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STATYBOS FACULTETAS

Department of Construction Technology and Management

Procurement and contractual criteria regarding BIM at European level

FINAL THESIS PROJECT
MODALITY: INVESTIGATION

Author
MARIA CORONADO ARROYO

Tutor
EUGENIO PELLICER ARMIÑANA

Cotutor
DARIUS MIGILINSKAS

VILNIUS, LITHUANIA – VALENCIA, SPAIN
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ABSTRACT

Procurement process has been a real challenge for the AEC Industry in the last years. The obstacles that have been showing up are significant for any facility project; cost overruns, delays, lack of coordination among agents or traditional procedures that cause companies to not take advantage of being competitive in the Construction Market. Risk allocation in contracting is also a key procedure to face in this period. Despite the problem, Building Information Modelling has responded as the looked-for innovation for the Industry; collaboration, optimization of schedule, cost saving, conflict detection and risk mitigation. Many Governments took part in its progressive implementation, like the United Kingdom, with its level of maturity 2 by the capacity of BIM in public projects. With the help of the European Commission, BIM can be promoted in public electronic procurement since 2014. However, not all companies are convinced to change their culture and work methods. Once they know about BIM, they think about economical investment and training, or those work teams that already started implementing it, have some bad opinions about some of their uses. That is why this present study has the objective of promoting a new set of criteria about the potential procedures of BIM uses in procurement environment. After analysing the European industry context and focusing on both procurement and BIM approach, the methodology of this study developed a survey for potential companies worldwide about the uses of BIM and their level of satisfaction. The results were statistically analysed with central limit theorem, where the mean, median and standard deviations were key points for the discussion of the results. Then, the combination of the survey results, guiding documentation and current standardisation elaborated the final set of criteria. As a conclusion, each criterion, presented in explicative tickets, uphold themselves as recommendations that derive in contribution statements, limitations in the study, and future lines for further investigations.

KEYWORDS:

BIM, CRITERIA, ANALYSIS, INDUSTRY, PROCUREMENT

RESUMEN

El proceso de licitación ha sido en los últimos años un desafío para la Industria de la Arquitectura, Ingeniería y Construcción. Los obstáculos que han ido surgiendo son significantes para cualquier proyecto de construcción; sobrecostes, retraso de plazos, falta de coordinación entre agentes o procedimientos tradicionales que provoca que las compañías no puedan aprovechar su competitividad en el Mercado de la construcción. La distribución de riesgos en los contratos es también un punto clave que afrontar. A pesar del problema, Building Information Modelling, BIM, ha resultado ser la innovación más deseada por la industria; metodología colaborativa, optimización del tiempo, ahorro económico, detección de conflictos y mitigación de riesgos. Muchos gobiernos han tomado parte en su implementación progresiva, como Reino Unido, con su nivel de madurez 2 por la capacidad de BIM en sus proyectos públicos. Con la ayuda de la Comisión Europea, BIM puede ser promovido en licitación pública electrónica desde 2014. Sin embargo, no todas las compañías están convencidas de cambiar su cultura y sus métodos de trabajo. Una vez que conocen sobre BIM, piensan sobre su inversión económica y formación, o de aquellos equipos que ya implementaron y tienen una mala opinión de algunos de sus usos. Por ello, este presente estudio tiene el objetivo de promover una serie de criterios sobre los procedimientos potenciales de los usos de BIM en el ambiente licitador. Después de analizar el contexto de la industria europea y centrarse en el enfoque de la licitación y del propio BIM, la metodología de este estudio desarrolló una encuesta para compañías internacionales potenciales sobre todos los usos de BIM y su nivel de satisfacción. Los resultados fueron estadísticamente analizados por el teorema del límite central, donde la media, mediana y la desviación típica fueron puntos clave para la discusión de resultados. Después, la combinación de los resultados de la encuesta, documentación clave y normativa BIM elaboró el set de criterios. Como conclusión, cada criterio, presentado en fichas explicativas, se sostienen como recomendaciones que derivan en contribuciones, limitaciones en el estudio, y futuras líneas para otras investigaciones.

PALABRAS CLAVE:

BIM, CRITERIO, ANALISIS, INDUSTRIA, LICITACIÓN

EXECUTIVE ABSTRACT

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Procurement and contractual criteria regarding BIM at European level</td></tr>
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Maria Coronado Arroyo</td></tr>
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<tr><td>1. Problem approach to resolve</td><td>In the design phase of construction, AEC industry companies still work with the traditional procurement methodology, whose procedures cause uncertainty in risk allocation, schedule delays and cost overruns. The companies have to adapt BIM methodology in their project because the future obligatory nature, promoted by Europe, but some of them do not know about its theoretical and practical implementation, whole others are resisting to change.</td></tr>
<tr><td>2. Objectives</td><td>A*To assess the concept of BIM
B*To analyse the principal uses of BIM and its Potential Value
C*To justify the importance of BIM uses in procurement background
D*To raise awareness about the most value BIM uses
E*To elaborate a set of criteria based on BIM uses and steering information
F*To suggest impactful recommendations in each criterion for its implementation</td></tr>
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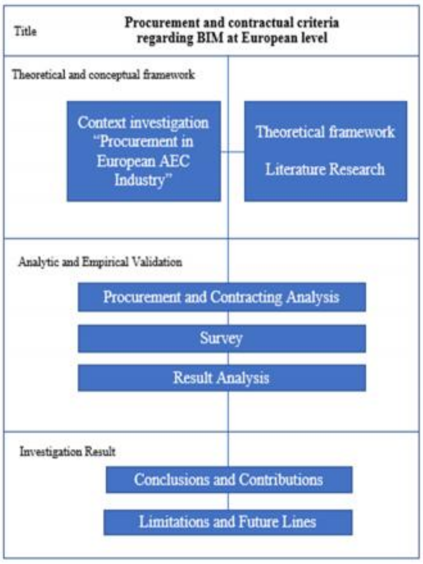

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<tr><td>4. Method</td><td>*First step is to develop the literature review with the help of the bibliometric reseach, looking for articles, books, specific websites and important documentarion, key for the investigation topic.
*Second step, the investigation has to be contextualised, through the study and analysis of the Procurement situation in the European AEC industry.
*Third step is an analysis the three main factors for the elaboration of the survey; Contracting, Procurement and the potential Uses of BIM. Those uses will be considered during all building performance period, then they will be filtered according procurement environment they are invoved in for the discussion of the results.
*Fourth step, the dissemination and folllowing collection of the results as the last part of the Methodology
*Fifth step, interpretation and discussion of the results.
*Sixth step as the conclusions, there will be contribution statements, aknowledgment of limitations and suggestion of new future lines of investigation.</td></tr>
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TITLE OF FINAL THESIS PROJECT	
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AUTHOR **Maria Coronado Arroyo**	
EXECUTIVE ABSTRACT (Maximum 1000 words)	
5. Objectives compliance	*A; Bibliographic research and elaboration of the definition of BIM. *"Theoretical Framework" chapter, "Step two_BIM concept" subchapter, "Definition"title.* *B; Inquiry of the potential Uses of BIM with a description and potential value features in a order list according the group classification. *"Aim Analysis" chapter, "Step three_BIM Uses" subchapter, "Uses of BIM" title.* *C; Justification and survey results selection of all BIM uses into the linked ones with procurement sphere. *"Methodology" chapter, "Step five_Survey assessment" subchapter. "Interpretation of results. Order of the scale results into rated results"title.* *D; Filter of the justified BIM uses connected to Procurement *"Methodology" chapter, "Step five_Survey assessment" subchapter. Interpretation of results. Order of the scale results into rated results"title* * E; Analysis of survey results, orientation documentation and standard guidelines as environment for the generation of a set of criteria *"Discussion of results" chapter, "Step Two_Set of criteria. Analysis" subchapter, "Table 5.2.3 Set of criteria List"* *F; Generation of criterion tickets which includes topic, description, impactful recommendations and references. *"Discussion of results" chapter, "Step Two_Set of criteria. Analysis" subchapter.*
6. Contributions	*Eitgh key criteria for BIM implementation *BIM uses selection for procurement environment *Survey results for level of satisfaction of BIM uses *Enhancement of e-procurement by European Commission *Promotion of virtual innovative procedures and developing tools for BIM *Encouragement of practical training through project pilots and Lean construction
7. Limitations	*Process of dissemination as a hard work *Unexpetedly low level of interest of potential participants *Short period for a further dissemination *Small number of the survey sample *Low level of understanding of the topic by some participants *Invalid responses of some participants

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INTRODUCTION

The main purpose of this thesis is to promote BIM as a methodology in the building's performance's lifecycle, specifically in contracting and procurement sphere. These subjects are the key points for a project's success, so the innovation is the scope that Building Information Modelling can bring to the multidisciplinary project industry as Architecture, Engineering and Construction.

The industry has been recently going through full of issues **(Ustinovicius et al. 2006)** in the contracting phases, such as waste of time or money. Obstacles which companies and public organizations, neither the Public Administration cannot allow nowadays (**Onyango, 2016)**. The experience and large and deep studies have proven that BIM helps with no hesitation the key parts where the main problems are **(Česnik, 2016)**, so this thesis can first talk about its rise, and then, about a specific purpose that even shed a light to the companies; how to use this methodology in an easy and accurate way, as a sort of set of guidelines as encouraging statements that clarifies to all organizations about where to start and what to do since the beginning using BIM. Having a knowledge about a theoretical framework about what BIM is contributing nowadays is as important as analysing the procurement and contracting phase, where exactly BIM can nail and enhance all projects from now, thinking about a European level and keeping in mind that, from now, the European Commission sees BIM as an essential part of the route from a concept design until a technical design of the project **(RIBA Enterprise, 2013).**

The content of this thesis is about the following introduction through the problem that will be studied with its need and atmosphere, also having an outlook of what happens in the AEC industry for having this issue. Objectives and hypothesis are critical here to discuss by the end. The second chapter of the thesis will be a theoretical framework study that includes the indispensable Literature Review, the concept of BIM and its influence in Europe. Following chapter is about an analysis of construction contracts, procurement methods and the popular uses of BIM that can directly influence in contracting and procurement, previously analysed. It will be needed to know about all of them.

With the help of those who are going to have a direct effect (public and private organizations), a survey will be proposed about all BIM Uses previously analysed, ordered and, finally chosen specifically in procurement environment. The survey proposal and the following study as a procedure in the chapter called Methodology, which will demonstrate how the instruments and population get through the collection, processing and statistical interpretation of the results, and will contribute to elaborate the set of criteria, specially made by the participants that will show up in the next chapter of the thesis; Discussion of the results, for the presentation and analysis of the criteria. Finally, there will be the Conclusion chapter that is included the contributions and constraints, also future lines for future studies.

STEP ONE_ PROBLEM STATEMENT

OBSTACLE, STARTING POINT

The starting point starts in the design phase of a project (conception, development and technology of the design). Private companies from the Architecture, Engineering and Construction industry in Europe are still having procurement traditional methods **(Chong et al, 2017)**, and those methods have lapses that make key participants of the project having problems with the schedule and costs (**EUBIM Task Group, 2017**). These lapses, reflected in the contract, might be lack of responsibility clarity in some situations, several consequences of late finish, changes in schedules scenario or overlap of works condition scenario (**Ustinovicius et al. 2006).** It does not help the fear of change of many companies. Being able to think about a full change of the system and procedures of bidding is an option that not all take, despite the need for adaptation to the new European policies and the competitiveness inside the Market.

THE NEED

Building information modelling has been, for the last ten years, since it started to be implemented, a valuable tool of progress for the AEC industry. BIM implementation means transparency, collaboration, interoperability of data model and cost and schedule benefits for the companies that are using it, also social and environmental impact BIM delivers (**EUBIM Task Group, 2017**). It is not a mystery that BIM has been used for the key issues in procurement methods, but there are still tasks to do for considering that BIM has totally resolved the problem **(Česnik, 2016)**. For a firm, it is important to develop a common work-method to deal with all the projects are involved in, plus the participation of all stakeholders. The root is always in the first stage of every project, the early phase of planning, where the contractual agreement establishes their goals and priorities for the project (**Migilinskas et al. 2013).** Getting to know the atmosphere between the need and problem is essential for an introduction.

ATMOSPHERE OF THE PROBLEM

European countries are the topic for the implementation of the need of BIM analysis and implementation. Some countries are last adopters in comparison with other that already started in BIM (**Mehran, 2016**), but there is also a good chance to analyse what those countries did a take as a reference. Another atmosphere topic is the way a country acts through standardisation framework**.** It basically means implementing BIM through standards and guidelines worldwide (**Migilinskas et al. 2013)**. These standards, that must be part of this study without any doubt, are related to reliability, transparency, accessibility of knowledge, strategy, interest, equality, competencies and adaptability.

AEC industry companies have also a lot to belong to an atmosphere issue. Particularly, the culture and customs of companies to face change or adaptation to the new are points to study, in relation to the key obstacles. The main challenge for the industry is to select the right tools that work in a whole to create a value (**Hardin & McCool, 2015**). Within company habits, there are still obstacles that the need of BIM is not well resolved. The bidding that a company does for getting a contract is the first step that clarifies the atmosphere (**Directive 2014/24/EU)**. Below, there is the procurement route which is covered by an official building's lifecycle;

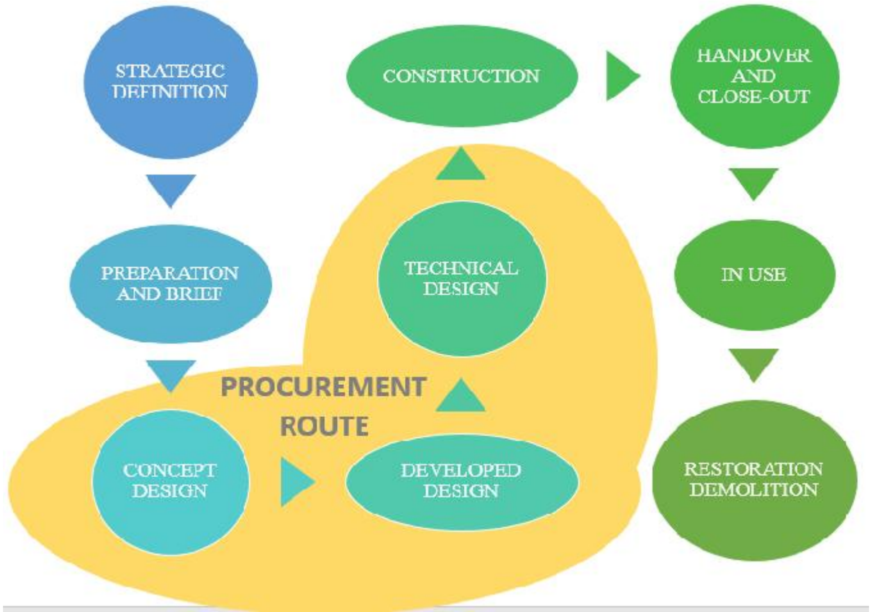

Figure 1) 1.1.1 Procurement Route in building's lifecycle (RIBA Enterprise, 2013)

STEP TWO_ AEC INDUSTRY

CURRENT SITUATION

PROCUREMENT METHODOLOGY

To have a general knowledge of the current situation, design phases are composed of the planning phase start-up, design management and procurement. In the planning phase already prepared a basic plan, main plan requirements and an overall schedule and project budget **(Chong et al, 2017)**. The procurement stage basically proposes different methods to choose and companies start bidding, according to the project's conditions (**Directive 2014/24/EU)**. Those conditions and requirements are included in a considered pre-contract, before the final conditions and type of procurement have been established. The importance of the final contract is connected to all design factors, as procurement does.

According to **(European Commission, 2017),** in the European AEC Industry, several public procurement rules must be established for the compliance of budget, time and quality. The main information about bidding properly is in the website, also it offers current business opportunities of tender calls. The current strategy is based on transparency, competitiveness and fairness across the Single Market, regardless the introduction of virtual service-oriented is starting in the recent past. The European Common Network and Database is a good occasion to keep going on the virtual adaptation.

CONTRACTING

Without a contract, there is no procurement method to choose. Analysing all type of contracts is a good goal, even more, if they relate to the factor of risk. In this specific case, design phase risks are related to management issue and decision making, such as changes, lack of communication or training, and so on **(Ustinovicius et al. 2006) (Chong et al, 2017).** For a good outcome from the planning phase, construction management must work on the value of the project, especially the owner's value (**Toth & Sebestyen, 2015**), the own building performance, collaboration with communication and dealing with risks (**Hardin & McCool 2015**). Thinking about risks, lack of information about the responsibility among the key participants is probably the most direct one in the beginning. It might be called risk allocation in the contract's conditions. Risk allocation has to be the key in the procurement types **(Ustinovicius et al. 2006).**

The traditional contracting system is linked to a hierarchical team organization where decisions making and risk control is assigned and transferred **(Martinez, 2015)**, so it is not properly shared in situations where the communication and full collaboration of the team is required. It is essential to get that the only tool for communication and checking of the contract is no other than meetings and messaging about that is going on. This lack of alternatives in the AEC industry might make future risks to come up during the building performance process.

MOTIVATION

JUSTIFICATION

The absence of standard BIM conditions in contract documents and issues of BIM as a collaborative framework implemented in the companies (**Migilinskas et al. 2013)** (**Porwal & Hewage 2013**), make a good opportunity to justify this project on a process. Analysing the three-key atmosphere (AEC industry, standardization framework and the European countries current progress) will motivate to resolve the problem formulation with BIM in procurement environment. Promoting the idea of every single standard already established, in every country member more advanced in the European framework, has to be adapted to a main common set of standards for new adopters. Driving new guidelines to those European countries that are new in the BIM implementation framework and there is no need to adapt themselves (**Mehran, 2016**). The AEC industry is always looking for its value (**Onyango, 2016)**, so, for the national and international firms, their value is the differentiation and establish their unique brand (**Hardin & McCool, 2015**). A uniqueness that encourages the industry of each country to be in the top in BIM context.

CONTRIBUTION

With this motivation and the analysis of the contracting system and procurement stage types, next step is a deep analysis of the main Uses or applications of BIM. Also, with the help of European companies and BIM experts, a BIM uses survey will be settled for every valuation of each application **(Chong et al, 2017),** but only those ones linked to the design phase. After data being collected, and statistically analysed, the combination of the survey results, orientation documentation and standardisation principles will create a set of criteria where the encouraging guidelines analysis of each criterion will be considered as a conclusive contribution.

PROBLEM FORMULATION

After the whole introduction picture, the problem formulation means, in a nutshell, that AEC industry companies do not know about the specific European guidelines about BIM application in their early stage projects.

STEP THREE_ OBJECTIVES

GENERAL

Establishing objectives is a fundamental part of the investigation. They have the role as guide of the study. The general objectives have a direct connexion with the problem formulation and they will help to resolve it. With no order by importance, general objectives are the following;

-To get to know the lifecycle project phases where BIM is used
-To boost the understanding of BIM standardisation
-To concern the new virtual procedures about procurement at European level
-To make the most of innovation and competitiveness in the European AEC Industry

SPECIFICS

The specific objectives are linked to the general goals and they reply more precise questions contemplated. All proposed as split goals that they can be resolved in this project and achieved to success. Here there are the following;

-To assess the concept of BIM
-To analyse the principal uses of BIM and its potential value
-To justify the importance of BIM uses in procurement background
-To raise awareness about the most value BIM uses, according to companies surveyed
-To elaborate a practical set of criteria based on BIM uses and steering information
-To suggest impactful recommendations of each criterion for its implementation

STEP FOUR_ HYPOTHESIS

Considered as statements in the project to speculate and ponder about the future results the project can reach. Lastly confirmed as true or false, the hypothesis proposed are presented;

-The analysis of BIM uses is an essential part of an effective implementation
-The use of BIM can be introduced in the employer's information requirements
-The Public Administration procedure is not as effective as expected about BIM implementation
-European Commission does not show United Kingdom as a BIM country reference
-AEC industry is taking BIM implementation as a very low process
-The decision of which level of BIM implementation should be in the hands of the Governments.

