It’s noteworthy to mention that 77 out of 175 participants were located in the United States of America which is equivalent to 44% of total survey. Remaining amount of participants who helped to conduct this scientific research were located at Turkey and Republic of Northern Cyprus.

Figure 4.

4.2. BIM Project Profiles

Respondents were asked to select a Project Type (PT) which has been done in their firm by using BIM in order to make construction line of business for following research. As it is shown in figure 5, all 175 participants of the survey were involved in 683 projects which has been shown by PT1 to PT14 indicators. These indicators are represented as commercial(PT1), Residential(PT2), Educational(PT3), Industrial(PT4), Airport(PT5), Transportation(PT6), Public & Government(PT7), Sports & entertainment(PT8), Water Supply & Resources(PT9), Bridges(PT10), Power Generation & Transmission(PT11), Tunneling(PT12), Pipeline Infrastructure(PT13) and None(PT14). It can be stated from Figure 5 that there are plenty of Residential and Commercial projects which utilize BIM but current usage of heavy construction and more specifically infrastructure, based on BIM is growing.
fast all around the world but still needs raising concerns of industry. On the other hand there will be another way to categorize selected respondents which has been done by firms’ projects value and illustrated in figure 6. According to survey data which has been elicited, most of involved firms’ are fell into more than $50 million range (42%), followed by $30-$50 million (31%). Therefore these result shows that I-BIM is also more applicable to large invested projects.

Figure 5.

Figure 6.

4.3. Adoption of BIM for different dimensions

During the previous decade, there were several BIM analysis and authoring tools available to design and monitoring different aspects of the construction industry. Due to survey results, as it illustrated in Figure 7, AutoDesk programs such as Revit and Navisworks are widely used in the selected country. Afterward, Graphisoft ArchiCAD by 14% and Tekla by 7% are the most common BIM tools which are being used by industry. Also, around two-third of the architecture firms are using AutoDesk and Tekla is a popular tool among the engineering firm according to the respondents.

Figure 7.

To investigate more on BIM adoption, respondents were asked about the BIM dimension (task) which they used for their firm’s projects. According to Figure 8, Visualization (3D) and scheduling (4D) were the most important BIMs dimension is used in projects. Likewise, Cost Estimating is one of the most critical tasks to finalize any project phases on time and on budget. It is raising a concern that 5th dimension of BIM needs more attention and there is high potential impact which could be investigated by researchers such as social cost effect in today’s construction activities by using BIM as a quantification tool.

Figure 8.
4.4. Contractual Relations

The agreements among all involved firms during the construction of any structure is one of the most important parameters of any successful project. By introducing BIM to construction industry, accuracy level of any construction activities increased. In this section, authors selected four parameters to be evaluated in the path of I-BIM utilization. According to respondent opinions, the collaboration of different companies’ staff for same project and responsibility for inaccuracies on project tasks are the most important beneficial aspect of I-BIM which is currently contractors and architecture firms are using it on their projects. In these cases, each person who is involved in project has access to online cloud system to create, modify and monitor any tasks, depending on their roles. This system clearly reduces any inaccuracies and make the quality and control management of the project at a higher level.

On the contrary of the first two parameters, Supportive contract forms for I-BIM and Appropriate insurance policy for projects are considered, not as a barrier nor benefit, but as underdeveloped parameters which need more perception by related parties. For instance, in the United States of America, there are some advantageous insurance policy which motivates customers to use those technologies. In construction industry, there are different types of insurance; but as technology is finding its own way to the industry, lack of beneficial insurance policy for the firms who are using I-BIM in their projects is sensate because as it mentioned, by using I-BIM there could be lots of revenue for everyone, including publics by saving the notable amount of tax payment to the government. Even as a solution, there could be clause in contracts agreements forms among the client (or the consultant firm’s on behalf of client) and contractors which shows the responsible firm is using I-BIM in the project and by using it, there would be exemptions for contractors and subcontractors due to advantageous of it.

As a matter of fact, BIM easily helped to contractual relations segment of the construction industry by making more proper collaboration among involved companies in the same project. More than
that, it aids to investigate any inaccuracies at any stage of any project and simply realize the responsible role who lead the task to error so by this manner any aspect of any project could be easily managed. It’s noteworthy to mention the uncertainty of third worlds countries about these matters because as it stated in CR2 and CR4 analogy figure 9 (b) & (d), around 40% of respondents are not sure how these two variables could help their firms. But hopefully in near future there will be appropriate insurance policy for the projects which are using BIM and I-BIM by the legislation experts all around the world.