STEP FIVE_INVESTIGATION METHODOLOGY OUTLINE

The investigation methodology of the thesis is based on;

- Title
- Theory, analysed in "Theoretical Framework"
- Analytic validation, for the "Aim Analysis" chapter
- Empirical Validation, for "Methodology" focused on the survey
- Discussion of the results, for set of criteria evaluations
- Conclusion, for contributions, limitations and future lines

And it is shown in the figure 1.5.1;

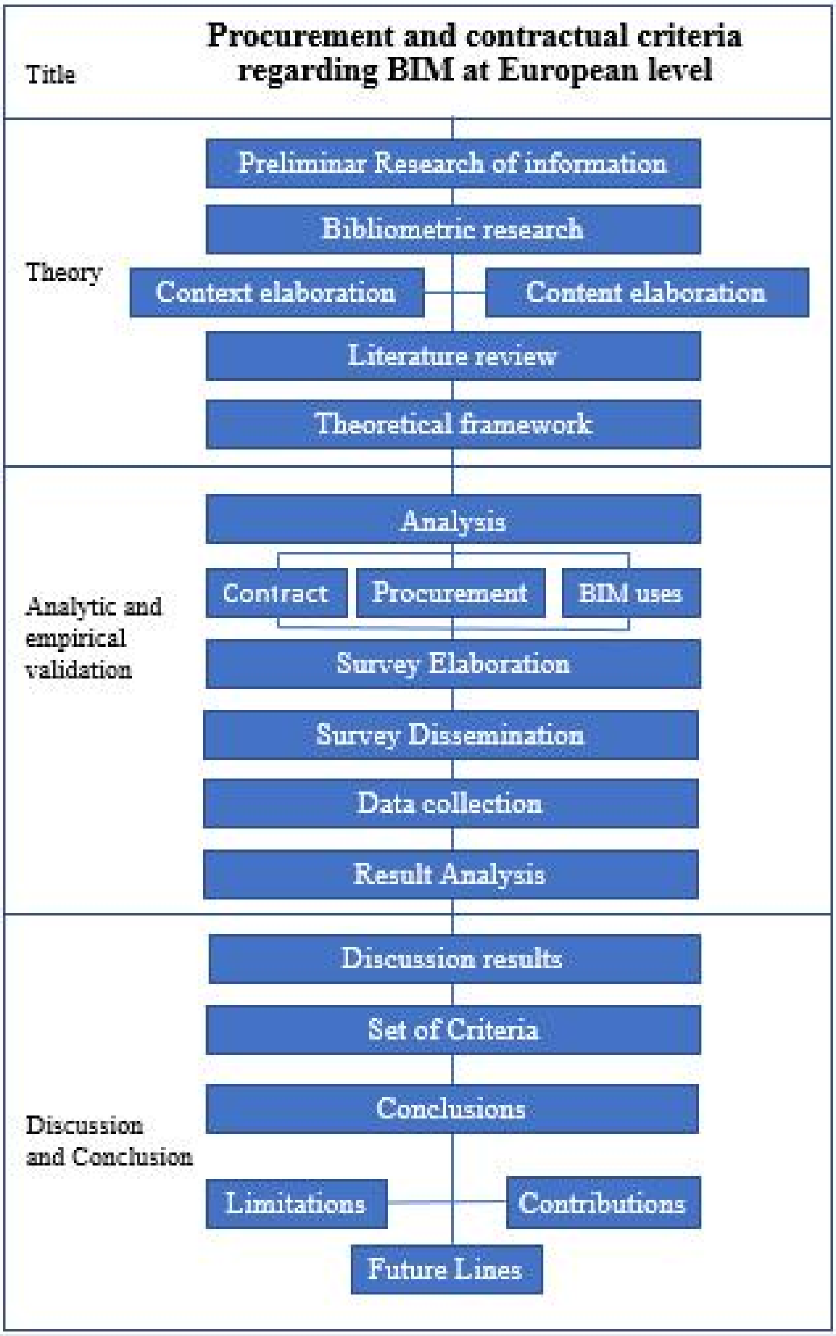

Figure 2) 1.5.1 Investigation methodology outline (Own design)

THEORETICAL FRAMEWORK

The investigation methodology of "Theoretical Framework", where it is previously shown in a literature review through a bibliometric research of information, context explanation and content conception, is displayed in the following figure;

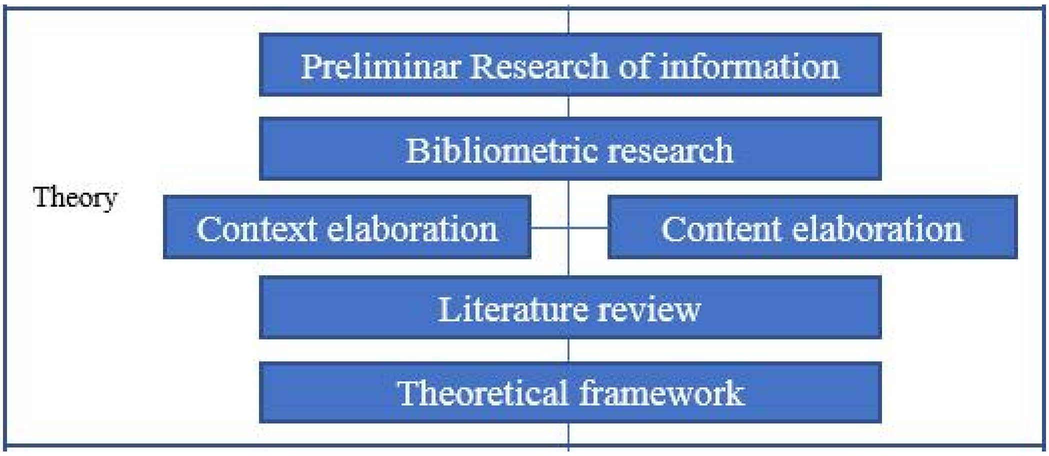

Figure 3) 2.0.1 Theoretical framework diagram (Own design)

STEP ONE_LITERATURE REVIEW

THE PROBLEM FORMULATION

According to some studies about several countries, the volume of requesting for bids is decreasing because of factors like identified and unidentified risks, uncertainty, lack of design information, poor communication among all participants in the lifecycle project (**Česnik, 2016)**. Also, the figure of the contractor does not have enough information for doing their work. They spend a lot of time, money and effort to get the public contract. Their eternal struggle is reaching a project on time and within budget (**Park et al. 2017**). Despite the procurements are being designed to enhance valuable innovations nowadays **(Nyström et al. 2016)**, European Public Administrations cannot allow that their projects do not fulfil with their schedules, deadlines and cost estimations previously fixed in the bidding phase, so there is the start point where the issue starts and it must be analysed. Also, AEC industry has officially more unemployment rate and the lowest industrialization of implementation level since the economic crisis burst. A few of larger organizations in Architecture field were asked about using BIM in bidding for public projects, they confirmed that while the cost still was a barrier to compete or enter, the process and practices changes are more challenging. According to Cooperative Research Centre (CRC) in Australia, there are too many technological barriers for BIM, so it is necessary to change the organization and the business processes. Universal accessibility and cultural change make hard to introduce BIM. Despite virtual sharing data is boosting in the industry **(AEC UK, 2015)**, products like "Dropbox", "OneHub" or "Syncplicity" still cannot beat the fear of copying while sharing the information among all project participants. As stated by Nick Tune, aCo-Builder UK member in BIM community, another of the issues related to BIM is the political struggle that contractors must deal in their own country, so it is preferred that the Construction industry had a common digital foundation in every country that faces with political and legal barriers. The willingness, ability for a project process simulation in design phase and an internal crowdsourcing creates the power to implement BIM technology. It has become a stronger tool for public procurement and for Government policies (**EUBIM Task Group, 2017**), therefore, Building Information Modelling methodology is the keynote for the bibliometric research for the literature review.

LITERATURE RESEARCH

BIM ACTUAL ADOPTION

It is well known that in the beginning BIM was used only by architects to optimise their solutions in visualization. Then, the contractors introduced it for space coordination, prefabrication and cost and schedule integrations, but the main issue in agent participation was focused on the role of the owners, who did not know about the process (**Mehran, 2016**). UK National Building Specification (**NBS RIBA, 2016**) has recently developed, inspired by the Periodic Table of the Elements, the Periodic Table of BIM, for a visual guide of the many key terms about the main concept and all factors related to BIM adoption. Introducing this table to the public sector make the beginning of this knowledge easy to share and develop it for the future by all stakeholders in the industry. The following figure represents the periodic table of BIM (**Addendum nº 6**);

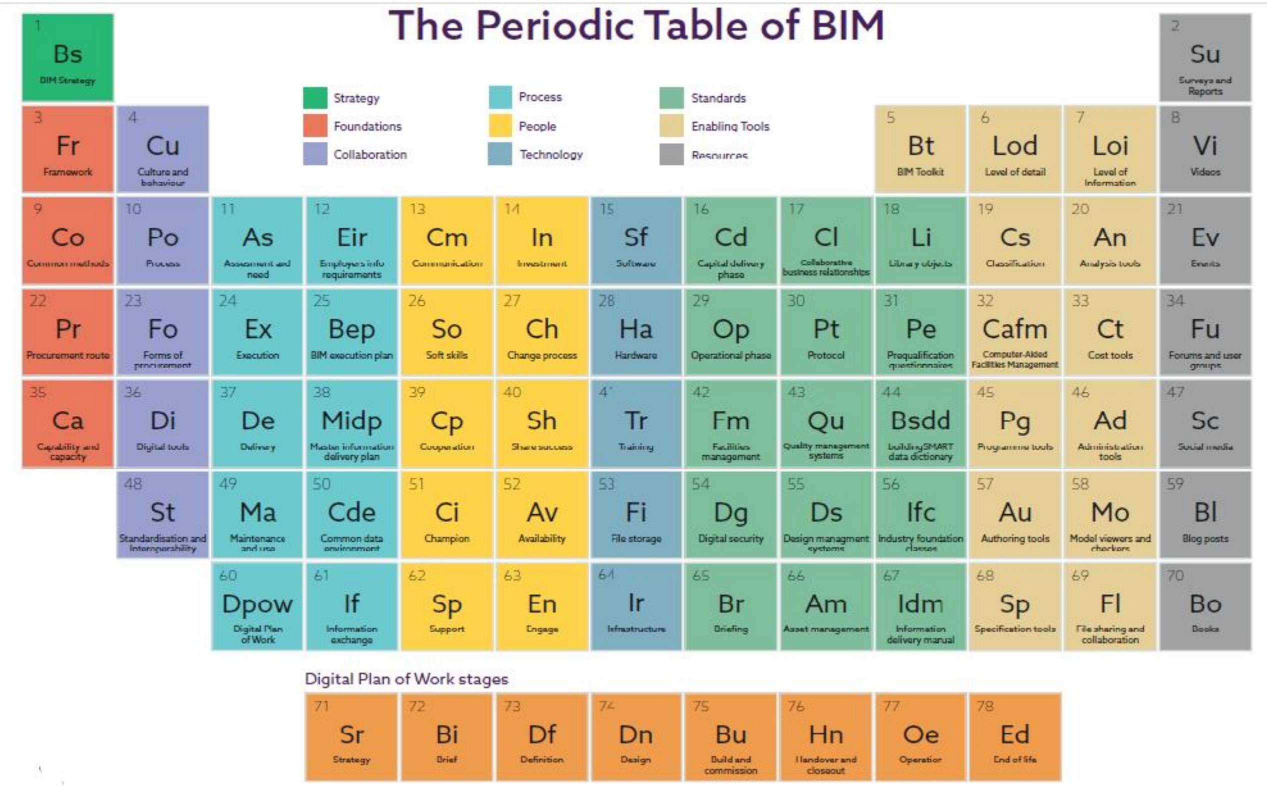

Figure 4) 2.1.1. Periodic table of BIM (NBS RIBA, 2016)

Despite the low-level owners' BIM involvement beginning, it is spreading out and the forecast says about bigger expansion in the future (**Mehran, 2016**). Some surveys comparing the US and UK project owner's participation disclosed the growth from an 11% to a 40% just only in the US, but, in UK owners' awareness grew up, since the Government required BIM in 2016, to an almost 98% of moderated involvement, or 38% of high involvement in 75% of their projects (**McGraw-Hill Construction, 2010**). Also, the Institute of Canada, made a survey to understand the issues of BIM adoption, where they realised that procurement is still organized around functions and projects, not around processes and, surprisingly, BIM still was not recognised in public clients.

Nowadays, many advantages are claimed, like the new emerging roles, collaborative atmosphere, conflict resolution, and so on. However, there is a need of several changes in distributions of roles and responsibilities, but changes take time (**Migilinskas et al. 2013).** Also, there are some disadvantages towards the implementation like the existence of dispersed and less coordinated initiatives, slow implementation, insufficient BIM training or limited knowledge by participants **(Eadie et al. 2013)**. Several studies have shown the development of BIM and BIM-related technologies for managing risks. Tools like matrix of risk, multicriteria decision-making method or computer simulations, determines the importance of risk assessment and monitoring and controlling the risk in the construction project (**Dziadosz & Rejment 2015**). Recently, the possibility of evaluation of a BIM success project has been analysed through Success Level Assessment Model for BIM projects (SLAM) method. It does a measurement of the success of multiple BIM projects using the same set of evaluation criteria as well as a collection of evaluation criteria with minimal additional work needed by project participants. As soon as BIM goals and BIM uses are defined, Key Performance Indicators, provided for the measurement of efficiency, effectiveness and quality **(Eadie et al. 2013),** might be identified and measured and, then, being evaluated and classified, according to the level of maturity. It is also undeniable that risks monitoring process needs a mathematical development because of their likelihood. Some risk measurement methods from other scientific fields have been used recently in the project management field, supported by new mathematical tools to have a risk monitoring and controlling system (**Toth & Sebestyen, 2015).** Another issue to face is the fact that, in its implementation, all documents might not be standards for the industry, especially for contract forms. To facilitate the knowledge management over the disciplines using BIM tools through industry standards, a common data format structure for information (Industry Foundation Classes IFC) transfer might be required sooner or later (**BuildingSMART, 2017**).

In January 2014, the European Parliament introduced a set of reforms to the European Union (EU) Public Procurement Directive to help reduce unpredictable costs and project overruns (**EUBIM Task Group, 2017**). It encourages some EU nations to adopt BIM mandates or policies. With the influence of BIM Special Interest Group (BIM2AIM), the UK ministry of Justice has recently completed its industry BIM practice guidelines in 2016. Current developments such as "Digital BIM toolkit" to collect and validate data from Level 2 BIM (**Ciribini et al. 2015**) and the newly-made guidelines are some of the main reasons why the UK has become a key to be followed by the rest of Europe.

BIM community promoted OpenBIM (initiated by Graphisoft, Tekla and other sponsors) as a universal approach to the collaborative design, realization and operation of the building based on open standards and workflows. OpenBIM is nowadays intended to be an initiative of several leading software vendors using the exchange-data model, through BuildingSMART alliance, Industry Foundation Classes (**BuildingSMART, 2017**). But, what did Europe start doing? In January 2014, the European parliament voted to modernize the contracting and public procurement normative recommending the use of electronic tools like BIM in public biddings. *"Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 public procurement"*. An interesting fact is also that the existing technique called "Value Engineering" has been recently proposed (**Park et al. 2017**) to be introduced in construction projects through BIM. Called as Value Engineering for Idea Bank in BIM projects, it will be able to promote usability, time-saving, quality and creativity with its database system.

INFORMATION ABOUT PROCUREMENT METHODS

Considering the European Commission and accounting for 15-20% of global Gross Domestic Product (GDP), public procurement represents a substantial portion of the EU economy and the economies of many countries around the world. Public procurement under the World Trade Organization's Agreement on Public Procurement has been estimated at around EUR 1.3 trillion nowadays **(European Commission, 2017**). The European Commission promoted the Electronic procurement platform (e-Procurement). Intended to be a useful usage and with the digitalization of the tools in the EU public procurement directive, it offers numerous benefits like transparency, innovation, higher efficiency and less bureaucracy (**Ciribini et al. 2015**). Despite there are some electronic barriers, new guidelines in the directive will be introduced gradually, like "central purchasing bodies should move to full electronic means of communication including electronic bid submission" by April 2017 or "e-submission should be made mandatory for all contracting authorities and all procurement procedures" by October 2018 (**Grilo & Jardim-Goncalves, 2011)**

Over time, new procurement methods started showing up, promoted by several countries; Cost Led Procurement (CPL) Integrated Project Insurance (IPI), Two Stage Open Book, Integrated Project Delivery (IPD) **(Migilinskas et al. 2013)** and Project Alliancing (PA) were some new proposals which are based on integration and interoperability. Introduced thanks to the British Government in 2011, CLP, IPI and Two stage have the same philosophy "we are all in the same boat", or in other words, cooperation and transparency. Besides, it is not easy the act of creating a reliable relationship with some companies that have their backgrounds (**Ciribini et al. 2015).** Green building project delivery might be one of the most significant among the new ones. Teamwork, critical thinking, problem-solving and sustainability are characteristics which make a synergy with the integration of BIM (**Luo & Wu, 2015)**. With soft skills and creative criteria, green BIM project delivery would have this process like it is shown here. The straightforward process of this green innovative project delivery looks like this;

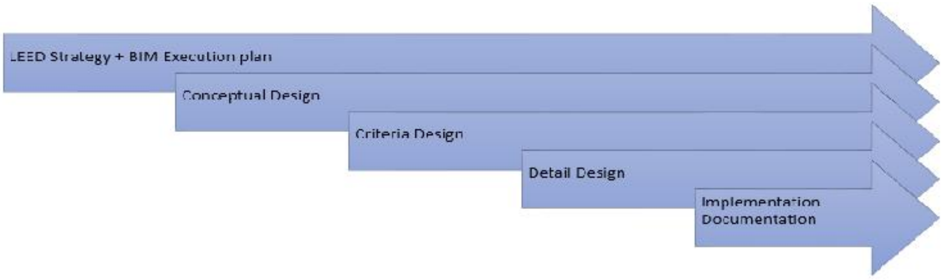

Figure 5) 2.1.2. Green Building Project Delivery (Luo, Y., Wu, W. 2015)

Related to construction contracts, risk management framework is a strategic key within procurement stage. Organizational culture, process structure, application of risk management process and development, and experience in risk management are the four pillars of the maturity factors of risk management. Recently, new computer programs are simulating problem process solving (**Grilo & Jardim-Goncalves, 2011)**. Despite its limited availability, these programs are good because of its knowledge system, which allows decision accuracy and risk identification. With a clear training and the following expert guidelines, companies can evaluate their risk management and its impact in every project they take part in (**Serpell et al. 2015**). Also, innovative techniques in risk allocation among parties, like Public Private Partnership (PPP), where a contractor takes part in the initial investment funding, could manage more accurate evaluations and more specific conditions with incentives **(Nyström et al. 2016).** Despite there are still legal barriers in risk allocation management, ConsensusDoc was created in 2010 as a digital alternative in construction contract documents, where BIM is already introduced as an addendum, allowing the key participants and stakeholders to access to the risk allocation in the project.

CONSIDERING THE FUTURE

In longer terms, public owners are starting to merge BIM data with infrastructure and Geographic Information System (GSI) data to future projects **(Chong et al. 2017)**. For example, Web Map Service (WMS) cadastre is used as a process through BIM integration and GIS databases in LEED (Leadership in Energy and Environmental Design) analysis like energy consumption or lighting (**Chen & Nguyen, 2016)**. The introduction of knowledge and effective solutions in AEC and Facility Management industry would derive in aspects such as the development of BIM integrated with Geographic Information System, not as a building scale only, but a city scale in the future (**Correa, 2015**). These systems would enable public owners to manage built assets in a safe and efficient manner. Although there are several barriers like managing the huge amount of data, cybersecurity and data exchange standards among different systems **(AEC UK, 2015)**.

Based on requests from its client owners, USACE (US Army Corps of Engineers) is undertaking an initiative to join geospatial information with its BIM data and civil information modelling (CIM) data, which comprises infrastructure information such as parking lots, location of street lights, utility conduits and water supply mains, among others. Another example is Geographic Markup Language (GML) introduced by Open Geospatial Consortium (OGC) (**Niu et al. 2015**). OGC, as an international non-profit organization, designs new open standards for improving geospatial data. Another current proposal, called "UK's Digital Built Britain" initiative, formed in 2013 as an outgrowth of their government construction strategy, is working together with the BIM Task Group to deliver what they define as "Digital built Britain Level 3 strategy", focused on BIM capability, comprising building, infrastructure and geospatial information. During this research, companies' innovations have shown up to improve a project lifecycle, such as SlimBIM™ virtual interactive model **(Virtual Viewing, 2016**), considered BIM Initiative of the Year in 2015, or noteworthy platforms, like "Women In BIM", (**Butcher, 2016**) to support a global community and create new opportunities for diversity in the industry

European BIM Summit

In this event, sponsored by BuildingSMART association, it is easy to find new experiences and debates about BIM where all participants can analyse new tools, services and innovative products. Also, new contents, connexions and networking are the basis of the BIM Summit. In the third edition in Barcelona (May 2017) the innovative country was France because of its investment in national digitalization in the economy. France presented the "MINnD" project, an interoperable information model for management of the French infrastructures, and "EDUBIM", an integration project about BIM where all participants take part in the building lifecycle. France suggests "Industrie du Futur" which requires the country to its development in the Construction industry and it visualises the pillars of technologic offer development, its performance, participant training, international cooperation under the standards and normative, and the future French promotion in the AEC industry. Last year, United Kingdom was the invited country for being declared as a "BIM country" and for accomplishing the requirements for Level 2 of BIM maturity in the same year **(Martinez, 2015)**.

RICS BIM Conference 2017

RICS (Royal Institution of Chartered Surveyors) is considered as the world's leading professional body for qualifications and standards in land, property, infrastructure and construction field. In August 2015, RICS had made a BIM guidance for Cost Managers, which includes the BIM environment working conditions, background information, internal procedures and BIM measurements. In 2016, RICS made a guidance about BIM for Building Surveyors. The next RICS BIM conference was towards the BIM adoption in Association of Southeast Asian Nations (ASEAN) and it was in Kuala Lumpur, Malaysia, in June 2017. The main topic was the set of challenges facing the early adopters in Asia's emerging economies and the best guidance on embedding BIM. Other topics include the role of RICS in the standardisation of BIM practices worldwide, approaches of data from multiple sources in collaborative working environments and approaches to establish a BIM team in the organizations.

Considering the European Public Administrations issues about their cost and schedule changes, the role of the European Commission in the establishment of new policies about public procurement is one of the most important contributions. All countries must consider, apart from their own rules and national legislations, the European Law for a transparent, fair and competitive public procurement across the European Market **(European Commission, 2017)**. The plus contribution of BIM implementation in bidding projects is a challenge for a traditional procurement sector, but, according to this literature research, BIM adoption is growing up in an exponential way. The surveys made in US and UK are the good and reliable example of this growth in owner's mentalities. The accuracy of the results determines the fast involvement and acceptance in countries where all can consider as references for the change to good.

According to ITeC, reference institution in the building sector, sponsor and board member of Building Smart Association, Nordic and English-speaking countries took the advantage with their legislation. From 2016, a gradual implementation started. But, BIM implementation strategies have different speeds in every country and it is demonstrated. At European level, Directive 2014/24/UE about public contacting establishes the use of electronic systems (like BIM platform) in the contracting processes of construction works, services and supplies, from September 2018. In the article nº 22, is related to the building information electronic modelling tools. It describes the possibility of the European memberships might demand the use of the specific tools for the electronic modelling of construction data in the contracting processes of construction works, services and supplies **(Česnik, 2016).** There is no doubt about the assortment of BIM tools and related technologies for the last 5 years, and even the possibility of evaluating a success of a project involved in BIM, like the SLAM method (Simultaneous Localisation and Mapping), does not only points out that elevated level of development, but it shows that there will still innovation in the future. The importance of establishing standards in the industry makes BIM members or sponsorships to take part into it, providing novel approaches or initiatives like OpenBIM, thanks to BuildingSMART alliances. BIM community and related-alliances have a lot to say and offer. Conferences, seminars, journals articles about this topic that have been found to explain this literature and to be evaluated to achieve the objectives of the thesis.

One of the biggest goals for the AEC industry is not only the creation of international initiatives, to promote public projects in the sector with the collaboration of the Governments, but also accomplish this initiative and their own interests. New bilateral relationships of business, increasing awareness in the Administration in the European countries, the progress and growth will be guaranteed. The creation of simultaneity and homogenization of the BIM implementation guidelines starts with the establishment of a set of criteria of BIM uses due its environment conditions and requirements. This set would contribute to unify the basic principles of BIM uses (**NATSPEC, 2011-2016**), so it unifies the guideline implementation in all EU countries.

The reality of BIM will originate newer contracts with it than with the traditional methodologies in public tendering. Thus, those contracts will have to include BIM requirements or procedures from their uses, that is why the importance of the criteria as basic material for the guidelines. Through the AEC industry, the existence and availability of a set of BIM competencies would assist organizations and project partners to identify criteria through competencies within procurement and tender/bid documentation. It would measure the competencies of the individuals, teams and organizations **(Chong et al. 2017)**. Also, it would clearly define the project requirement through standardised competencies. The project workflow would be smoothed, so the professional training of BIM will be developed in a brief period. With this target, there will turn up new business models and the guarantee of innovation. The internationalization of the ideas reflected in the guidelines would mean a labour culture exchange and the connection of outcomes and new alternatives or approaches.

STEP TWO_BIM CONCEPT

DEFINITION

Well-known as a complex phenomenon, Building Information Modelling is considered as a philosophy, type of software, work methodology or a process of many in the industry. In this study, BIM can be defined as a "digital representation of a building, an object-oriented three-dimensional model, or a tool of project information to enable interoperability and information exchange with related software applications" (**Miettinen & Paavola 2014).** The combination of CAD system, intelligence and interoperability, makes an effective formula (**Migilinskas et al. 2013)**.

According to the US National Building Information Model Standard Project Committee, BIM is considered as the perfect digital representation of the physical and functional qualities of a building or facility. It's the key for sharing information during building's lifecycle. BIM can be simply classified into its dimension scope in eight levels **(Smith, 2014)**;

-**1D** Idea. Considering Market studies, previous planning and the idea conception.
-**2D** Vector. The basic project where the process is about design and calculus.
-**3D** Modelling. For width, height and depth.
-**4D** Planning. 3D expanded with time planning.
-**5D** Cost control. 4D with feasibility estimation.
-**6D** Sustainability. 5D with energy analysis and resources management.
-**7D** Facility Management application. 6D with project's lifecycle management.
-**8D** Safety. 7D with accident prevention

In the concept consideration, some factors come into play like disciplines (Architecture, Structural Engineering, etc.) or attributes, which represent the physical structural elements to manage, change or control in the software **(Eadie et al. 2013)**. Well-thought-out as a fully integrated procedure in firms, BIM makes easy to understand the projects through parametric objects, also their visualisation feature helps all users in a perceptual and cognitive way to face issues automatically, as a problem solving (**Park et al. 2017**).

Software vendors also take part in the BIM environment about what is BIM solution for them; collaboration basis, change administration through database and preservation in other applications. BIM is considered both technology and systematic method and process that is changing the project delivery, designing and organizational management of construction, so its collaboration and communication environment could make the risk identification easy to mitigate in an early stage (**Onyango, 2016).**

ENVIRONMENT BIM

BIM four key elements are not others than collaboration, representation, process and lifecycle, interacting to create the efficient environment (**Bradley et al. 2016).** The following figure is the graphic example how BIM environment looks with the four elements;

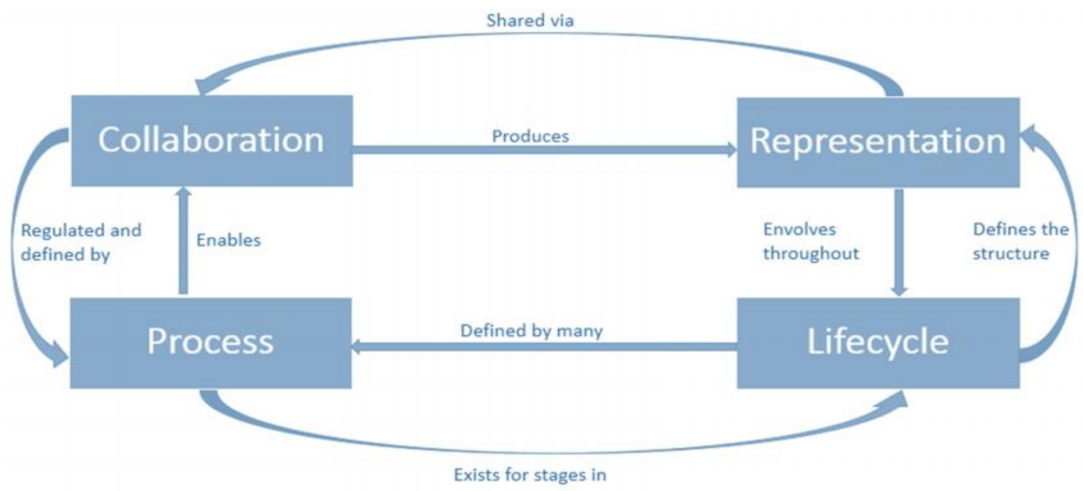

Figure 6) 2.2.1 Four Key elements in BIM Environment (Bradley et al. 2016)

According to other authors (**Miettinen & Paavola 2014**), the four key elements, in a utopic scenario, are;

1-Models of BIM data used with other software and tools.

The data interoperability is allowed by Information and Communication Technology and standards. -The challenges to accomplish are interoperability and a system integration.

2-Collaboration

New arrangements like Project Partnering, Project Alliancing, Integrated Project Delivery **(Martinez, 2015).** The challenge is a fast integration of the discipline. Barriers to consider are the organizational and legal issues **(Eadie et al. 2013).** As a goal, multi-party contracts on sharing risk and reward (risk allocation)

3-Lifecycle

Barriers to consider are limitations in BIM stage implementation (last operational phase) or lack of knowledge among participants.

4-Productivity

As a goal, BIM guidelines and textbook rules and standards should be considered **(Chong et al. 2017)**.

BIMTaskGroup summarised that BIM has four levels of maturity. The maturity levels are meant to be the degrees of BIM capacity in the adoption and delivery (**Mehran, 2016**). Although most of the companies that use BIM are mainly in the level 2, some companies have started with level 3 (**Alreshidi et al. 2017**). Other authors have also thought the classification of the maturity levels lie it is shown next;

Level 0	Level 1	Level 2	Level 3
CAD (not BIM)	**2D/3D BIM**	**3D BIM**	**iBIM**
Drawing lines, texts. 95% produces 2D drawings lacking coordination, increasing costs by 25% (waste and rework)	Models, objects, collaboration, 2D/3D spatial. Potential to remove waste by 50%	Coordination error and reduce	Integrated, interoperable data. Potential to mitigate risk and increase profit through a collaborative process

Table 1) 2.2.1 Levels of BIM (Barnes, Davies 2014)

As a figure, the maturity levels of BIM are presented below;

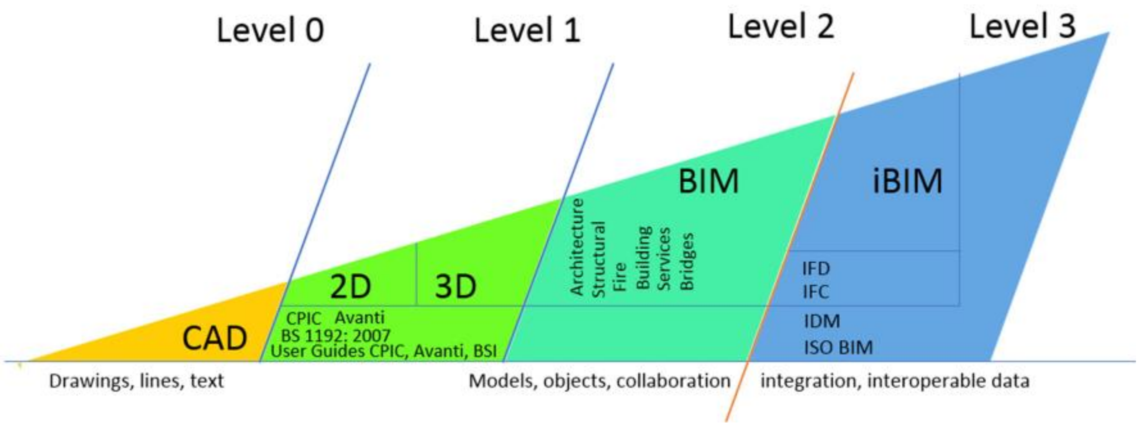

Figure 7) 2.2.2 BIM levels of Maturity. (Bew-Richards 2008-2016)

The main aspect for the effectiveness in a fully integrated and collaborative BIM environment is, without doubt, its standardisation (**Onyango, 2016)**. Through BIM-related standards, all challenges that face BIM are leaded.

STEP THREE_CURRENT SITUATION IN EUROPE

EUROPE PARTICIPATION

Written in the literature review, the number of countries that start implementing BIM is increasing over the years. Either with standardisation or the need of being adopted in the big Market. Private companies and public organizations are getting more competitive at an international level (**Directive 2014/24/EU)**. The rapidly increasing of BIM implementation in Europe is due to the private and Government owners' interests of having faster adaptation and benefits, and it is proven that contractors have received not only their benefits, but also have learned about getting the most of BIM, being able to improve their project delivery system **(McGraw-Hill Construction, 2014)**. The great powers, wealthy countries are the strong global actors that lead the main decisions about the progress of their countries. That is happening on every topic that is involved, and infrastructure's main public projects that countries invest millions with public money is one of those topics (**Mehran, 2016**). The positive impact that BIM has done into the Industry have made to consider that a country could change its economic perception in order to start over with BIM methodology **(Martinez, 2015)**. Its value has grown up exponentially, so the European countries' interests do. The repercussion of BIM in the European market is evident. One of the characteristics that show a country is taking a good advantage and make the most to implement BIM is in the level of maturity their public projects, or private ones in the AEC national industry have (**Onyango, 2016**). For example, countries like France, Spain and Italy are all starting with level 2 of BIM, but it does not mean those ones might be considered as references. The implementation has lots of factors to cover, not only the maturity, but the environment, studied in the last chapter, is one of the main keys to consider that a country is doing well. A research has been done **(McGraw-Hill Construction, 2014)** for having an understanding about period, implementation, expertise and engagement rank between European countries and all regions, and the results give these graphic figures;

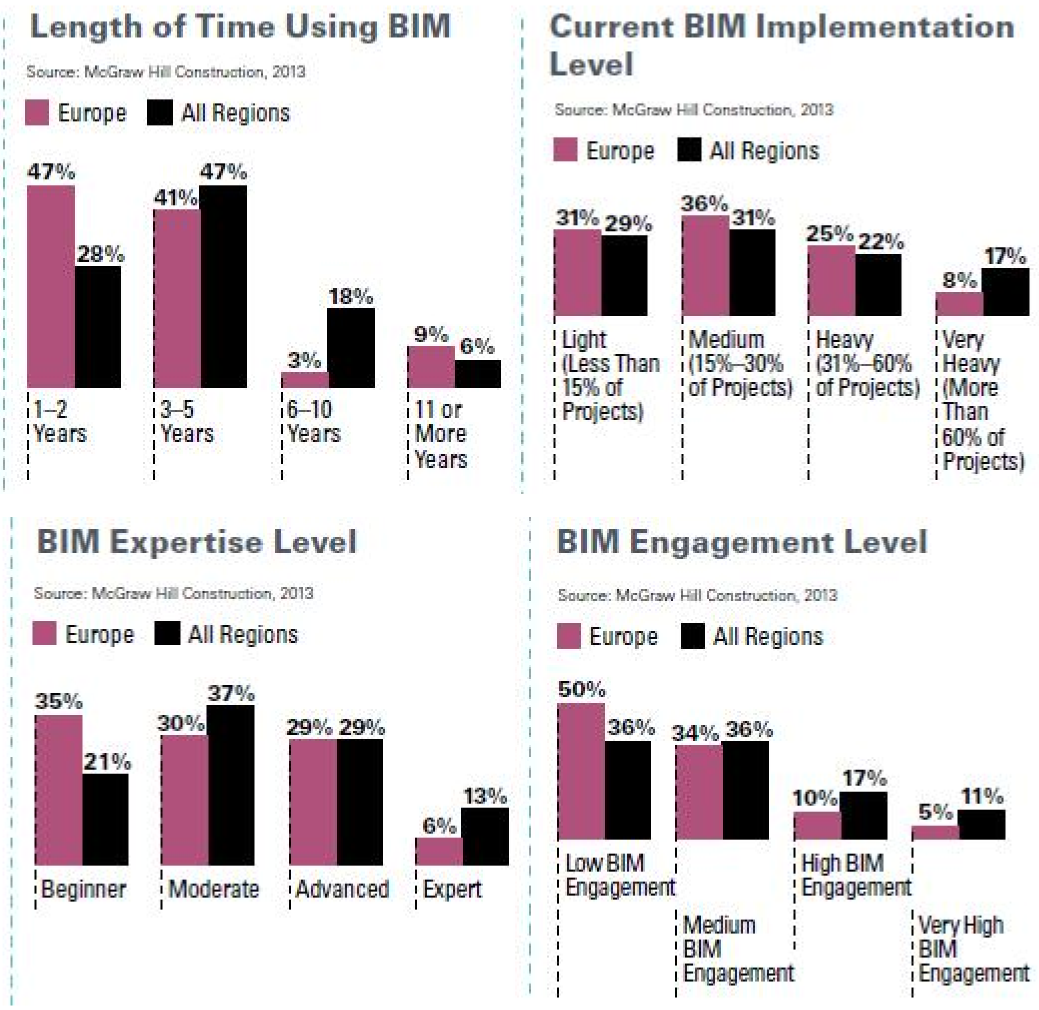

Figure 8) 2.3.1. BIM for construction data (McGraw-Hill Construction, 2014)

In the words of all participants as representatives for the report of McGraw-Hill, the assembled data is illustrated in each graphic; the significative length of time is in the first two years, implementation between light and medium level in the project execution, beginners in the level of expertise and a low BIM engagement. So, the data can be interpreted as Europe is participating as BIM beginner contractors, so all regions do. It is a fact that the United Kingdom and the United States are two of the main worldwide references, both have got their own BIM guide, second based on the first one, and even their own paramount standards. With the help of the expert organization, groups of interests and national firms, have developed BIM execution plan and exchange information as contract addendum in the agreements (**CICRP, 2010)**. Based on UK's BIM guidance and US's participation in contract addendums propositions, Australia is another country that, thanks to non-profit organizations like NATSPEC which promotes BIM in the industry, also have their own protocols, standards and documentations (**NATSPEC, 2011-2016**)

UK. THE REFERENCE

The United Kingdom has proven that it is the country more involved in Building Information Modelling **(Eadie et al. 2013)**. After years of introducing the methodology, in 2011 the British Government obliged that all projects must be carried out with BIM. UK Government created its Strategic Plan, which represents the recommendations for BIM, based on the standards by level 2 of maturity (**EUBIM Task Group, 2017**). In 2016, the UK Government would establish that BIM had to be mandatory on all public contracts. The interest in the sector raised since the strategy (**Miettinen & Pavoola, 2014**).

Nowadays, if a company in the UK want to hire a government project, it must be level 2 maturity, for its compatibility (**Hore, 2017**). When the UK started with its strategy, first created BIM Task group as a Government initiative, whose main goal is a fully collaborative framework between government clients and supply-chain contractors, in order to change the practices into BIM and with an electronic delivery system **(McGraw-Hill Construction, 2014).** Through the Initiative, COBie was created as a structured data-exchange format (Construction Operations Building Exchange) by USACE, helping to capture and record important project data since the primary point. At the same time, The Ministry of Justice promoted then the "BIM Mandate" to, at least initially, make the Government to improve the productivity and efficiency in the industry (**Mehran, 2016**). In this full adaptation of BIM, where many organizations, private and public ones, including the UK Government, the BSI (British Standards Institute) made their contribution creating a sharing standard (PAS 1192:2) for building information as key points between client and supply chain. Developing PAS 1192:3 standard for facility and asset management makes clear that BIM Task Group is expanding and developing innovation, and still there is a long and promising way to go. The cultural alliance for collaboration plays an interesting role, but also, getting to become a BIM proficient power means a lot for a country (**EUBIM Task Group, 2017**). Focused on the lifecycle of the project, standards, and a lean and facility management process, BIM Mandate is a wider adoption for neighbouring countries' transition to BIM approach.

STEP FOUR_BIM INFLUENCE

CHARACTERISTICS

The features of BIM can be studied with SWOT analysis. **(Isikdag & Zlatanova, 2009).** SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) is intended to be a practical tool for somebody who wants to know about a project, organization or even a methodology like BIM, specifically its inner and external characteristics. SWOT analysis with BIM methodology already connects in a holistic approach both the internal and external environment (**Bell & Rochford, 2016**). Hence, through BIM environment, SWOT analysis is the perfect reflection for the study of their characteristics within its effect. The following figure is a simple representation of the analysis;

Figure 9) 2.4.1. SWOT Classification (Bell, Rochford 2016)

The composed matrix results in this analysis; Strengths as an inner characteristic with a helpful upshot, Weaknesses as an inner feature with a possible harmful effect. Opportunities as an external highlight with a helpful achievement, Threats as an external aspect with a harmful outcome. In the case of BIM implementation, the characteristics are classified in this tables;

Figure 10) 2.4.2. BIM SWOT classification (Isikdag & Zlatanova, 2009)

According to CMAA (Construction Management Association of America), in their eighth Annual Survey of Owners in U.S. report (**Farr & Piroozfar, 2014**) possible BIM benefits are also;

• Enhanced communication and collaboration
• Process standardisation achievement
• Reliability in specification and regulations
• Productivity in assets
• Better perspective and innovative strategy
• Fewer labour costs

But also, CMAA Foundation recognises that there are hurdles like;

• Complex system
• Lack of industry standards
• Poor integration
• Diverse needs and interests of stakeholders
• Unclear business value and ROI [return on investment] in the implementation.
• Absence of trust.