**Figure 9.**

### 4.5. Education

The relation of education and I-BIM is irrefutable because any new technology needed to be taught by experts and learn by apprentice to be more applicable. According to the respondent’s opinions, there is lack of expert personnel around the world which cause high cost of training and education. This is easily one of the strongest barriers to utilize BIM in any sector including infrastructures. As a solution of E1 variable, industry and government as an assembly need to work to bring I-BIM to life by changing universities curriculums and organizing workshops to increase the awareness of all related parties even more of what has been stated in figure 10 (b), because this the future of construction industry.

Afterward, it’s noticeable to discuss background education of academia about I-BIM as another barrier. Due to comments of respondents, there are not enough must-take courses in universities which precisely focus on different aspects of BIM. Most of the interested apprentice need to attend in high-cost workshops to learn a new program or getting familiar with the concepts of this technology. But if the mentioned assembly gather and work properly to overcome E1 variable, both academia and engineer going to be more familiar with I-BIM. Therefore due to availability of expert personnel, all related costs including workshops will be decrease because of high insensitive contest among parties.
The third parameter which has been asked was Information Sharing in I-BIM. This factor is easily one of the biggest advantages of I-BIM according to a high ratio of the respondent for considering it as a positive influence on I-BIM. Nowadays, Programs such as BIM 360, Tekla, BIMsight, Autodesk Revit and Navisworks, BIMobject, and BIMx are assisting most of the firms around the world to organize their construction activities in a proper way. Generally, Information sharing is being done by some of these programs through the cloud-base web service which provides team members access to data to improve decision-making and avoid expensive delays. Therefore it’s noticeable to consider E3 as the only pure benefit of education category of I-BIM by refereeing to supportive facts which has been mentioned.

Figure 10.

4.6. Financial

One of the most important investment for a successful I-BIM implementation is training and it has been the greatest barrier on the path to I-BIM adoption based on figure 11 (c). According to study’s results, respondents recognized F3 as a critical problem and firms are trying to provide more training to their staffs in order to resolve this concern. Also, Initial Cost of I-BIM software, figure 11 (a), has been ranked as a second financial barrier for the I-BIM adoption. Indirectly, this Parameter indicates the number of I-BIM user in the industry because one of the main reason of any expansive product could be the lack of customer or consumer which it led to high cost of the production in order to cover the expenses of manufacture products and make a reasonable profit for company. In addition to these two barriers, it is noticeable to mention the cost of development, figure 12 (b), as another obstacle which categorized as a software upgrade and hardware maintenance. According to the literature review, American companies spent less than 2% of their net revenue on hardware, hardware maintenance, software, software upgrades, or training. Relatively, hardware and software costs funded the most to overall expenses, whereas hardware maintenance and software upgrades expenses are less than 0.5 of overall net revenue of the firms.
The survey has been tried to investigate tangible costs associated with utilization of I-BIM, software and training, companies’ turnover and stakeholders’ involvement. Somehow, these costs are the ones which easier to quantify and compare to the other factors. In spite of the fact that these factors and costs are undeniable, still, lots of organization and government has doubt about I-BIM utilization for their projects. Due to the respondent opinion in this survey, any companies who involved with big projects get benefits from I-BIM adoption and by following changes, the turnover of companies will increase extensively as it has been stated in figure 12 (a) but for third world countries still there are doubts about F4 factors due to economic condition of those countries. Furthermore, public and private sectors as major stakeholders’, F6 variable, could play a key role in the success of I-BIM by promoting and providing support for implementation, research, and development in the future. It is a matter of fact that in advance countries, stakeholder involvements are more passable compere to third world countries. This fact can be prove by referring to figure 12 (c) which most of the American are consider F6 factor as a benefit but in Turkey, more than 50% of respondents were not sure about how this variable could effect on their companies progress and improvement.