An inquiry to expert was done to find out the most significant barriers that BIM might have, in a technical and non-technical approach, like it is shown here;

Technical	Non-Technical			
	Social-Organizational	Financial	Contractual	Legal
BIM Maturity issues	Resistance to change	BIM cost of adoption	More benefits from confusions	Intellectual property and copyright
Interoperability issues	Lack of trust in new technologies	BIM cost of training	No maturity in fully BIM contracts	Wrong or incomplete data liability
BIM model issues	Absence of BIM understanding	Limited budget	Absence of BIM related aspects	Absence of considerations in BIM contracts
Huge data inputs/outputs	Different users' skills	Human services cost	Legal concerns in BIM	No legal framework for adoption BIM
Limited data storage	Lack of BIM training		Adaptation process into BIM contracts	
Limited accessibility (rights issues)	No motivation			
Lack of data sharing tools	Dealing with clients' awareness			
Absence of data tracking, checking and versioning control tools	Traditional standards and practices still used			
Coordination with BIM large models issues	Avoiding potential risks and mistakes			
Lack of notification tools				

Table 2) 2.4.1. Technical and non-technical BIM barriers. (Alreshidi et al. 2017) (Eadie et al. 2013)

Same authors confirm the most significant benefits of BIM in the next table;

ICT	Socio-organisational	Expertise	BIM process	Financial and Legal
Effective communication	Client Motivation	Experience	Clear implementation	Financial resources covering
Collaboration coordination practice	Client early involvement	BIM tools skills	Clear collaboration plan	Business motivation
Collaboration coordination tools	Educate expertise	Interpersonal relationship	Sharing data method	Business opportunities creation
Reliability in BIM technologies	Technical training provided	Criticism acceptance	Check points setting	Overall legal framework
Sharing data effective methods	Collaboration and commitment	Collaboration willingness	Replacement to integrated delivery method	Roles and responsibility allocation
Common data environment	Leadership with shared goals	Sharing information trust		Clear Data ownership
Track information	Roles and responsibilities allocation	Relationship with client		
		Problem solving		

Table 3) 2.4.2 BIM benefits. (Alreshidi et al. 2017) (Migilinskas et al. 2013)

KNOWLEDGE AND EXPERIENCE IN COMPANIES

Nowadays, more companies embrace increasingly the implementation of BIM through software like ArchiCad, Revit or eQUEST (**Chong et al. 2017)**. But not all the knowledge a company can get from BIM is within software usage. From the main four elements considered in the first step of this chapter (collaboration, representation, process and lifecycle), a company enhance its knowledge and level of implementation, connected directly with the level of maturity required (**Mehran, 2016**). It is also good to know about how many software in the market vendors are using for several types of BIM utilities, here they are the main examples;

Type of BIM usage	Software
Design Authoring	Revit Architecture, Bentley BIM, ArchiCAD, Tekla, Vectorworks
MEPF (Mechanical Electrical Plumbing Fire) Authoring	ArchiCAD MEP, Revit MEP, AutoCAD MEP, Bentley BIM, AutoSprink
Civil Authoring	Bentley Inroads and Geopak, Autodesk Civil 3D
Clash detection	NavisWorks Manage, Bentley Navigator, EPM Model Server
4D Scheduling	Synchro, Vico, NavisWorks Simulate, Primavera, MS Project
5D Cost Estimating	Innovaya, Vico, Tokmo
Specifications	Speclink-e, E-Specs
Model Checking Validation	Solibri
COBIe	Tokmo COBIe exchange
Energy Analysis	EcoDesigner, Ecotect, Green Building Studio, EnergyPlus, DOE2

Table 4) 2.4.3. Software for BIM usages (Neary et al. 2010)

Aspects that a company should know about BIM framework are involved into three factors (**Alreshidi et al. 2017**);

1º *People*. People's main challenges are the understanding of BIM and its maturity, participants' behaviour, trust in the team and following collaboration issues that might show up in the process. People as actors are related to the team, people who are involved in the projects.

2º *Process*. These challenges are the absence of commonly agreed objectives about the use of BIM, not having a clear procedure about the use, information delivery issues, variety skills in the team and some sharing issues in the process. Processes are related to contracts because the workflow is supported in this way by the legal frameworks (**Directive 2014/24/EU)**.

3º *Data*. Including challenges like data ownership, possible copyrights, Intellectual Property (IP), interoperability, amount of big data, inconsistency data, compatibility data, transportation, storage and loss of data. Data management are connected to ICT (Information Communication Technology) technologies **(AEC UK, 2015)**.

Despite the implementation, companies confess that they are working on their own strategies and models, in order to not to share their information with others. Factors like competition, copyright, data loss or other worries that companies are aware of, make them take the decision of designing their own methods and team collaboration **(Migilinskas et al. 2013)**. In the AEC industry, Big Data can contribute with knowledge innovations in the field of BIM. Despite BIM cannot take advantage of Big Data (because of the data volume, type of velocity or acquisition of data), it can take part in development tools, automation of tasks and transformation of BIM processes (**Correa, 2015**).

STANDARDISATION FRAMEWORK

First, it is useful to know that a standardisation is strategic to optimize the sources and to get a common basis for, in this case, project management. AEC industry has to get and arrange open standards that guarantee the compatibility of the different resources and tools that the market and virtual e-market have nowadays **(Grilo & Jardim-Goncalves, 2011).** BIM is meant to be an important complement in the building contract and consultants' and other designer's appointments (**Barnes & Davies, 2014),** based on the current standardisation. Despite some weak points like strict standardisation or too much variation to adapt, standardisation plays a decisive role in BIM implementation since the beginning. (**EUBIM Task Group, 2017**). The main goals of BIM standardisation are the orientation of companies and professionals of the AEC sector by the Governments and public authorities as the main support (**Miettinen & Pavoola, 2014**) and, also, the networking that might be turned up after the application of the rules.

BIM STANDARDS

BIM Standards can be defined as established features for data exchanges in a BIM project **(Martinez, 2015)**. Standardisation related to BIM is directly connected with building contract formats. Nowadays the standardisation classification is in the four-maturity levels, (**Onyango, 2016)** like it was shown before, but now the standardisation information is included;

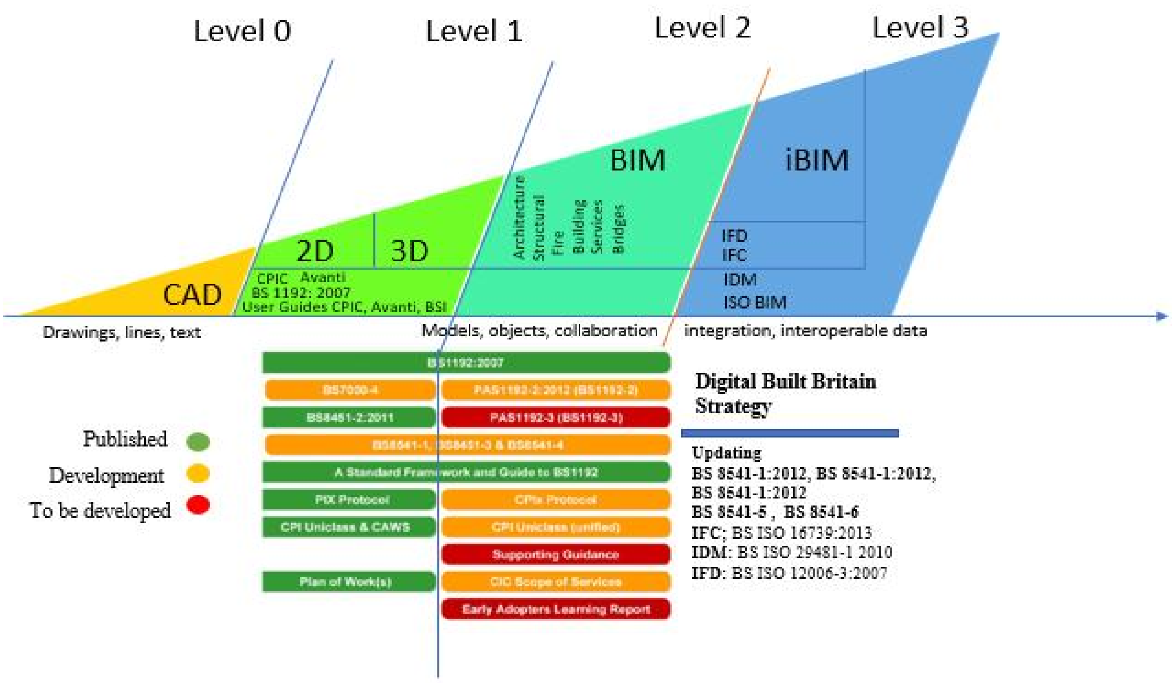

Figure 11) 2.4.3. BIM Standardisation in Maturity levels. (Bew-Richards, 2008-2016)

The first and most complete BIM standard, focused on a model format, is the Industry Foundation Classes, where it means about all the data for product and process modelling that can be shared and exchanged during the project's lifecycle (**Grilo & Jardim-Goncalves, 2011)**. IFC is an open data model format which defines component's geometry and other physical properties to allow the transfer of data between applications. IFC is managed by BuildingSMART (International Alliance for interoperability) and documented in ISO (International Organization for Standardization) (**Bradley, 2016) (Česnik, 2016)**. IFC describes the taxonomy which objects can be defined through attributes and objects' relationships can be set out. Although, it is well-known that all each software vendor has their own BIM model format (**Correa, 2015**). Every BIM project must have its own protocol, computer-aided design (CAD) standards for use by other consultants or construction modellers. Spain, as a valuable member in standardisation, has UNE as the Certification and Standardisation Spanish Association, where AENOR is a key participant, also a key member in BuildingSMART**.** In 2011, "AEN/CTN 41/SC 13" Organization of information models in building and civil works" was created focused on BIM, specifically for an introduction to AEC professionals who are not still using BIM.

Every country has their own authority that can participate in the European or international committee in the creation of a new standard. Now, the international BIM standardisation is reflected in the "Committee ISO/TC 59/SC 13, Building and Civil Works. Organization of information about construction works". This regulation has the main goal for the BIM standardisation for information and data sharing and exchange during its project's lifecycle. ISO/TC 59/SC 13 regulation collect a set of standards. Those are responsibility of the regulation **(AENOR, 2016)**;

- ISO/TS 12911:2012 Framework for building information modelling (BIM) guidance.
- ISO 16757-1:2015 Data structures for electronic product catalogues for building services. Part 1: Concepts, architecture and model
- ISO 12006-2:2015 Building Construction. Organization of information about construction works. Part 2: Framework for classification
- ISO 12006-3:2007 Building construction. Organization of information about construction works. Part 3: Framework for object-oriented information
- ISO 16354:2013 Guidelines for knowledge libraries and object libraries
- ISO 22263:2008 Organization of information about construction works. Framework for management of project information
- ISO 29481-1:2016 Building information models. Information delivery manual. Part 1: Methodology and format
- ISO 29481-2:2012 Building information models. Information delivery manual. Part 2: Interaction framework
- ISO/NP 16739-1 Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries. Part 1: Data schema using EXPRESS schema definitions.
- ISO/NP 16739-2 Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries. Part 2: Data schema using XML schema definitions.

At European level, the European Technical Committee has developed, with ISO, CEN/TC 442. (**AENOR, 2016**). With this standard, all BIM processes can be coordinated. It would be a good opportunity to deal with strategic partners or future ones. The objectives of this standard are;

1 Adoption of the main international standards (ISO) as European standards (CEN)
2 Collaboration with ISO for the development of new standards
3 Consideration of related European standards
4 Introduction of sustainability and environmental aspects
5 Development of European technical reports (e.g. terminology, methodology, etc.)
6 Exchange of IFC standards and information
7 New documentation related to data dictionary or definition methods.

The structure of CEN/TC 442 is composed by;

WG 1; Strategy and planning
WG 2; Exchange information
WG 3; Information Delivery Specifications
WG 4; Support data dictionaries
WG 5; Chairperson's advisory group

STANDARDISATION IN EUROPEAN COUNTRIES

The strategic partners of the European Technical Committee are the United Kingdom, Scandinavian Countries, Germany, Austria and France, so, they can be considered as the biggest references of BIM countries (**Mehran, 2016**). As a BIM country reference, UK's standards form a set of important level processes for the collection, specification and transfer of information throughout the lifecycle of built assets. The earliest standard assigns shared information with specific states which help share information sooner, but still allows, for the information, to change before it is fixed as a binding issued design. The most significant standard is PAS1192-2: 2013, Specification for information management during capital/delivery phase of construction projects using Building Information Modelling (**Hore, 2017**). This standard specifies requirements for achieving BIM in Level 2.

According to United Kingdom (**AENOR, 2016**), it is compulsory to present the project in BIM format to have a public contract since 2016. The main objectives of this strategy are simple and accurate; costs and carbon footprint reduction **(Chong et al. 2017)**. The sustainability is nowadays a principal issue in the UK. Some European countries have shown standards, like Finland and Norway, where both common requirements take the approach of an extensive set of BIM requirements (structural model, as-built or quantity take-off requirements) (**Bradley, 2016**). Also, provides information about how the model will be analysed and the best practices by the supplier. Procedural frameworks provide a methodology for the tailoring of a BIM solution to a specific project. Another example in Netherlands, provides a framework of specific subjects without specifying a formal BIM process (but producing BIM execution plan). In France, BIM is obligatory in building works since 2017. Also, in Germany, the private sector promoted a BIM plan with the help of the German Government in 2015. Scandinavian countries have motivated the usage of BIM in the obligatory use in some case studies (**AENOR, 2016**). The following table demonstrates the principal European mandates focused on BIM;

Country	Mandate	BIM data required	Building Sizes requiring BIM	Submittal File formats	Reasons for establishing Policy	Supporting Materials	Date of current mandate/s	Future Plans
***Denmark**. Building property agency under Ministry of Climate, Energy and Building*	Executive Order No 118	Project lifecycle (architecture through O&M)	5M kroner and higher for national projects – 20M kroner and higher for regional and municipal projects	IFC, NATIVE	-Reduce energy consumption in buildings -Improve productivity • Shorten project delivery timeframe • Improve coordination and communication among team members		2007/2013	
***Finland:** Senate Properties*	Common BIM Requirement 2012	Project lifecycle (architecture through O&M)	All national public projects	IFC, NATIVE	• Support making design and construction lifecycle process safe • Support making design and construction lifecycle process compliant with sustainable development • Utilize models for facility management	Guidelines (updated in 2012)	2007/2012	
***Norway:** Statsbygg*	Statsbygg BIM Manual 1.2.1	Architecture and Handover data	All national public projects	IFC, NATIVE	• Reduce errors and omissions • Improve communications and coordination • Gain efficiencies • Increase energy efficiency • Use cutting edge research, technologies and processes to improve the built environment	BIM Manual 1.2.1	2005 / 2013	Additional BIM data requirements expected by 2016
***United Kingdom:** The Cabinet Office of Government Construction Board*	Government Construction Strategy	Project lifecycle (architecture through O&M, defined in the U.K. as Level 2)	All national public projects	COBie, Native, PDF	• Reduce construction costs • Reduce project delivery time • Make UK's design and construction industry more competitive globally • Help UK meet carbon reduction targets for buildings	BIM Task Group provides support for both the UK government and supply chain	2011	BIM requirements will apply in 2016.

Table 5) 2.4.4. Current BIM mandates in Europe (Bradley, 2016) (Chong et al, 2017)

Definitions of file formats
IFC (Industry Foundation Classes): open standard for exchanging BIM data between different proprietary software applications
COBie (Construction Operations Building Information Exchange): open standard for the capture and delivery of information needed for facility management (FM)
Native: proprietary software standard from the authoring tool of a BIM model
PDF (portable document format): typically extracted automatically from a 3D model authored in BIM software
DWF (design web format): proprietary to Autodesk, used to transmit 3D model information in compressed form to reduce file size

But, why promoting BIM in the countries where have less or zero implementation? There are some reasons why. The adaptation of new international trends will mean more competitivity and market dynamization (**Mehran, 2016**). Also, there will be a quality raised in the projects, so it also will denote openness and transparency of the information, specifically in the procurement phase **(Grilo & Jardim-Goncalves, 2011).** This reason proves cost reduction in the execution of projects and more equity in the investment of public projects (**Directive 2014/24/EU)**, one of the motivations for this project. The European Commission recently promoted the European BIM TASK GROUP for the development of political directives within Europe **(Česnik, 2016).** Participants are mainly Public Administration representatives; public bidders, infrastructure agents or managers and, also, Real State assets managers or consultants. All of them from the fourteen Member States. Their motto is the union of the different national efforts under a European common approach **(EUBIM TASK GROUP, 2017)**.

AIM ANALYSIS

The investigation methodology of "Aim Analysis" as "Analytic validation" is composed by the bottomless examination of contracting methodology (linked to risk concept), procurement setting and BIM usages. It is displayed in the next figure;

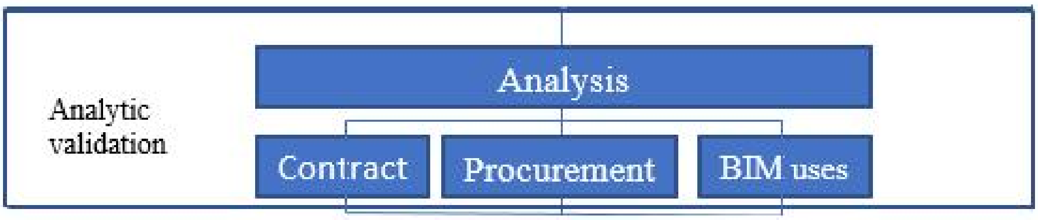

Figure 12) 3.0.1 Aim Analysis diagram (Own design)

STEP ONE_PROCUREMENT METHODS

Before the classification, it is important to know the most influencing factors in the procurement methods **(Hardin & McCool, 2015)**;

- Type of project or building
- Level experience of the designers
- The risk of the project
- When it should be completed
- Its budget
- If the contractor is involved during the design phase or not
- When it possible to contract the designer and builder under one agreement
- When the designer and builder share the risk, and with the client

The best way to know which one best fits with BIM implementation is to analyse all type of procurement methods, traditional and new ones, through their advantages and disadvantages among them.

DESIGN-BID-BUILD

Considered the most common and traditional type in contracting, DBB or Unit Price contract reveals that the client (or owner of the project) has two contract agreements, one with their consultant (or architect) and another with the contractor (builder) **(The Joint Contracts Tribunal Limited, 2011)**. There is not an overlap in the design and construction phase. Despite the contractor is the responsible for the workmanship and materials, the client has officially all the risk of the project (fully liability in design). Sometimes, the client can choose which subcontractors are going to work with the contractor (**Hardin & McCool, 2015).** The contractor is appointed by competitive tendering, and they can also be chosen in a negotiation before tendering (Accelerated Traditional Method). The documentation is a detailed Bill of Quantities to identify and quantify the activities of the project's performance **(Nyström et al. 2016)**, which can be adjustable and non-adjustable quantities.

Leverages

- AEC industry is familiar with the method
- It is a straightforward competition. The lowest price offer is the winner of the tendering
- It doesn't have legal barriers
- The client has control over the design thanks to the relationship with the architect

Disadvantages

- There is no communication with the architect and contractor during the design phase
- Any communication means cost overruns
- The existence of change orders may create future gaps and errors
- The increasing litigation due to lack of collaboration
- It is a slow process

The illustration of the traditional method is seen below;

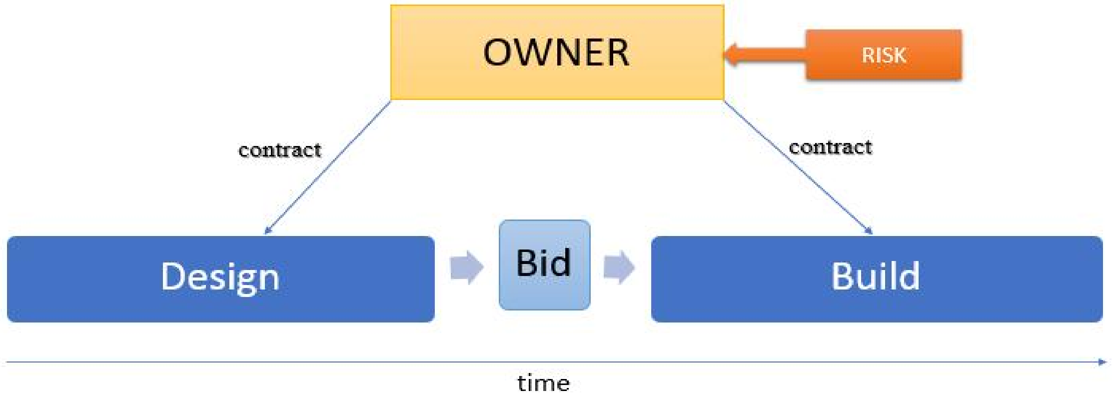

Figure 13) 3.1.1 Design-Bid-Build Diagram (Hardin & McCool, 2015) (Česnik, 2016)

BIM in DESIGN-BID-BUILD

The best time to reduce cost is in the design phase, and BIM methodology can add value to this type of procurement. It creates a coordination between the contractor and their subcontractors in facilities systems. There will be clearly an initial estimating process easier for the contractor since design phase and it means a better level of clarity and understanding during all lifecycle project (**Hardin & McCool, 2015)**.

DESIGN AND BUILD METHOD

In this method, the client chooses a consultant for the design and cost requirements, like in the traditional method. The owner just manages one contract with the contractor or design builder. The contractor is, in this case, the responsibility for the design extent, even they have their own consultants. Hence, the agreement with the client, who does not have the whole risk of the project, would be for design and construction, or design development and production information based on client's consultant's information in the tendering documentation **(Nyström et al. 2016)**. Somehow like the traditional method, the contractor is chosen by competitive tender or negotiated agreement. There are two types of design-build methods;

- Single direct; design and build agreement negotiated with one contractor
- Competitive; one or more stage operations negotiated with several contractors. It results in developed design and certainty of cost and timing.

In this case, this method is good at promoting collaboration because there is an overlap between the two phases, so consultant and contractor are required as a team (the environment is based on trust).

Leverages

- There is more chance for a collaborative atmosphere
- Decision contractors based on price, quantitative and qualitative decisions.
- It is the fastest delivery method from design and construction
- The client only manages one contract (with a design builder or contractor)
- The contractor may manage the cost estimating throughout design process
- There are zero change orders

Disadvantages

- It requires a lot of trust and collaboration for the success
- The contractor spends more time and money competing for the contract
- This method is not yet accepted in all places

The figure of the Design and Build method is below;

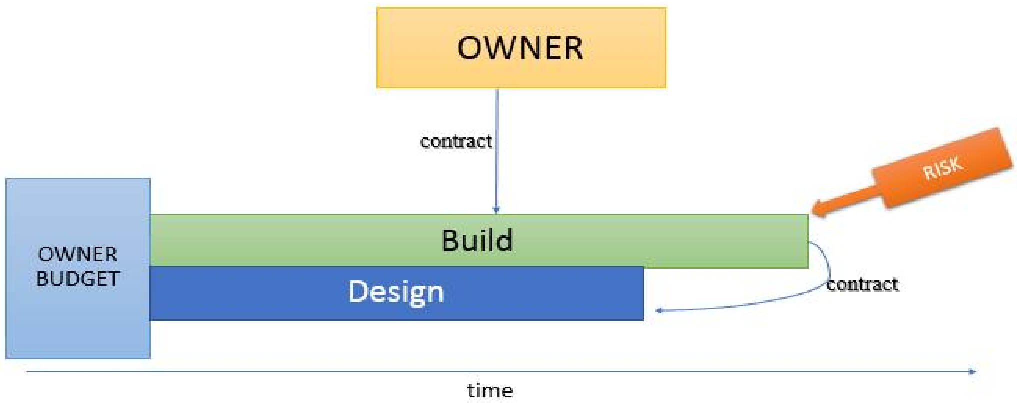

Figure 14) 3.1.2 Design and Build Diagram (Hardin & McCool, 2015) (Česnik, 2016)

BIM IN DESIGN BUILD METHOD

The best benefit is having constructible models during design phase. In the traditional method, BIM is limited because models have to show “design intents”. The use of constructible models allows a team to be proactive. Engineers and architects might use one platform the create design models, and subcontractors may create another model to use for fabrication. There is a difference with details but coordination. One model for everyone to share instead of doubling the effort individually (**Hardin & McCool, 2015)**.

CONSTRUCTION MANAGEMENT AT RISK METHOD

In this method, the client appoints a consultant (architect) to prepare the project drawings and the project specification. The contractor (construction manager) is chosen by tender and interviews, they are paid for the scheduled services, prime costs and management fee. The construction manager faces the execution of the Works, but not necessary and directly involved. They choose work contractors for those Works and, also, they might accept design liability. They also have the commitment to give GMP (guarantee maximum price) established in the design phase, so the contractor has a risk due to this GMP for delivering the project. If the contractor exceeds the price, they lose their fee. In management contracting, work contractors are directly responsible to the construction manager **(The Joint Contracts Tribunal Limited, 2011)**.

Advantages

- Early contractor involvement
- It adds value for the collaboration between design team and construction manager.
- Decision of the contractor is based on price and quantitative and qualitative factors
- It allows contractor to run estimates in design (value analysis for construction)
- Construction might start before design is complete (speed up in the project)

Disadvantages

- Contractor may not be brought early enough for a significant impact
- Contractor early involvement does not mean a contractual obligation for the design team to share their models (only the drawings).
- Contractor spends more time competing in this method (more money)
- Owner still must manage two contracts, and owns all the risk
- Contractor still change orders in construction phase not previously identified in the first agreement phase, because the owner still has the control of the design

This option has an advantage over Design bid build method because the constructor can help to resolve potential issues before construction phase, and provide an estimation cost in design process. The figure of Construction management and Risk method is presented here;

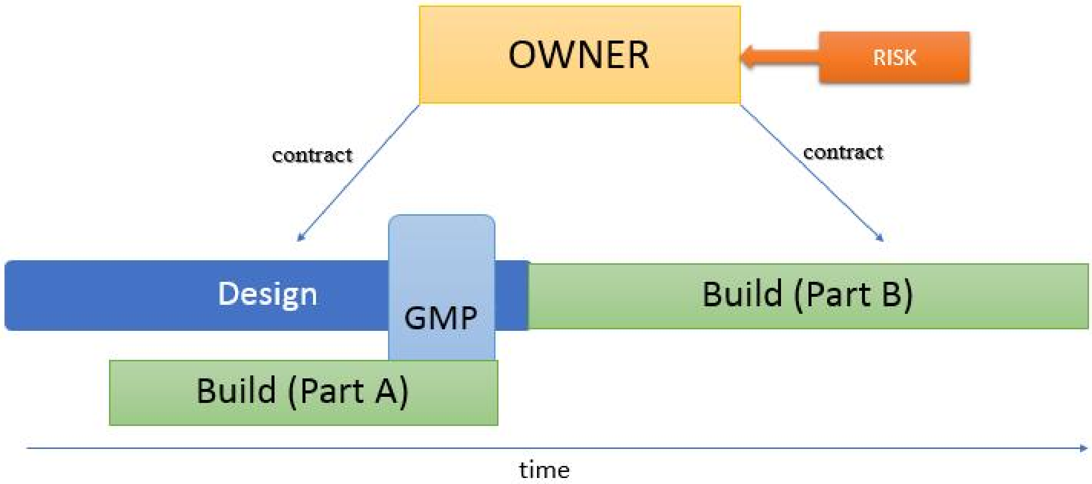

Figure 15) 3.1.3 Construction Management and Risk Diagram (Hardin & McCool, 2015) (Česnik, 2016)

BIM IN CONSTRUCTION MANAGEMENT AT RISK

One limit for BIM in the method is the timing of the contractor involvement in design phase. The constructor might be required to use BIM in his first agreement in design phase, but not to design team to create models. It might delay constructability review. If a contractor is brought in the last time on design phase for doing a full project simulation, he cannot make changes or change decisions. Requiring BIM in this method, like the others, helps to avoid gaps and errors (**Hardin & McCool, 2015).**

INTEGRATED PROJECT DELIVERY

In this method, there are some aspects that make it have a better result than the previous options. The team includes the participation of all stakeholders, and they work collaboratively due to their interests (**EUBIM Task Group, 2017**). The information is shared at many levels; expertise and knowledge are a contributing key in the process. The risks are shared between the owner, architect and contractor, but also the reward, based on the project success.

Advantages **(Martinez, 2015)**

- There are no orders for change
- The decisions are quantitative and qualitative, they are based on price
- Contractor can manage the cost by running estimates throughout the design process
- It is the most rapid delivery method

Disadvantages

- The contractor and architect spends more time-consuming and money competing for the contract
- Not yet accepted in all places

Integrated project delivery method is presented here;

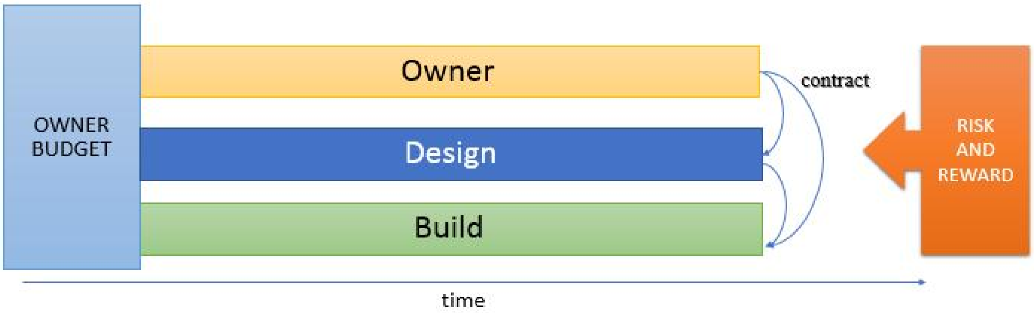

Figure 16) 3.1.4 Integrated Project Delivery Diagram (Hardin & McCool, 2015) (Česnik, 2016)

BIM IN INTEGRATED PROJECT DELIVERY

Project managers can play an essential role in this process with the support of the stakeholders to adopt BIM in IPD principles. The main goal behind IPD is to exploit the value of the finished asset, by setting incentives for the stakeholders. With the participants' interests, collaborative design and decision making are enabled, so reducing abortive work and enabling increased efficiency through data sharing (**Hardin & McCool, 2015)**. The results of the implementation BIM in IPD are;

1. Mutual respect and trust
2. Mutual benefit and reward
3. Collaborative innovation and decision making
4. Early involvement of the participants
5. Early goal definition
6. Intensified planning
7. Communication
8. Appropriate technology
9. Full organization and leadership (**EUBIM Task Group, 2017**)

Among other applications, IPD has materialized as a delivery method that could most effectively facilitate the use of BIM for construction projects. However, the public sector is not still ready for implementing BIM at IPD level. Construction firms are used to working in traditional ways, that is why changes are slow. Evaluation of the competitive bids solely based on the low-bid award system (**Porwal & Hewage, 2013**). Here is the BIM partnering proposed method compared with the traditional Design Bid Build procurement;

	Traditional D-B-B	BIM partnering
Hiring of design consultant		
Selection method	Direct selection Qualification based selection	Qualification based selection
Design approach	2D CAD	2D-3D, BIM
Preparation of tender documents		
Drawings	2D designs	2D design BIM
Cost estimation	Substantive (class B) using 2D drawings	Substantive (class B) using 2D drawings/BIM
Level of designs	2D detailed design	Tender: 2D detailed design & BIM (level 200) Construction: BIM (level 300 +)
Contractor selection		
Method	Open tender/pre-qualified Lowest bidder	Pre-qualified Lowest bidder
Evaluation criteria	Qualified A/E	BIM capable A/E/Subcontractors
Contract award	One step - construction award	Step 1- partnering award Step 2- Construction award
Contractor's involvement		
	During construction	During design and create BIM (level 300 +) During construction

Table 6) 3.1.1 Comparison DBB with BIM partnering methods (Porwal & Hewage, 2013)

STEP TWO_CONSTRUCTION CONTRACTS

TYPES

The agreement between two or more parts for the compliment of the objective of a project they are taking part in is the best definition for a contract. In this investigation, the type of contracting should be according to the multidisciplinary AEC/FM industry. The category of a construction project contract is based on the price and in the cost, two specific contracts in each category **(Elshakour, 2015).**

PRICE-BASED CONSTRUCTION CONTRACTS

1º Lump Sum Contract

Contractor bids a single fixed price for the works in the project scope. It is a liability for the contractor to estimate the project cost and they add overhead their profit depending on the price of the project. The contractor has also all the risks, no one for the owner. They include a percentage cost associated with the risk in the final cost. Also, they have the incentive as an award for the early finish, but also a penalty for finishing late. Perfect contract when the scope and schedule are well defined at the design phase because there will be flexibility for modifications during the construction period **(The Joint Contracts Tribunal Limited, 2011).**

2ºUnit Price Contract

The whole price of the project is calculated in unit price contract, in other words, based on the price of each element's unit. The contractor is paid by the rates of those items, which are specified in the bill of quantity. Then, the owner can check if he is being charged with un-inflated prices for some goods or services. In this case, both owner and contractor share the possible risk, but there are no incentives for finishing earlier. This contract has more flexibility for change orders in the design phase than in the lump sum contract. The construction phase can start before the end of the design period, so there will be uncertainty in the total cost, that is why this type of contract is recommendable **(NEC3, 2013).**

COST-BASED CONSTRUCTION CONTRACTS

3º Cost Plus Contract

The contract comprises a payment of the actual costs, purchase and other expenses from the work. The contractor is, in this case, paid based on the actual cost of the project including direct, indirect costs and a specific fee (fixed fee or percentage). The owner has all the risks and a management involvement of the project. On the other hand, the contractor has not any risk if they finish later the works, but they do not have incentives. This type is suggested when there is an existence of uncertainty or hesitation in the first stages of the project. The contractor can start with the construction before design period finishes **(The Joint Contracts Tribunal Limited, 2011)**.

4º Target cost Contract

This type is similar to the lump sum and cost-plus contracts. The contractor is paid based on the actual cost plus a fee (fixed or percentage of cost), in case the total cost does not exceed a certain target cost required by the owner **(NEC3, 2013).** The contractor carries risk in case the is an increment of the cost of the project, but also, they are rewarded with a percentage of the savings between the target (limited) and the actual cost which is rewarded for **(Elshakour, 2015)**. The following table shows the key differences among the main four types of contracts to make clear which is more suitable, according to the owner or contractor;

Point of Differentiation	Lump Sum Contract	Unit Price Contract	Cost Plus Contract	Target Cost Contract
Advantages with respect to the **contractor**	Incentives for early finish	Low risk	No risk	Rewards for any savings between actual and target cost
Disadvantages with respect to the **contractor**	High risk	No incentives for early finish	No incentives for early finish	Share risk with the owner
Advantages with respect to the **owner**	No risk Total cost is defined at early stages	Share risk with the contractor	Can start project without finishing designs	Target cost is defined at early stages
Disadvantages with respect to the **owner**	Contractor desire to decrease costs may be to detriment of quality	Total cost is uncertain at early stages	High risk Total cost is uncertain at early stages	Share risk with the contractor
Flexibility of design changing	Limited flexibility	Has flexibility to change design	More flexible to design stages	Limited flexibility

Table 7) 3.2.1 Types of construction contract differentiation (NEC3, 2013)

ANALYSIS

Signed by all participants, any project has the same contract, and there is not typical contract in a multidisciplinary project-based industry like AEC. Construction contract provides legal bidding agreement, for the owner and builder. It defines how the payment is going to be, the duration, quality and other specifications. The process, general and specific terms, financing conditions, requirement about safety and security and risk management must be included and plainly described in the contracts (**Trinkūnienė & Trinkūnas, 2014).** When the contractor is chosen and all terms and conditions are negotiated, it is time to choose the type of contract among all existing. The selection might depend on a multiple criteria method. For an effective decision-making in the selection of the type of contract, the Employer's Information Requirement (EIR) underwrites models which should be produced in each project stage, determining the criteria method (**Barnes & Davies, 2014)**. Nevertheless, the point of trust is which determines sometimes the conditions and decision of the client, even when the lowest price bidder has all the chances to get the project **(NEC3, 2013).** For the contract, the improvement of the investment finally achieved, it turns into efficiency and productivity for the AEC industry **(Nyström et al. 2016)**.**).** Some have determined (**Trinkūnienė & Trinkūnas, 2014)** that the specialised information system (data) with the knowledge as evaluation and the experience as negotiation, all together create the strategy in a contract.

RISK MANAGEMENT

After having an overall view of what risk management means in the literature, risks have to be considered as a measurable part of the well-known uncertainty in construction projects (**Diadosz & Rejment 2015**). Managerial factors are the key related to cost and schedule, so it means time and financial consequences **(Eadie et al. 2013)**. Its reflection in construction contracts an effective way to keep the approach of risks in all companies **(NEC3, 2013)**. If the contracting conditions do not change, any task for controlling and managing risk is worthy, so it means that risk does not disappear in the next phase of the project (**Toth & Sebestyen, 2015)**. Also, considered as a possibility of a loss, risk management needs to have a procedure or methodology behind that studies the identification of the risk, related factors, its impact, classification and an analytical application of a method, according to the problem, and the following review. So, independently of the type of procurement method chosen, the client should focus, since the concept design, in the possible external and internal effects **(Nyström et al. 2016).**

Despite the quantification of the risk is an arduous work, the analysis of the risk factors is getting more resourceful in the industry. So, the risk analysis is a crucial part of the risk management. Its composition address identification, assessment, and decision-making methods. Designed by Project Institute, through Project Management Body of Knowledge (PMBOK) international standard guide of good practices, the decision-making procedure most effective is the following;

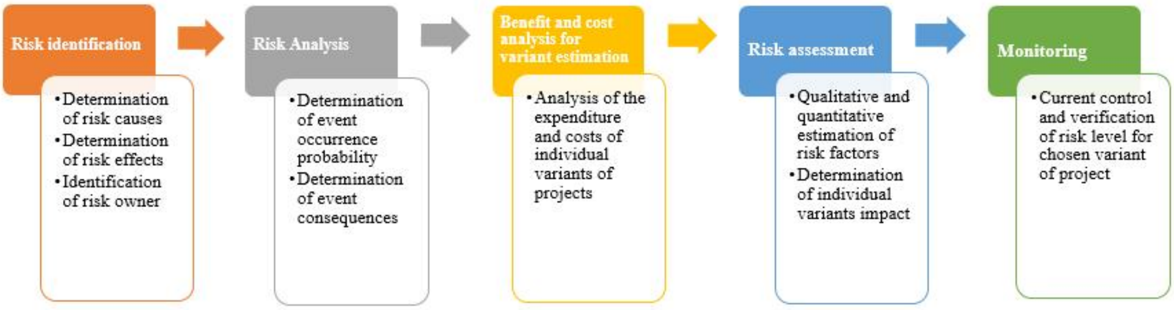

Figure 17) 3.2.1 PMBOK Decision-making procedure (Diadosz & Rejment, 2015)

For the first step of the identification of risks, or possible deviations from expectations (**Toth & Sebestyen, 2015),** there are tools like brainstorming technique, Delphic, checklists or evaluation of experts. The following matrix of risk is a good example of visual presentation of risk identification level, organized by the probability of occurrence and the impact factors. It is well known as risk assessment matrix;

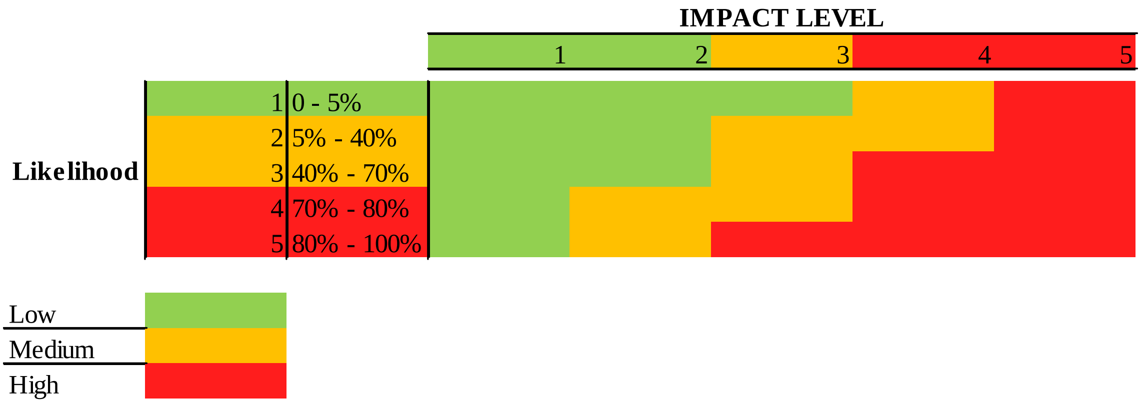

Figure 18) 3.2.2. Matrix of level of risk (Diadosz & Rejment, 2015)

There is also another sort of matrix more developed, by "PRINCE 2" methodology. Despite it is made by the decision maker with their own subjectivity, it is an accurate strategy for the risks that might occur in the project. The decision maker bases their choices in a multi-criteria approach, according to the significance they assume in the risk assessment classification. The next table shows how a risk can be registered;

					Risk assessment				
Nº	RISK	Owner of risk	Reason/cause	Effect	Probability	Impact	Level of Risk	Response strategy	Cost of strategy
1									
2									
...									