### 4.7. Managerial

In managerial aspect of I-BIM utilization, ten variables have been selected. According to the respondent opinion, BIM adoption for infrastructure projects has a positive impact on factors such as client requirements, coordination among project parties, project size and complexity, project quality management, project scheduling, and time management, Project life cycle cost and leadership and management supports as illustrated in figure 13 and 14. It’s notable to imply to relation between M1 and M2 with CR1, E3 and F6 variables which has been discussed in more details for all related factors of each case study in variables assembly section. Basically it shows that these two managerial factors has strong link with collaboration in-between of all related parties and more
specifically information sharing on I-BIM platform. This relation can lead any project to less conflicts, proper coordination and finest environments in order to fulfill all necessary requirements of project which has been asked by client. On the other hand these relation will lead to most accurate financing of a project which has direct relation with M4 and M6 factor because it can avoid any possible cost and time overrun of a project which has effect on any potential conflict among parties including financial aspects.

**Figure 13.**

One of the factors which need more concern in today’s world is a social cost. Gilchrist [45] proposed it as a project contractual costs and comprised it as direct, indirect and social costs but in order to measure it for specific purposes, social cost has been grouped based on the area of impacts such as economic activity, pollution, traffic, and ecological/social/health. Due to the survey result there is a strong belief about I-BIM assists on quantification of social cost in a more accurate way which it may lead the scholar to reach these purpose by using I-BIM in further work but this topic needs more concerns from all researchers around the world. Also, as variables M4 and M6 has been taken into consideration for BIM, there will be similar opportunity for I-BIM utilization as well since more than 90% of respondent were clarify these two factors as a benefit it which has been stated in figure 14 (a) and (c).

**Figure 14.**

One of the other important preliminarily aspects of any project is EIA reports of it which. The main purpose of using Environmental Impact Assessment is to safeguard the environment to make sure that the government when deciding whether to grant a project which may have critical impacts on the environment, does so in the full knowledge of the likely significant effects, and takes this into account in to the decision making the process. In this regards, I-BIM utilization can and will have a positive impact on EIA as it identified in figure 15 (c) as a benefit by questionnaire responses.
4.8. Public Authority

Public Authority or more specifically, the governments, has a key role in the success of any nation in the path of developments. In this research, there have been three factors which have critical impacts on the success of I-BIM utilization. Every piece of information that a project owner may need about a facility throughout its life can be made available by using I-BIM as an information warehouse to produce an electronic version of any piece of documents. The main barrier about this module is about the construction industry because it does not yet have the open standards and infrastructure to mine that information and collect it to organize it in most sufficient way and distribute it with all involved firms and companies. In May 2015, the latest edition of National BIM Standards of United States published and it contains nineteen reference standards, terms and definitions; nine information exchange standards; and eight practice guidelines to support users in their implementation of open BIM standards-based deliverables by national BIM standard of U.S. which is shown the fact of incomplete national standards as it stated for PA1 variables by figure 16 (a).

In spite of mentioned barriers, the awareness level of the construction industry is growing by the help of academia and youth generation who are joining it. This fact can be supported by the relation between PA2 and E2 variables since both industry and academia need to have a clear understanding about all five categorize of I-BIM utilization. Moreover, this critical parameter is certainly playing an important role to merge conventional construction methods with I-BIM. By completion of this merge, the construction industry will be led to new era which Owners, planners, realtors, appraisers, mortgage bankers, designers, engineers, estimators, specifiers, facility managers, safety engineers, occupational health providers, environmentalists, contractors, lawyers, contract officers, subcontractors, fabricators, code officials, operators, risk managers, renovators, first responders and demolition contractors all can benefit by having access to I-BIM.

Figure 16.
4.9. Variables Assembly

Relation of all discussed variables under each category is irrefutable. In order to prove these relations, correlation matrix for each country has been presented and figure 17 shows it for Turkey and figure 18 for United States of America. As it has been stated before, under the Contractual Relation category, CR1 and CR3 are considered as advantageous factors. Based on presented matrix, these two factors has a relevant relation to each other, E3 and most of the managerial factors. It is noteworthy to mention independency of CR1 variable from financial and public authorities’ variables. Education, as a second category, has three independent variables. The relation among E1 and E2 proves the bond between educate of fresh engineers and lack of expert personnel. This fact can possibly lead the construction industry to compensate deficiency of educated staff for any construction project including infrastructure. On the other hand, E1 factor has a strong connection with financial and public authorities’ variables. This relation can prove the role of government for both advance and third world country in order to increases awareness of industry and provide enough facilities to cover lack of regulation and standards. Therefore, this factor can lead any government to provide financial resources to support utilization of I-BIM on related projects to avoid any potential time and cost overrun for any type of infrastructure projects. It’s significant to mention the independency of E3 from financial variables but conversely it has a strong link with all managerial variables including M2, M3 and M7 for both case study countries.