Table 8) 3.2.2 Risk registration (Diadosz & Rejment 2015)

In a nutshell, risk monitoring and management system have the goal of being a stable theme in the contractual environment (**Toth & Sebestyen, 2015).** It is possible to help companies to evaluate their risk management in procurement period. It can also improve the existing situation with expert recommendations. The process of risk monitoring and management is decisive in procurement management, both linked by the cost impact probability. Unfortunately, there is the undeniable fact that still, companies do not have a well-developed Risk management system within Procurement Management (**Serpell et al. 2015**).

STEP THREE_BIM USES

ANALYSIS

Already known the concept of "BIM", but not about "BIM use" concept. BIM use or application is a method of applying BIM during a project or building's lifecycle to get their objectives **(AEC UK, 2015)**. It makes the information as a meaning in both workflows and processes, so it means that a BIM use produces an impact in four factors; estimating, scheduling, safety and logistics (**Hardin & McCool, 2015**), considered vital for the following elaboration of the list of BIM specific uses in this content. All uses should be classified for the project purpose, for the good implementation of BIM in the project. The best way is through all stages that contain the lifecycle of the project (**Kreider, et al. 2010**). This classification has benefits like organization, coordination, efficiency in resources and sustainability. To easily identify BIM use, first it is important to know about the BIM characteristics, already explained and classified through SWOT analysis **(Isikdag & Zlatanova, 2009)**.

Hence, BIM uses are understood by the complementation of their theoretical purposes and characteristics, and they might be classified based on the effects of the application in the project, but it is easier to classify in a practical way, like the stages of the lifecycle of the project, or even based on the practical purposes that a facility manager is able to categorize **(Chong et al, 2017)**. When the characteristics and purposes are presented, then the Uses list might start to be elaborated. After the authors analyses every concept of the purposes, through the objectives, and characteristic list, it is time to determine the classification of the implemented Uses. Due to its complexity, BIM uses cannot be classified based on one factor or level of maturity or lifecycle stage. The first step is to identify BIM goals and Uses. The point is defining the potential value of BIM on the project and for the team members, through the BIM goals. Within goals, are the objectives of the project, like the reduced schedule time, or the interoperability. Main goal: to define the measurable goals. This guide **(CICRP, 2010)** has found 21 common uses thanks to project studies or interviews with experts. Project goals related to BIM. They have to be specific for each project, be measurable. The main connexion of all is with 3 factors are "reduce project schedule duration" "increasing quality" and "reducing project cost". Some goals might relate specific uses.

USES OF BIM

1. Building (Preventative) Maintenance Scheduling
2. Building System Analysis
3. Asset Management
4. Space Management and Tracking
5. Disaster Planning
6. Record Modelling
7. Site Utilization Planning
8. Construction System Design
9. Digital Fabrication
10. 3D Control and Planning
11. 3D Coordination
12. Design Authoring
13. Engineering Analysis
    a. Energy Analysis
    b. Structural Analysis
    c. Lighting Analysis
    d. Mechanical Analysis
    e. Other Engineering Analysis
14. Sustainability (LEED) Evaluation
15. Code Validation
16. Programming
17. Site Analysis
18. Design Reviews
19. Phase Planning (4D Modelling)
20. Cost Estimation
21. Existing Conditions Modelling

Although this is the official list of BIMs uses, in this project all those uses have been studied, dissect and reorganised for the elaboration of a necessary survey which will be explained in the methodology. Also, new uses have been found in recent studies about integration usage and management. From the previous list, a newly modified list is now that one which will be aim of the survey and following analysis;

1. **Building (Preventative) Maintenance Scheduling**

Building System Analysis

    2. **Daylight simulation**

3. **Asset Management**

Space Management and Tracking

4. **Space management**
5. **Construction process Tracking**

Disaster Planning

6. **Risk planning disaster scenario**

7. **Record Modelling**

8. **Digital Fabrication**

3D Control and Planning

9. **Geographical information**
10. **Quality control**
11. **File version control**
12. **3D scanner monitoring**

3D Coordination

13. **3D visualisation and coordination**
14. **Virtual reality**
15. **Augmented reality**
16. **Clash detection**

17. **Design Authoring**
18. **Engineering Analysis**
19. **Sustainability (LEED) Evaluation**
20. **Code Validation**
21. **Programming**
22. **Site Analysis**

Design Reviews

23 **Design checking and assessment**

Phase Planning (4D Modelling)

24. **Urban planning and Design**
25. **Site Utilization Planning**

Cost Estimation

26. **Cost estimation**
27. **Quantity take-off Estimation**

28. **Existing Conditions Modelling**

Integration

29. **Supply integration**
30. **Data integration**

31**. Additional information integration**
32**. Design and fabrication integration**
33 **Issues analysis integration**

Management
34.**Safety management**
35.**Risk management**
36.**Facility management**

The final analysis of each use of BIM is presented, ordered and classified among the type of widespread use in accordance with the recent research. The classification has been settled as straightforward activities, which might be understandable by all organizations and population that are recently getting into BIM concept; visual, planning, programming, estimation, detection, management, control, integration and analysis are the nine types of uses, leaving behind the official study according to the project's lifecycle classification, understood by the expertise **(CICRP, 2010)**.

Visual uses

3D visualization and coordination

It brings the ability to navigate to the model and understand the real position from the 2D plan. It is the introduction of 2D to 3D model, interactive and more visually developed. Clash detection software is used during de coordination process to determine field conflicts by comparing 3D models of building systems.

Potential value:

-It coordinates building project through a model
-It reduces/eliminates field conflicts
-It visualises construction
-It increases productivity
-It reduces construction cost
-It decreases construction time
-It increases productivity on site
-More accurate as built drawings

Augmented Reality

A type of view whose elements are visually increased by a virtual sensor such as sound, record, illustration or geographic information.

Value:

-Virtual tour to next levels
-Better visualization for key participants
-Concept communication and visions for the model
-Faster appreciation of many parts the building
-Accessibility to the virtual information

Virtual reality

A process which It allows to visualise exactly how a model would look in a real environment, and explore it inside and out.

Potential Value:

-It generates a 3D environment with existing cameras, lighting and material.
-It generates photo-realistic images or renders of the project to guide the viewers
-It creates a map which can be exported, viewed and files.
-It provides a faster project completion

Geographical information (GIS)

A process which visualises, manages, analyses and collates data based on any location. It manages assets geographically while identifying opportunities with less risk and adapting to the future.

Potential Value:

-It creates accessible formats to clarify data
-It enables to instant reaction and forecasts risks
-It mitigates ground movement on bigger infrastructures projects
-It facilitates the data collection with mobile technology

Daylight simulation

A process which studies and quantify the amount of sun's light in the project with daylighting analysis. Important key information is that the good daylight comes from the sky, not the sun directly and daylighting metrics are useful when predicting energy savings and effectiveness in a workspace.

Potential Value:

-It creates comfortable and aesthetic spaces
-It reduces cooling and lighting loads
-It represents contrasting times through illuminance renderings
-It helps users to avoid errors caused by manual data while preparing simulation
-It simplifies the 3D daylight modelling process
-It makes the process more user-friendly

Record modelling

A 3D model holds a truthful representation of the physical conditions and environment of a facility and its assets. This has potential to contain information related to Mechanical, Electrical, and Plumbing (MEP), and architectural elements.

Potential Value:

-Providing documentation of environment for future uses
-Address to reduce project delivery times, risk, costs and lawsuits.

Existing Conditions Modelling

A team develops a model of the current conditions of a site in a facility area.

Potential Value:

-Building documentation of historical background for future uses

-It enhances efficiency and precision of documentation about present conditions

Digital fabrication

A process that utilizes machine technology to prefabricate objects directly from a 3D Model. The 3D Model is spooled into appropriate sections and inputted into fabrication equipment for production of system assemblies.

Potential Value:

-It automates building component fabrication

-It minimizes tolerances through machine fabrication

-It maximizes fabrication productivity

Planning Uses

4D building maintenance scheduling/planning

The functionality of the building structure (walls) and equipment (plumbing) is uphold during the life of the facility. A maintenance program improves the building performance and reduces its cost.

Potential Value:

-It plans maintenance activities proactively

-It enhances corrective and emergency maintenance

-It evaluates different maintenance approaches based on cost

-It allows facility manager to justify cost of the maintenance program

-Dynamic phasing plans offering multiple options and solutions to space conflicts.

-Integrate planning of human, equipment and material resources with BIM model to schedule and cost estimate

-Identification of schedule, sequencing or phasing issues

Risk planning (disaster scenario)

There is an accessibility to critical building information in a model and information system. The dynamic information would be provided by a building automation system (BAS).

Potential Value:

-It provides police, fire, public safety and first responders access to critical building information in real-time

-It improves the effectiveness for emergency

-It minimizes risks to responders

Urban planning and design
A process which is used for the development and proposal for development planning, urban generation and urban specialization planning. It analyses spatial data from GIS and reviews environmental elements in the development plan.

Potential Value:

-It helps to reduce working time and cost

-Securing compatibility among data

-It improves consistent work processes

-It enhances project quality with integrated management of geospatial data and a reduced environmental impact.

Site utilization planning
A 4D model represents both permanent and temporary facilities on site, with the construction activity schedule. The model can include labour resources, materials and associated deliveries, and equipment location.
Potential Value:

-General plan for temporary facilities or material deliveries

-Identification of critical points and time conflicts.

-It selects a feasible construction scheme

Programming Use

Programming
A process in which a 3D program is used to evaluate the project. The BIM model allows the project team to analyse space and accomplish the standards and regulations.
Potential Value:

-Efficient and accurate assessment of design performance regarding dimensional requirements by the client.

Estimation uses

5D Cost estimation
The model can be used to make an accurate sum approximation in the design process and provide modifications to save time and money.
Potential Value:

-Stay within budget with preliminary cost estimate while design progresses

-Provide cost information during design phase

-Focus on value adding estimations about identifying construction assemblies, price generation, factoring risks.

Quantity Take Off (Material and Cost estimation)
Creation and development of material and budget assessment in the design phase.
Potential Value:

-Estimation of material quantities with subsequent revisions
-Better visual representation of the construction elements for their estimation
-Exploring distinctive design options and concepts within the budget
-Avoiding time-consuming for the estimator
-Chance to focus in future estimation issues

Detection uses

Clash detection
Including identification, inspection and reporting of obstacles in a model. Used for checking both completed and ongoing work, it allows to walk through the model and discover any prior collisions in the construction site.
Potential Value:

-It reduces the risk of human error during model inspections
-It reduces construction cost
-It increases the accuracy and save hours of re-work

Construction process tracking
A process which creates parameters and views for tracking maintenance. Also, using schedules to plan replacement and preventive maintenance, and using filters and graphic overrides to select and highlight elements in 3D views.
Potential Value:

-It enhances workflow
-More efficiency in tracking accuracy
-Flexibility in issue management in project environment

Management Uses

Safety Management
The process identifies future conflicts and risks, with a schedule program, planning measures and with a visual presentation of the site conditions.
Potential Value:

-It helps to eliminate construction site hazards
-It reduces cost related to jobsite injuries
-It reveals safety risks
-It helps to coordinate schedules
-It improves key participants’ safety and security training

Space Management (conflict detection, tracking)
BIM is used to allocate, manage and track workspaces and related resources. The model will allow the facility management team to analyse the use of the space and manage changes during the facility's life.
Potential Value:

-It identifies and allocates space for appropriate building use
-It tracks current use of space
-It ensures optimum use of facility's space resources
-It assists in planning future space needs

Risk management
A process which manages to recognize and mitigate the possible risks that a project might get at an early stage with the use of BIM during its lifecycle.
Potential Value:

-Software and transfer limitations
-It controls file storage
-It promotes interoperability
-Schedule and cost control in design phase
-Sharing responsibilities (more communication)

6D Facility Management (Operation and maintenance)
A process which organizes management system for the repair, operation and maintenance for the facility's lifecycle. Facility managers can get locational information about a problem in the building, along with complete product specifications, warranties, maintenance procedures, design data, etc.
Potential Value:

-Easy visualization for repairing and maintenance issues
-Improvement in the whole-life costing evaluation of the facility
-It helps for Inspections and other preventive maintenance functionalities.
-It maintains up-to-date facility and equipment data (maintenance schedules, warranties, cost data, upgrades, damages, etc.)

Asset management
The physical building, system, environment and equipment must be maintained, operated and upgraded efficiently to satisfy the owner and users with the lowest and most appropriate cost. The use focuses on data contained in a record model to determine the cost implications of building assets. Also, it performs and analyses facilities and equipment condition assessments.
Potential Value:

-It provides a source for tracking the use, performance and maintenance of a building's asset for the owner, maintenance team and finance department.

-It produces quantity take-off of current company assets which aids in financial reporting, bidding and estimating future costs implications.

-It allows future updates of record model to show current building asset information after replacements or maintenance by tracking changes

-It aids financial department in analysing several types of assets through an increased level of visualisation

-It increases the opportunity for measurement and verification of systems during building occupation.

Design authoring

A process in which a 3D software is used to develop a BIM model. At the same time, it examines the model. Also, the instruments for the analysis value the possibility of adding or even modifying the information.

Potential Value:

-Transparency in the design

-Control and quality in the design, cost and timetable

-Powerful design visualization

Control Uses

Quality control

A process which coordinates and supports 4D scheduling, safety and quality management in the project.

Potential Value:

-Improvement of design quality

-It minimizes errors due to better coordination with documents and the team

-Lower costs and shorter lead times

-Automatic, accessible, precise and consistent information

File version control

A process which controls the deliverables documents which have been modelled and a level of development provided.

Potential Value:

-It ensures accessibility and interoperability between parties

-Shared coordination

-Successful identification of BIM data

-It guarantees ownership and data security

3D laser scanning monitoring

A process which acquires building spatial data in three dimensions through laser scanner to capture occluded areas and minimize missing data. Each scan generates a point cloud full of millions of data points.

Potential Value:

-Increasing accuracy in projects

-It reduces errors and rework

-Improvement of quality control

-3D visualization and spatial analysis

-Response to changes

Design checking and assessment

A 3D model is used to showcase the design and evaluate the program in factors such as layout, sightlines, lighting, security, ergonomic, textures and colours. Virtual mock-ups can be done in detail to analyse other design alternatives and solve design and and future constructability issues.

Potential Value:

-It models distinctive design options and change real time during design review

-It creates shorter and efficient design reviews

-It resolves conflicts in a mock-up and model the potential fixes in real-time

-Preview of visual space and layout during design review

Code Validation

A process with code validation software is utilized to check the model parameters against project specific codes. This use is not a widespread use, but it will be prevalent in the design industry.

Potential Value:

-It validates the building design with specific codes (like International Building Code, Americans with Disabilities Act guidelines)

-It reduces code design errors, omissions or oversights (time-consuming)

-Continuous feedback on code

-Reduced time by local code officials

-It saves time for multiple checking for code compliance

Integration Uses

Supply integration

A process which regulates incorporation of the flow of material, information, money, work crews and capital equipment among a set of strategically aligned companies.

Potential Value:

-More reliable and transparent collaborations among the suppliers

-Supporting information sharing

-Cost and time reduction

-Communication and coordination between supply chain and team members

Data integration

A process which combines from several sources into meaningful and valuable information.

Potential Value:

-It reduces management risks

-Efficiency

-Reliable and up-to-date data

-Visualization and information analysis

Additional information integration

A process which combines with data integration. Information and data changes are introduced in the model.

Potential Value:

- It reduces management risks
- Efficiency
- Reliable and up-to-date data
- Visualization and information analysis

Issues analysis integration (way-finding, crowd behaviour)

A process which introduces the analysis of possible issues like way finding or crowd behaviour by the simulation and analysis of panic situations or spatial problem-solving.

Potential Value:

- Improvement of build environment design
- Early detection in risks during operational stage of the building

Design and fabrication integration

A process which introduces the design technology, digital fabrication for structural components. It enables digital design-to-fabrication workflows and the use of structural building information models for the digital fabrication of materials, like structural steel.

Potential Value:

- Better control in manufacturing process
- Eliminated errors between design and fabrication models
- Accurate, coordinated and consistent model for sharing data
- Fully collaboration reducing costs and improves delivery schedules

Analysis Uses

Engineering analysis (Structural, energy, lighting)

A modelling software uses the BIM model to determine the most effective engineering method based on design specifications. Information is the basis for what will be passed on to the owner and/or operator for use in the building's systems (i.e. energy analysis, structural analysis, emergency, evacuation planning, etc.).

Potential value:

- Automating analysis and saving time and cost
- Improve expertise, quality and services offered by design team
- Achieve optimum, energy-efficient design solution by applying various analyses
- Faster return on investment with audit and analysis tools for engineering

7D LEED sustainability analysis

A process in which a project is evaluated based on LEED or other sustainable criteria. Sustainability evaluations can be applied across all phases of a project.

Potential Value:

-It accelerates the design review and LEED certification process with efficient use of a single database with all sustainable features present and archived.

-It improves communication between participants to achieve LEED credits and decrease redesign efforts.

-It aligns scheduling and material quantities tracking for more efficient material use and better cash flow analysis.

-It optimizes building performance by tracking energy use, indoor air and space planning for the adherence to LEED standards leading to integrated facility management using BIM model.

Site analysis

BIM and Geographic tools are used to evaluate assets for the best possible location for a future project. The data is used to select the best site location for the building. Through supervision and executive management, it determines if potential sites meet the required criteria according to the project requirements.

Potential Value:

-It decreases costs

-It increases energy efficiency

-It minimizes risk about harmful material

-Faster return on investment

METHODOLOGY

The investigation methodology of "Methodology" as "Empirical Validation" follows with the survey proposal and elaboration, whose dissemination and subsequent collection of data clarify the analysis of the results. It is presented in the next figure;

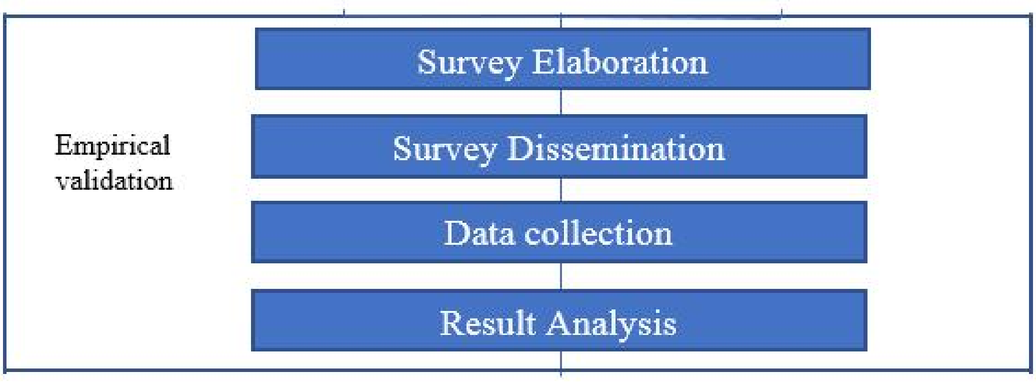

Figure 19) 4.0.1 Methodology diagram (Own design)

STEP ONE_ SURVEY PROPOSAL. STRUCTURE

THE NEED

To raise the problem formulation, BIM uses is the last step this investigation has arrived. So that flows from the need in the introduction, BIM implementation not every public and private project, but inside AEC industry as a collaborative work-method. After analysing BIM uses, getting to know which ones best fit with "BIM environment" is a useful effect to establish some criteria as a final discussion. Keeping in mind the key factors of BIM environment as a context, the proposal that flows from this investigation and analysis is the inquiry of a survey to a specific kind of population; public body/ authorities and private firms from AEC industry are the best groups for the survey proposal. The need of this survey is proposed because it will clear up, according to the population's opinion and level of satisfaction during the time they have been using BIM, the awareness of the top uses. The following analysis of the survey will end up with a set of criteria that is meant to be a basic series of guidelines for the industry's companies in Europe. This proposal or criteria will be in the next chapter "Discussion of the results". The criteria environment diagram is thought like the following figure;

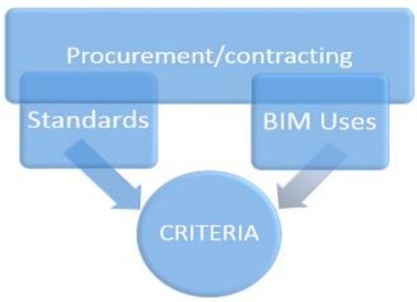

Figure 20) 4.1.1 Criteria Environment (Own design)

TYPE OF SURVEY

There are several types of methods in surveys to get the results from a population's valuation. Classified in two kinds of surveys, interviews and questionnaires, both can be in a direct or indirect canal. Interview survey might be done by person, telephone or via message, but the time factor is decisive to not take this kind of survey. The questionnaire survey is the best option, it is more suitable to different respondents, opened in terms of accessibility through internet and its visual design makes the number of participants to grow up in a brief time. The questionnaire survey proposed here is the LIKERT SCALE questionnaire;

	1- Strongly disagree	2 - Disagree	3 - Undecided	4 - Agree	5 - Strongly agree
Sentence 1			x		
Sentence 2		x			
Sentence 3				x	
Sentence 4					x
Sentence 5	x				
...			x		

Table 9) 4.1.1. Likert Scale questionnaire (Own design)

Likert Scale questionnaire is a simple kind of survey that enables a classification in odd numbers of the answers about the participant's opinion or level of satisfaction. Participants can choose only one state in every sentence or question from every line of the questionnaire and all results are measured and analysed.