As respects of previous discussion, there is an interconnection between all financial variables except E4 and E6. This contradiction is a key factor to prove the importance role of stakeholders, especially in development countries. Because to gain an advantage from I-BIM in order to increase potential involved companies’ turnover, the stakeholders’ involvement is unavoidable. The next category is managerial variables with 10 significant factors, all related to nature of construction, time, cost, quality and labor collaboration. Environmental Impact Assessment of any project with a proper leadership and management through all team parties including government can lead any project to success and it can be defined accordingly on the way of I-BIM utilization based on correlation of M8,
M9 and M10 with all other 23 variables, especially with CR2, E3, F6, M3 and PA2. It’s noteworthy to mention that M1 to M7 variables are independent from financial and public authority variables. This fact prove that by utilization of I-BIM for infrastructure, any project can be delivered by time with the most adequate budget and parties without interfering of government or more specifically project’s client. It is interesting to mention about solid link in-between of all Public Authority factors with financial variables. This irrefutable fact demonstrate the path on the way of I-BIM in order to untie knot of this issue, Therefore, all infrastructure project be able to gain enough benefit out of I-BIM.

Figure 17.

Figure 18.

5. Conclusions
In recent times, there has been interested in inventive construction approaches. BIM is among the commonly accepted way of achieving integration in the different stage of the construction projects and its benefits enhanced the schedule and planning stage alongside coordination and operation. In order to increase the quality of the project and save more time and cost, I-BIM is the best solution but implementation of it has its own challenges and it is a risky path due to multiple factors including lack of expert personnel, insufficient budget, inadequate national standards and regulation issues. The major objective of this study were to identify and prove the existing lack of using BIM for infrastructure projects at selected countries in order to mitigate the existing barriers on the way of I-BIM by identifying obstacles and privilege of it. Based on the findings of data mining, factors such as incomplete national standards, lack of government regulation, initial cost of software, availability of expert personnel, and cost of training and education are the most considerable barriers on the way of I-BIM utilization. However, factors such as information sharing, staff collaboration, inaccuracies responsibility, client requirement, cost and time control, quality management and social costs are considering as the most important privilege of I-BIM which can make client, contractor, consultant
team and governments, as an assembly and they will be able to share benefit of collaboration, representation, process & lifecycle to create an innovative and efficient project environment.

It can be concluded that, in the literature, there have been numerous factors which contribute to BIM implementation for infrastructure projects in different categories. Authors have been tried to categories all related factors in a most accurate way in order to prove the fact of importance of using I-BIM. This study will help to compare the relation of each factor among the others because these are more likely to be interrelated to one another. As a future study, a new model can be developed in order to shows effect of I-BIM in social related cost for infrastructure projects to mitigate or reduce it. Moreover, as another research topic, there is a potential to develop a program to finally quantify the social costs based on the BIM or I-BIM depend on the nature of projects. Also, the relation in-between I-BIM variables in these manuscript can be investigated as a standalone topic to discover a true relation in-between of all related variables of I-BIM utilization.

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The authors wish to thank the following companies and organization for their help and participation in distributing the survey: Trenchless Technology Center, BIM4Turkey, GENX Design and Technology, GeoEngineers, Stantec, Jacobs/CH2M, Carollo, Garver, Kleinfelder, RJN and CTBUH Future Leader Committee Global.

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Biographies

**Borhan Ghasemzadeh** is a PhD candidate in construction management who currently work as senior instructor at Final International University. In 2018 he traveled to United States of America as a research scholar at Trenchless Technology Center to collaborate on data collection in order to embed BIM for infrastructure projects. His teaching expertise are LCCA of construction project, BIM usage to insure quality assurance of projects and construction management.