STEP TWO_POPULATION AND INSTRUMENTS

POPULATION

The survey is intended to be answered by a specific group or community; AEC/FM public authorities and private companies that BIM concept is familiar to them to be able to do the questionnaire. For doing this survey, the companies must be classified within the type of organization, the size and, also, the period the companies have been using BIM.

Optional response of the name of the company; keeping in mind the confidentiality, companies and organizations that fulfil the survey can decide about showing their company name in the online questionnaire. It is the first question in the survey that led a company to decide about privacy, it is the only optional response.

Type of company; according to AEC industry reports, the most characteristic classification about the type of companies are the followings;

-Client/Realtor; dedicated to buying and selling properties, also the consultancy about their management.
-Surveyor; inspection and cost management of projects
-Design; taking part in architectural projects or manufacturing
-Contractor, dedicated in the construction and structural projects

-Maintainer/Management, project and facility management
-Academic/Scientist, in the university or innovation and development departments
-Others; freelance workers, combination of two or more of the previous options

Size of the company; according to the European directive where the classification of the size of a company, considering the number of people working there (**2013/34/EU**).

- Micro. Less than 10 people working there
- Small. Between 10 and 49 people
- Medium. Between 50 and 249 people
- Large. 250 or more people working there

Period the company has been using BIM; in this investigation, the period starts from zero, then the shortest period in a year, and straightaway, between specific years until the top of the time BIM has been shown up in the industry outlook.

- They are not using BIM
- Less than a year
- Between 1 and 2 years
- Between 2and 5 years
- Between 5 and 10 years
- More than 10 years

LIST OF INSTRUMENTS

Since the beginning of this methodology preparation, the instruments and tools which have been used, and during the process to elaborate the survey and the following procedures, is summarised around the technological devices that a University student can have access into;

-Internet as an application software
-Windows system software
-Likert scale questionnaire virtual paper format
-Uses of BIM made as the survey content
-Gmail way of contact
-Laptop as the hardware
-Microsoft Excel worksheet
-Google Docs form

STEP THREE_PROCEDURES

MEAN OF CONTACT AND SENDING

The main for contacting the companies was Internet through mass communication tools;
-In Gmail, direct and personalised messages to companies and colleagues who are already working in the industry.
-LinkedIn; expertise open groups to spread the survey out. Also through direct messaging among contacts that the author of this thesis has in the platform.
-Facebook groups; same as LinkedIn.
-Others; direct messages of well-known people that the author considered competent to be interviewed for the survey. Also, it is included web and social media to reach audience.

REPLY. DATA COLLECTION

The ways the participants have replied first as sign of acceptance to participate have been diverse. Many them have accepted through a direct message, before fulfilling. Also, there were willing to fill the questionnaire with no reply for confirmation. It is a fact that, after a check of the responses, there were some new ones not expected, so those were more difficult to get how they came from, but no for the data collection. The responses were automatically kept in Google Forms, in the same time in Google Drive cloud.

Every response was added to the previous answers and, all together, created the whole picture of the results in a graphic visualisation, where only the author can access. Also, the content of the virtual survey can be modified during the period companies can still have access and able to participate before have enough number of responses and close the questionnaire. 38 were the total responses, but 8 of them were invalid for the quality of the satisfaction scale responses. So, the total sample of the data collection was 30. Despite the reliability of the results depends on the sample size, the sample number is small but elemental for considering the central limit theorem for statistical analysis in the interpretation of the results **(Vargas, 2008).**

MEASURABLE PROCEDURE. APPLICATION OF INSTRUMENTS

The way Likert scale is measured is according to the rate from 1 to 5 as the highest level of satisfaction. Already seen in in a nutshell in the type of chosen survey, every BIM use explained in the analysis, is exposed one by one as a statement in the column of the survey's table. The participants chose the suitable number of the satisfaction scale with an X, one by line by Use. The results of every participant are automatically collected up for an extraction rate during this process. The results are finally together to get from the survey application visual graphics about the statistics that have been created for that period. Those statistics are then directly analysed and compared through an Excel worksheet. The type of company, size and the period of using BIM are collected in a specific graphic, and every use they value in a bar graphic, easy to visualise and compare while having a look before checking the numbers' results in the Excel.

STEP FOUR_RESULTS. INFORMATION PROCESSING

PRESENTATION OF RESULTS

After the procedure explanation, the results have been collected up in graphics where all companies' main characteristics for the classification; the type, size and the period BIM has been used. The type of the company previously categorised in the population last point, has the following results; leading the representation the type of "Others". That probably means that the majority of the participants are involved in more than one type of work, like the combination of two or more of the other types, that already have less percentage on their own. Here the results of type of company of all those who have been participating are;

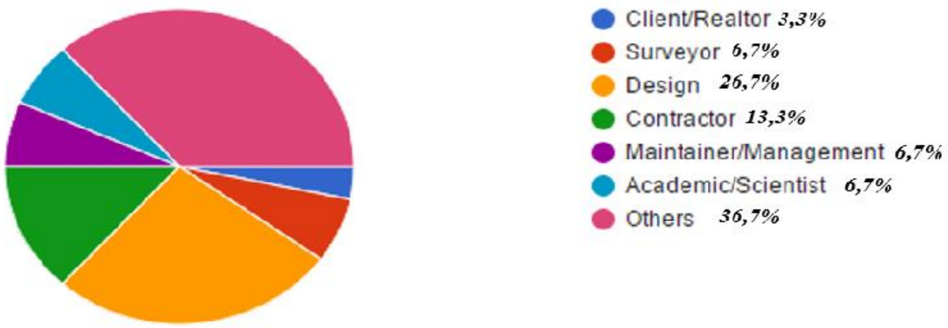

Figure 21) 4.4.1. Type of company results

The size of the company results is completely balanced, but the most significative ones are the small and medium organizations, the most active ones, and those that will already get a bigger impact in BIM implementation, have a lot to contribute. It is a positive sign that more than the half of the participants are in these categories. The results of the classification of the size of the company of the participants;

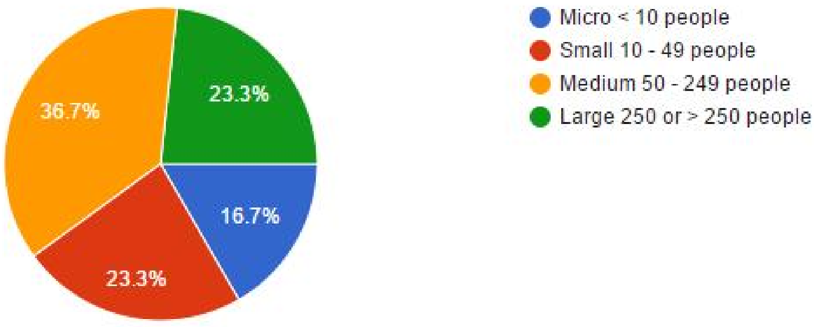

Figure 22) 4.4.2. Size of company results

The period the company has been using BIM is the last visualisation result about the identification of the participants. It is also a balanced result here;

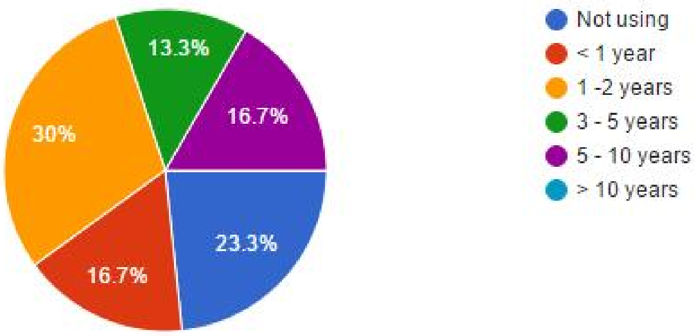

Figure 23) 4.4.3. Period of company using BIM results

BIM USES

Based on this colour set, all BIM uses have been also organised in bar graphics, 36 simple graphics to have a general outlook about what the companies value from 1 to 5 level about them;

Figure 24) 4.4.4. Satisfaction Scale

The brief graphics are going to be analysed in the next step, Survey assessment with a more complex visualisation of the results. All graphic results from the online survey are in the **Addendum Nº4**

STEP FIVE_SURVEY ASSESSMENT

INTERPRETATION OF RESULTS

VALIDITY OF RESULTS

In the period of the survey responses started with the objective of collecting up valid responses from the organizations that wanted or accepted to participate in the questionnaire. Unfortunately, some the responses were clearly not acceptable for the responses. Also, incomplete answers are invalid but, thanks for the settings of online survey, the responses must be fully completed, otherwise any participant cannot submit.

Some companies, 22 of the 30 who did the questionnaire, wrote the company name. It means that they accepted to be identified for this analysis. With the identification, a geographical statistic can be also studied. Not all these 22 companies have a location in Europe. Despite the thesis is focused on the AEC/FM European industry, it is acceptable to collect responses from other continents like America or Asia. Those ones in Europe identified have location in Lithuania, Spain, Denmark, Germany and UK. Those outside Europe had location in Canada, Sri Lanka and Singapore

Some of the companies were interested in the progress of this study, others were geographically identified by their name. Despite it is a study that looks to Europe, having further responses is positive because it helps to have new and useful approaches about the uses.

ORDER OF THE SCALE RESULTS INTO RATED USES

For the analysis, an order should be established on the companies' key identifications; size, type and the period they are using BIM. Keeping in mind the motivation of this thesis, procurement and contracting are the decisive points of the study, so the not all BIM uses are going to be under this analysis of the results, only those ones that, considered for this study, are truly connected with contracting and procurement methods. Reminding the list of BIMs uses and, also, their information and potential value of each one, are marked. **(Kreider et al. 2010).**

Visual uses

3D visualisation and coordination
Augmented reality
Virtual reality
Geographical information
Daylight simulation
Record modelling
Existing Conditions Modelling
Digital fabrication

Planning Uses

4D building maintenance scheduling/planning
Risk planning (disaster scenario)
Urban planning and design
Site utilization planning

Programming Use

Programming

Estimation uses

5D Cost estimation
Quantity Take Off (Material and cost estimation)

Detection uses

Clash detection
Construction process tracking

Management Uses

Safety Management
Space Management
Risk management
6D Facility Management
Asset management
Design authoring

Control Uses

Quality control
File version control
3D laser scanning monitoring
Design checking and assessment
Code Validation

Integration Uses

Supply integration
Data integration
Additional information integration
Issues analysis integration
Design and fabrication integration

Analysis Uses

Engineering analysis (Structural, energy, lighting)
7D LEED sustainability analysis
Site analysis

The final list of BIMs, according to their use in procurement and contracting phase, is concentrated in sixteen uses.
3D visualisation and coordination
Geographical information
Existing Conditions Modelling
Urban planning and design
Programming

5D Cost estimation
Safety Management
Space Management
Risk management
Design authoring
Design checking and assessment
Code Validation
Data integration
Engineering analysis
7D LEED sustainability analysis
Site analysis

ANALYSIS GRAPHICS

The graphic results are in **Addendum nº 5**. The following tables are the conclusive results of the most valued type, size and period of BIM used; First, the characterisation table shows the percentage of each type, size and period using BIM that the participants are in;

	TYPE							
	Surveyor	Others	Maintainer	Design	Contractor	Client/Realtor	Academic	Design&Others
Total	2	11	2	8	4	1	2	**19**
%	6.67%	36.67%	6.67%	26.67%	13.33%	3.33%	6.67%	**63.33%**

Table 10) 4.5.1. Type of company

The most significant types are "Design" and "Others", together, they are the 63,33% of the total. Design group has major number of participators after "others", which is the most valuable group because of the variety and combinations of other types of companies. On the other hand, the next table is about the size of the firms;

	SIZE				
	MICRO	SMALL	MEDIUM	LARGE	SMEs
Total	5	7	11	7	**18**
%	16.67%	23.33%	36.67%	23.33%	**60.00%**

Table 11) 4.5.2. Size of company

The most valuable group in the size classification is no other than the combination of Small and Medium companies, regarding economic issues in the market in Europe. It means the 60% of the total of the participants. The last table is about the Period;

	Period of BIM					
	Not using	<1 year	1 - 2 years	3 -5 years	5 -10 years	Not using - 2 years
Total	7	5	9	4	5	**21**
%	23.33%	16.67%	30.00%	13.33%	16.67%	**70%**

Table 12) 4.5.3. Period the company has been using BIM

In this study, the most significant period considered has been from zero (not started yet) to 2 years. The importance of those who have not started yet, gives the rounded idea of which statements have worse or best expectations, and the recent and negative impact reflected in those that are using from less than a year until two.

STATEMENTS	TYPE																				GENERAL	MEDIA	Σ(ẋn-ẋ)	DEVIATION	VARIANCE	S. DEVIATION
	Design&Others																			MEAN	MEAN	N		(ẋn-ẋ)^2	[Σ (ẋn-ẋ)^2]/n-1	√([Σ (ẋn-ẋ)^2]/n-1)
[3D Visualization and coordination]	4	3	5	4	5	4	5	5	5	5	5	3	4	5	2	5	4	5	2	4.21	4.07	5.00	4.38	19.16	1.0643	1.0317
[Geographical information]	3	2	3	4	4	1	4	1	5	5	1	2	3	2	1	4	5	5	2	3.00	2.97	3.00	6.32	40.00	2.2222	1.4907
[Existing Conditions Modelling]	4	2	3	4	4	2	3	2	4	4	1	3	3	4	2	3	4	4	2	3.05	3.03	3.00	4.12	16.95	0.9415	0.9703
[Urban planning and design]	5	3	4	3	5	1	3	1	4	1	1	2	3	2	2	4	4	5	2	2.89	2.73	3.00	5.98	35.79	1.9883	1.4101
[Programming]	5	3	4	3	4	3	4	5	3	3	1	2	4	2	2	2	1	4	2	3.00	2.93	3.00	5.10	26.00	1.4444	1.2019
[5D cost estimation]	5	4	5	3	5	4	3	5	4	1	3	4	3	2	2	1	2	4	1	3.21	3.33	3.00	5.93	35.16	1.9532	1.3976
[Safety Management]	5	3	2	3	3	3	4	2	3	2	1	2	3	1	2	3	2	3	1	2.53	2.23	3.00	4.33	18.74	1.0409	1.0203
[Space Management]	5	4	4	4	5	3	3	5	5	2	1	2	3	1	1	4	1	3	1	3.00	2.83	3.00	6.48	42.00	2.3333	1.5275
[Risk management]	5	2	2	3	5	2	3	1	5	2	1	3	3	1	2	3	1	3	1	2.53	2.30	2.00	5.72	32.74	1.8187	1.3486
[Design authoring]	5	2	4	4	4	2	4	1	4	1	2	4	3	1	1	5	2	5	2	2.95	2.80	3.00	6.24	38.95	2.1637	1.4710
[Design checking and assessment]	5	2	4	4	5	3	5	5	4	1	1	2	3	4	2	4	4	3	2	3.32	3.20	4.00	5.67	32.11	1.7836	1.3355
[Code Validation]	5	4	2	3	4	2	4	5	3	2	1	1	3	1	1	3	1	2	1	2.53	2.50	2.00	5.89	34.74	1.9298	1.3892
[Data integration]	5	2	4	3	5	3	4	5	4	1	1	1	3	4	2	5	2	4	2	3.16	3.03	3.00	6.04	36.53	2.0292	1.4245
[Engineering analysis]	5	4	5	3	5	4	5	1	3	1	5	2	3	5	2	5	5	4	2	3.63	3.53	4.00	6.20	38.42	2.1345	1.4610
[7D LEED sustainability analysis]	5	4	5	2	5	1	3	1	3	1	5	2	3	2	1	4	2	4	1	2.84	2.67	3.00	6.52	42.53	2.3626	1.5371
[Site analysis]	4	3	2	3	5	1	5	5	3	3	1	2	3	1	1	3	1	4	2	2.74	2.83	3.00	5.97	35.68	1.9825	1.4080

STATEMENTS	SIZE																		GENERAL	MEDIAN	ẋn-ẋ	DEVIATION	VARIANCE	S. DEVIATION
	SMEs																	MEAN	MEAN			(ẋn-ẋ)^2	[Σ (ẋn-ẋ)^2]/n-1	√([Σ (ẋn-ẋ)^2]/n-1)
[3D Visualization and coordination]	5	4	4	5	4	5	5	5	5	5	4	5	3	3	5	5	3	2	4.28	4.07	5.00	3.95	15.61	0.9183	0.9583
[Geographical information]	5	3	4	4	1	4	1	5	2	5	1	1	1	2	2	4	2	2	2.72	2.97	2.00	6.29	39.61	2.3301	1.5265
[Existing Conditions Modelling]	5	4	4	4	2	3	2	4	3	4	4	1	1	3	4	3	4	2	3.17	3.03	3.50	4.74	22.50	1.3235	1.1504
[Urban planning and design]	4	5	3	5	1	3	1	4	1	1	1	1	3	2	2	4	1	2	2.44	2.73	2.00	6.04	36.44	2.1438	1.4642
[Programming]	3	5	3	4	3	4	5	3	3	3	4	1	1	2	2	2	3	2	2.94	2.93	3.00	4.79	22.94	1.3497	1.1618
[5D cost estimation]	5	5	3	5	4	3	5	4	3	1	4	3	3	4	2	1	4	1	3.33	3.33	3.50	5.66	32.00	1.8824	1.3720
[Safety Management]	4	5	3	3	3	4	2	3	1	2	1	1	1	2	1	3	2	1	2.33	2.23	2.00	5.10	26.00	1.5294	1.2367
[Space Management]	3	5	4	5	3	3	5	5	2	2	1	1	1	2	1	4	2	1	2.78	2.83	2.50	6.41	41.11	2.4183	1.5551
[Risk management]	3	5	3	5	2	3	1	5	1	2	1	1	1	3	1	3	2	1	2.39	2.30	2.00	6.02	36.28	2.1340	1.4608
[Design authoring]	2	5	4	4	2	4	1	4	3	1	1	2	1	4	1	5	5	2	2.83	2.80	2.50	6.36	40.50	2.3824	1.5435
[Design checking and assessment]	3	5	4	5	3	5	5	4	4	1	1	1	2	2	4	4	5	2	3.33	3.20	4.00	6.16	38.00	2.2353	1.4951
[Code Validation]	3	5	3	4	2	4	5	3	4	2	4	1	1	1	1	3	3	1	2.78	2.50	3.00	5.75	33.11	1.9477	1.3956
[Data integration]	4	5	3	5	3	4	5	4	2	1	2	1	3	1	4	5	3	2	3.17	3.03	3.00	5.87	34.50	2.0294	1.4246
[Engineering analysis]	5	5	3	5	4	5	1	3	3	1	3	5	2	2	5	5	5	2	3.56	3.53	3.50	6.20	38.44	2.2614	1.5038
[7D LEED sustainability analysis]	4	5	2	5	1	3	1	3	3	1	1	5	1	2	2	4	5	1	2.72	2.67	2.50	6.60	43.61	2.5654	1.6017
[Site analysis]	3	4	3	5	1	5	5	3	3	3	4	1	1	2	1	3	4	2	2.94	2.83	3.00	5.74	32.94	1.9379	1.3921