**Tolga Celik** is a lecturer of Construction Management in Eastern Mediterranean University. He has obtained BEng Civil Engineering from Cardiff University, MSc in Construction Management from Loughborough University and PhD in Construction Management from Salford University. Over the last six years he has involved in construction costing, estimation, adverse impacts of construction on the society, social costs, and sustainable construction methods. His teaching areas are construction management and engineering economics.

**Fooad Karimi Ghaleh Jough** is an assistant professor in Civil Engineering Department at the Final International University in Kyrenia, Cyprus. He received his PhD degree from the Eastern Mediterranean University, Famagusta, Cyprus in 2016. His research activities have included studies in design of reinforced concrete structures, metaheuristic algorithms in seismic risk analysis, and BIM modeling.

**John C. Matthews** has over 16 years of experience in the rehabilitation and inspection of infrastructure systems. He currently serves as the Director of the Trenchless Technology Center (TTC) and Associate Professor of Construction Engineering Technology at Louisiana Tech. He previously served as Pipe Renewal Service Line Manager at Pure Technologies, as Water Infrastructure Lead at Battelle, and as a Research Associate at the TTC. He has given more than 150 conference and workshop presentations and authored more than 220 technical publications. He is an active member of NASTT, currently serving on the Board of Directors.
## Table 1. Summary of I-BIM Benefits and Barriers

<table>
<thead>
<tr>
<th>Primary Factor</th>
<th>Sub-Factor</th>
<th>Sources</th>
<th>Summary and assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contractual Relations (CR)</strong></td>
<td>CR1: Collaboration of different companies staff for same project</td>
<td>[9] [36] [38]</td>
<td>Currently there are different software tools available and this variation causing barriers to user. This issue can lead any enterprise to conflicts with other involved parties. Therefore a supportive management plan with an international software package can help to overcome this barrier.</td>
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<tr>
<td></td>
<td>CR2: Supportive contract form for I-BIM</td>
<td>[46] [47] [48]</td>
<td></td>
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<tr>
<td></td>
<td>CR3: Responsibility for inaccuracies</td>
<td>[48] [49] [56]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CR4: Appropriate insurance policy for project</td>
<td>[57] [59]</td>
<td></td>
</tr>
<tr>
<td><strong>Education (E)</strong></td>
<td>E1: Availability of expert personnel</td>
<td>[29] [38] [39]</td>
<td>Regarding to the project’s nature, it can be difficult to find expert user who handle all aspects of project and due to variation of software tools, sharing information is sometimes difficult between users. This issues can be resolved by educate conversant engineers.</td>
</tr>
<tr>
<td></td>
<td>E2: Education awareness of academia</td>
<td>[44] [55] [56]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E3: Information sharing in I-BIM</td>
<td>[57] [60]</td>
<td></td>
</tr>
<tr>
<td><strong>Financial (F)</strong></td>
<td>F1: Initial cost of software</td>
<td>[9] [28] [38]</td>
<td>Adopting BIM is a promising returns for any construction business but due to high down payment, it could be a burden for small and Medium sized enterprises. Part of industry professional believed that in long term there will be huge capital outlay for any enterprise by reducing design errors and increasing productivity.</td>
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<tr>
<td></td>
<td>F2: Cost of implementation process</td>
<td>[39] [41] [50]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F3: Cost of training and education</td>
<td>[41] [51]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F4: Company’s turn over</td>
<td>[54] [56]</td>
<td></td>
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<tr>
<td></td>
<td>F5: Cost of development</td>
<td>[58]</td>
<td></td>
</tr>
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<td></td>
<td>F6: Stakeholder involvement</td>
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<td></td>
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<tr>
<td><strong>Managerial (M)</strong></td>
<td>M1: Client requirement</td>
<td>[9] [28] [37]</td>
<td>Construction management of any project is always involve with knowledge areas such as risk, time, cost, quality, procurement and etc. BIM is a great asset to distinguish these knowledge from one another and introduce features such as clash detection in early stages of planning, better coordination and collaboration among staffs, save time in scheduling (4D) and wealth in cost estimation (5D) and etc. Moreover, there will be a potential for quantification of social cost through the BIM platform.</td>
</tr>
<tr>
<td></td>
<td>M2: Coordination among parties</td>
<td>[38] [39]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M3: Project size and complexity</td>
<td>[41] [42]</td>
<td></td>
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<tr>
<td></td>
<td>M4: Project life cycle cost</td>
<td>[49] [51]</td>
<td></td>
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<tr>
<td></td>
<td>M5: Project social cost</td>
<td>[52] [54]</td>
<td></td>
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<tr>
<td></td>
<td>M6: Project scheduling and time management</td>
<td>[56] [57]</td>
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<td></td>
<td>M7: Project quality</td>
<td>[58] [59]</td>
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<tr>
<td></td>
<td>M8: Environmental impact assessment of project</td>
<td>[60]</td>
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<tr>
<td></td>
<td>M9: Project geographic location</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>M10: Leadership and management support</td>
<td></td>
<td>There has been a lack of guidelines so far to standardize</td>
</tr>
<tr>
<td><strong>Public Authority (PA)</strong></td>
<td>PA1: Incomplete national standard</td>
<td>[9] [27] [38]</td>
<td></td>
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</table>

*Note: The numbers in square brackets [ ] represent the sources of the information.*
PA2: Awareness level of the industry [46] [48] [51] [53] the process of adopting BIM for infrastructure projects. Lack of legislation is making stakeholders concerned of the ownership of data or models within the digital assets. Therefore there is a need for clearer standards.

PA3: Lack of government regulation

| Table 2. I-BIM implementation components |
| --- | --- | --- | --- |
| Indicators | Variables | Mean Score | Ranking |
| CR1 | Collaboration of different companies staff for same project | 7.109 | 9 |
| CR2 | Supportive contract form for I-BIM | 6.161 | 13 |
| CR3 | Responsibility for inaccuracies | 7.483 | 3 |
| CR4 | Appropriate insurance policy for project | 6.005 | 16 |
| E1 | Availability of expert personnel | 4.360 | 21 |
| E2 | Education awareness of academia | 5.050 | 19 |
| E3 | Information sharing in I-BIM | 7.441 | 5 |
| F1 | Initial cost of software | 4.015 | 22 |
| F2 | Cost of implementation process | 3.997 | 23 |
| F3 | Cost of training and education | 3.879 | 24 |
| F4 | Company’s turn over | 5.387 | 18 |
| F5 | Cost of development | 4.891 | 20 |
| F6 | Stakeholder involvement | 6.452 | 12 |
| M1 | Client requirement | 6.942 | 10 |
| M2 | Coordination among parties | 7.110 | 8 |
| M3 | Project size and complexity | 7.129 | 7 |
| M4 | Project life cycle cost | 7.932 | 1 |
| M5 | Project social cost | 7.473 | 4 |
| M6 | Project scheduling and time management | 7.862 | 2 |
| M7 | Project quality | 7.341 | 6 |
| M8 | Environmental impact assessment of project | 6.144 | 14 |
| M9 | Project geographic location | 6.006 | 15 |
| M10 | Leadership and management support | 6.509 | 11 |
| PA1 | Incomplete national standard | 3.489 | 26 |
| PA2 | Awareness level of the industry | 5.488 | 17 |
| PA3 | Lack of government regulation | 3.817 | 25 |
Conclusion

Lack of expert I-BIM operators in infrastructure industry and financial doubts for enterprises in order to do investment in this sector

Client, contractor, consultant team and governments, as an assembly can share benefit of collaboration, representation, process & lifecycle to create an innovative and efficient project environment

Analysis & Discussion of Results

Probability analysis of all categories and appraise reliability ratio
data mining among selected countries regarding to 26 selected variables

Organizational chart and trace I-BIM utilization between USA & Turkey by multiple analysis and figures

Data Collection

Define five individual categories including managerial, Financial, Education, Contractual Relations & Public Authority

Prepare and distribute questionnaire survey among 187 respondents

Problem Identification and Adjustments

Identify & prove existing lack of BIM utilization for infrastructure projects

Establish a new dimension as an I-BIM

Comprehensive analysis & discussion among selected countries for all variables

Novelty

Selection of two countries as a case study. United States of America has been selected as an advance country and Turkey as a third world country in order to explore potential differences on BIM utilization for infrastructure projects.

Exploration of Sources

Selection of two countries as a case study. United States of America has been selected as an advance country and Turkey as a third world country in order to explore potential differences on BIM utilization for infrastructure projects.

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