STATEMENTS	PERIOD USING BIM																					GENERAL	MEDIAN	ẋn-ẋ	DEVIATION	VARIANCE	S. DEVIATION
	NOT USING - 2 YEARS																				MEAN	MEAN			(ẋn-ẋ)^2	[Σ (ẋn-ẋ)^2]/n-1	√([Σ (ẋn-ẋ)^2]/n-1)
[3D Visualization and coordination]	5	5	4	4	4	3	5	5	3	3	4	4	5	2	3	2	5	4	5	3	2	3.81	4.07	4.00	4.82	23.24	1.1619	1.0779
[Geographical information]	5	5	3	4	4	2	3	1	1	2	3	3	2	2	3	1	4	5	5	2	2	2.95	2.97	3.00	6.08	36.95	1.8476	1.3593
[Existing Conditions Modelling]	5	3	4	4	3	2	3	1	1	3	4	3	4	1	1	2	3	4	4	4	2	2.90	3.03	3.00	5.46	29.81	1.4905	1.2209
[Urban planning and design]	4	4	5	4	2	3	4	1	3	2	3	3	2	2	2	2	4	4	5	1	2	2.95	2.73	3.00	5.38	28.95	1.4476	1.2032
[Programming]	3	5	5	4	4	3	4	1	1	2	2	4	2	1	1	2	2	1	4	3	2	2.67	2.93	2.00	6.06	36.67	1.8333	1.3540
[5D cost estimation]	5	4	5	4	3	4	5	3	3	4	3	3	2	4	2	2	1	2	4	4	1	3.24	3.33	3.00	5.46	29.81	1.4905	1.2209
[Safety Management]	4	1	5	2	2	3	2	1	1	2	3	3	1	1	1	2	3	2	3	2	1	2.14	2.23	2.00	4.96	24.57	1.2286	1.1084
[Space Management]	3	3	5	4	3	4	4	1	1	2	3	3	1	3	3	1	4	1	3	2	1	2.62	2.83	3.00	5.56	30.95	1.5476	1.2440
[Risk management]	3	2	5	4	2	2	2	1	1	3	2	3	1	2	1	2	3	1	3	2	1	2.19	2.30	2.00	4.82	23.24	1.1619	1.0779
[Design authoring]	2	2	5	4	4	2	4	2	1	4	3	3	1	1	2	1	5	2	5	5	2	2.86	2.80	2.00	6.52	42.57	2.1286	1.4590
[Design checking and assessment]	3	4	5	4	4	2	4	1	2	2	3	3	4	1	2	2	4	4	3	5	2	3.05	3.20	3.00	5.38	28.95	1.4476	1.2032
[Code Validation]	3	2	5	3	3	4	2	1	1	1	2	3	1	1	1	1	3	1	2	3	1	2.10	2.50	2.00	5.27	27.81	1.3905	1.1792
[Data integration]	4	4	5	4	3	2	4	1	3	1	3	3	4	1	2	2	5	2	4	3	2	2.95	3.03	3.00	5.56	30.95	1.5476	1.2440
[Engineering analysis]	5	3	5	4	4	4	5	5	2	2	3	3	5	3	2	2	5	5	4	5	2	3.71	3.53	4.00	5.50	30.29	1.5143	1.2306
[7D LEED sustainability analysis]	4	3	5	3	2	4	5	5	1	2	2	3	2	1	1	1	4	2	4	5	1	2.86	2.67	3.00	6.68	44.57	2.2286	1.4928
[Site analysis]	3	4	4	4	3	3	2	1	1	2	3	3	1	3	1	1	3	1	4	4	2	2.52	2.83	3.00	5.22	27.24	1.3619	1.1670

Table 13) 4.5.4 Type results

Table 14) 4.5.5 Size Results

Table 15) 4.5.6 Period Results

The results in tables 4.5.4, 4.5.5 and 4.5.6 indicate the mean, median, variance and standard deviation, whose interpretation shows the statistical variations of each statement, compared to the total mean of the results. These three tables are focused on the characterisation classification of the participators in the survey. The simple mean is defined as the average of all the numbers, the sum of them is divided by the number they form. The median is considered the middle score. But with the median, the variance and standard deviation (root of the variance) are meant to be a measure about how far the data is spread apart. With the formulas in the tables for getting the variance and then, standard deviation. The aim of the table is the standard deviation, where when they are close to zero, they are less far from the mean. The interpretation of the results will be disclosed in the following chapter as a leading analysis, according to each Type, Size and period of BIM used.

DISCUSSION OF THE RESULTS

The investigation methodology of “Discussion” shows how the discussion of the statistical study of the survey results, and with the guiding references during the assessment of the thesis, develops into the set of criteria. It is presented in the next figure;

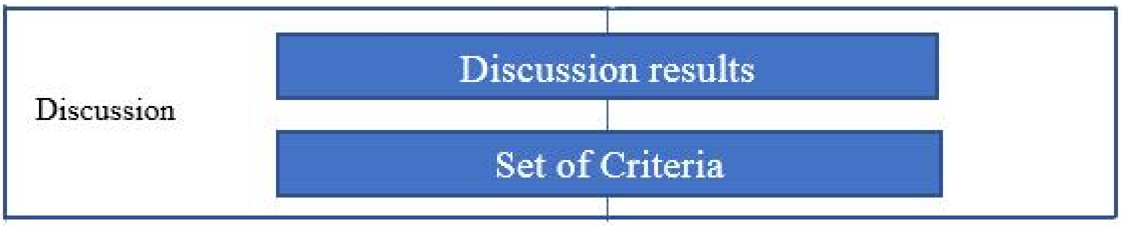

Figure 25) 5.0.1 Discussion diagram (Own design)

STEP ONE_USES BIM DISCUSSION ANALYSIS

According to Type of Company

The type “Others” was considered the combination of some official types of companies, also it has more number of responses in this survey, so “Others” was previously considered that it has the most significative and strongest opinion about the topic. “Design” companies have a hefty opinion and different approach to BIM software and the survey has the second large cluster of responses, so their opinion with “Others” can be more focused to analyse and get a conclusion from their experiences.

In general terms, there has been a wide variety of opinions about all uses, according to the means obtained in the tables. The point of this discussion is outlining harsh opinions from the two significative groups, weighed in every type of group. Visualisation group of uses is in an appropriate position in the means. Almost all organizations have a good opinion about it, hence the balance is positive. The same balance with the Planning group of uses, where “Urban Planning and design” is characteristic in procurement.

There is no valuation completely positive or negative in Programming Uses, neither in Cost Estimation, so they are not considered harmful. However, Management group is noteworthy in the survey; Safety and Risk Management have the worse opinion by the participants. Also, in Control uses, “Design checking and assessment” and “Code validation” have a bad judgment by companies that work for design. Any signification in Integration uses, but Analysis group has as negative judgement in the use of “7D Sustainability”.

According to Size of company

The most significant sizes for this study are small and medium companies. They were settle on the graphic results. Despite this, there is no significant difference between the general mean of each usage and the specific means, regarding SMEs. Considering the Visualisation uses group, their results do not show a negative verdict to discuss, except in "Geographical Information" usage. Planning group has also a negative result from the mean. Although, Cost Estimation group has got good mean results in the table, according to the size classification. Neither small companies do not think good about the usage of Programming, nor about the group Management. Safety management has the worst response, and space, risk managerial and design authoring uses are frowned upon by the medium companies. Despite "Code Validation" from Control group has a low mean, it has a positive balance for the other use "Design checking and assessment". Integration uses do not tell anything to discuss more than a variety of different opinions among all sizes, like Engineering analysis, that has a good response. Unfortunately, the other two types analysis (LEED and Site) have a general bad judgment in that regard.

According to Period with BIM

All periods are considered important in the study, but there were, in the last chapter, well-thought-out those ones that do not have started yet in BIM implementation with no experience opinion, but expectations they have about the uses analysed here. Also, the group from less than a year or between 1 and 2 years, as the ones that recently started and have also expectation about how they are doing for their early implementation.

Broadly, Visualisation group has, like in the two previous studies, a satisfactory answer. Despite Geographical information does not have all points to be a well valued in this classification, the rest make turn the balance to positive as a general view. Planning use has not a high score, but close to the median. Pointedly, Programming use has a significant and critical opinion by those that have started using BIM, and good expectation by those that have not used yet. Nevertheless, Cost estimation and Integration have a favourable opinion. Management uses are still having negative points by the companies that recently started, although other's high expectation's companies. Space management and design authoring have their worst result. Even though code validation is not well accepted for those that recently started with BIM, Control usage has a good evaluation. Same happens with integration with BIM. Unfortunately, analysis uses have also a bad assessment about 7D LEED sustainability and site analysis.

General outlook of the results

According to the general classification of the uses; Visualisation and Estimation uses are the most valued by the companies that participated in the questionnaire. Reminding that the analyses uses from the graphics responses, this general approach enhances the elaboration of a set of criteria for the companies. Also, Integration, like Planning, usage has not significative negative judgement to include as a key point in the set of criteria. The worst uses to discuss about guideline creation are management, programming, control (focused on code validation) and Analysis (7D LEED and Site engineering). Programming use is crucial in the route for a proper BIM implementation, and if companies have a general negative valuation, there is a need to take it as one the references for the final criteria set, in order to a good and accurate BIM implementation for the companies and organizations that are about to be in BIM world, and also for a fast adaptation and update for the rest of firms and groups that already started. It is the same in the rest of the cases of BIM group uses. Before establishing the points for the elaboration of the criteria, the following table presents also a key point to deliberate, the measure of how spread the scores are out from the mean. The standard deviation shows the amount of variation or dispersion of the data from the survey results;

STATEMENTS	TYPE	SIZE	PERIOD BIM
	S. DEVIATION	S. DEVIATION	S. DEVIATION
[3D Visualization and coordination]	1.0317	0.9583	1.0779
[Geographical information]	1.4907	1.5265	1.3593
[Existing Conditions Modelling]	0.9703	1.1504	1.2209
[Urban planning and design]	1.4101	1.4642	1.2032
[Programming]	1.2019	1.1618	1.3540
[5D cost estimation]	1.3976	1.3720	1.2209
[Safety Management]	1.0203	1.2367	1.1084
[Space Management]	1.5275	1.5551	1.2440
[Risk management]	1.3486	1.4608	1.0779
[Design authoring]	1.4710	1.5435	1.4590
[Design checking and assessment]	1.3355	1.4951	1.2032
[Code Validation]	1.3892	1.3956	1.1792
[Data integration]	1.4245	1.4246	1.2440
[Engineering analysis]	1.4610	1.5038	1.2306
[7D LEED sustainability analysis]	1.5371	1.6017	1.4928
[Site analysis]	1.4080	1.3921	1.1670

Table 16) 5.2.1 Standard deviation results

Despite Visualisation group has in Geographical Information higher deviations, it has a general positive approach about it, also in the mean, so there is no a key point for the criteria elaboration. Planning and integration groups have no significance in deviation, like in general conclusion. Programming has a low deviation, regarding the size of the companies, but is roughly a negative result to consider in the criteria. Although, Cost estimation criteria is not included for their results, in the set, as positive outcomes like in

Visualisation group. Management uses are also involved as high score for standard deviation, like Control usages. Despite control has no connotation in the previous table, Code Validation will be contemplated in the elaboration set, like the specific uses of 7D LEED and Ste Analysis. In this case, 7D Analysis has the highest deviation from the media in the table 5.2.1. Summarising, “Programming”, “Management”, “Control” and “Analysis” uses will be chewed over for the set of criteria.

STEP TWO_SET OF CRITERIA. ANALYSIS

Independently the type and size of the company, all of them are the most suitable users of this set, and this proposition should include specific guidelines and recommendations. In this level of the thesis, it is well-known that BIM technology has to be used for the development of the building performance according to their standards from their level of maturity. So, by this step, it is time to make a final analysis through a summary table, which will clarify the final purpose of the study, a set of guidelines for companies and organizations. As a conclusion, the set will be presented here as a form of visual tickets, including its description, recommendations with a reference. The contribution might be stimulating for BIM implementation and development for all type of companies, untried and experienced, big and small, among others. The next table shows the visual analysis;

AEC INDUSTRY	PROCUREMENT / CONTRACTING			
	STANDARDS GUIDELINES		SURVEY	
	PRACTICAL	THEORETICAL	1. VISUAL USES	✓
	Open Standards	Stepped implementation	2. PLANNING USES	✓
	Model structures	Definitions, background	3. PROGRAMMING USES	✗
	Digital delivery processes	Cross commissions	4. ESTIMATION USES	✓
	With specific budget	Continuous development	5. MANAGEMENT USES	
	Workshops	Common framework adaptation	Safety	✗
	Collaboration procedures	National adaptations, under common European	Space	✗
	Coordination procedures	Investment in BIM resources	Risk	✗
	Public and private Initiatives	Transparency	Design Authoring	✗
			6. CONTROL USES	
	ORIENTATION DOCUMENTS		Design checking and assessment	✓
	PMBOK	RICS documentation	Code Validation	✗
	UK PROTOCOL	Pennsylvania University Reports and Studies	7. INTEGRATION USES	✓
	European Commission Normative	GSA Building Information Modeling Guides	8. ANALYSIS USES	
	Public Procurement Directive	Building SMART news	Engineering Analysis	✓
	AEN/CTN 41/SC 13” Organization of information models in building and civil works		7D LEED Sustainability	✗
	HandBook EUBIM Task Group for BIM in the European Public Sector		Site Analysis	✗

Table 17) 5.2.2 Analysis for Set of Criteria

The subsequent table indicates the final set of criteria for this thesis;

SET CRITERIA
Collaboration Strategy
Networking and Attitude
Industry Pilot Project
E-Procurement
Suitable software
BIG DATA
BIM European Plans
LEAN Construction + BIM

Table 18) 5.2.3 Set of Criteria list

The following figures are the analysis, in form of tickets, of each key criterion;

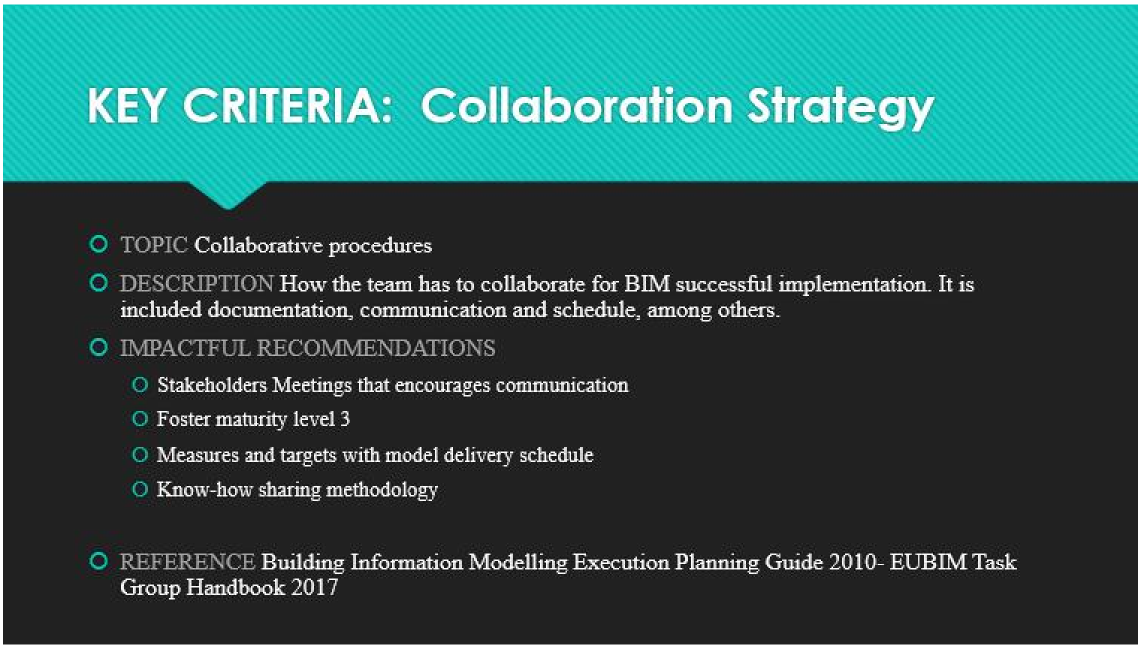

Figure 26) 5.2.1 Key Criteria no 1 (Own design)

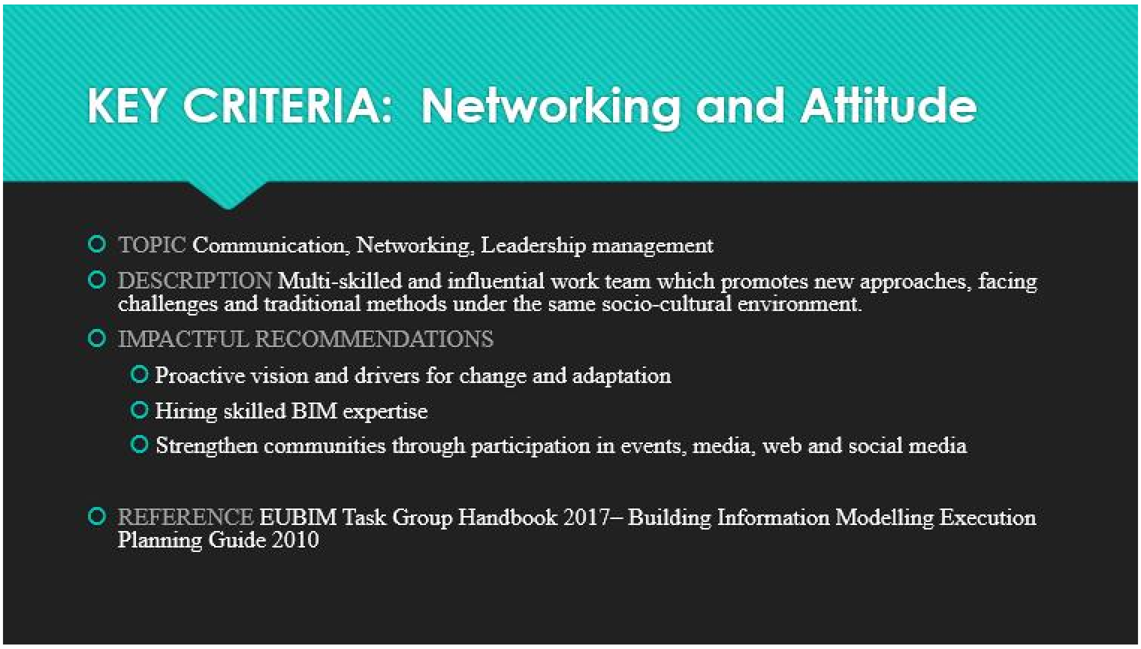

Figure 27) 5.2.2 Key Criteria no 2 (Own design)

Figure 28) 5.2.3 Key Criteria no 3 (Own design)

Figure 29) 5.2.4 Key Criteria no 4 (Own design)

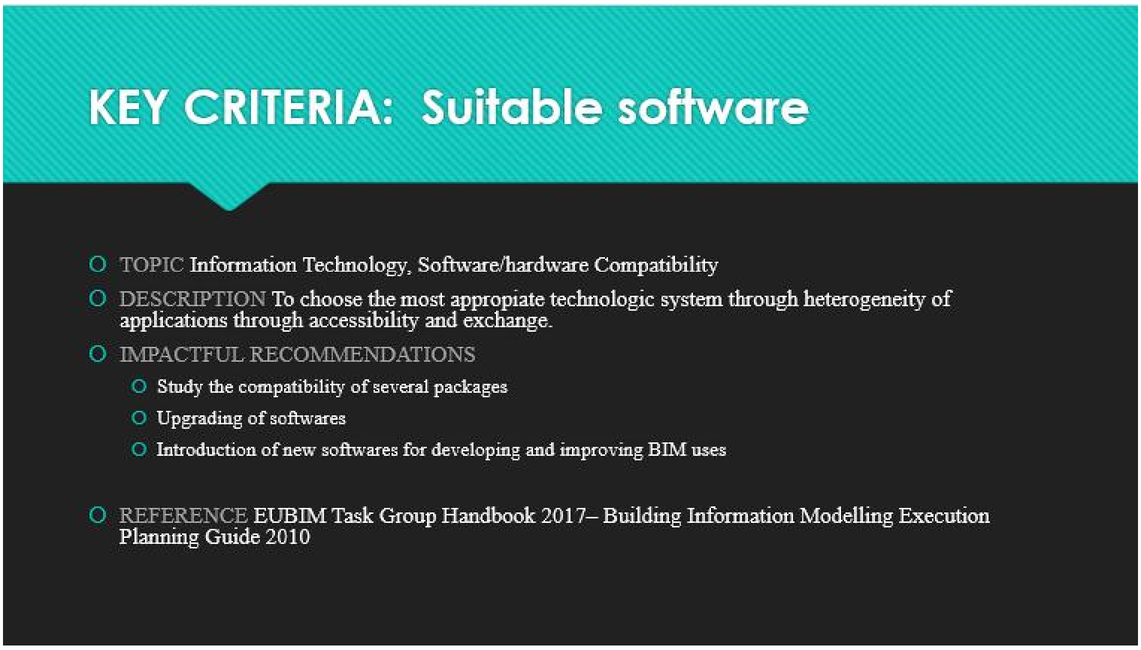

Figure 30) 5.2.5 Key Criteria no 5 (Own design)

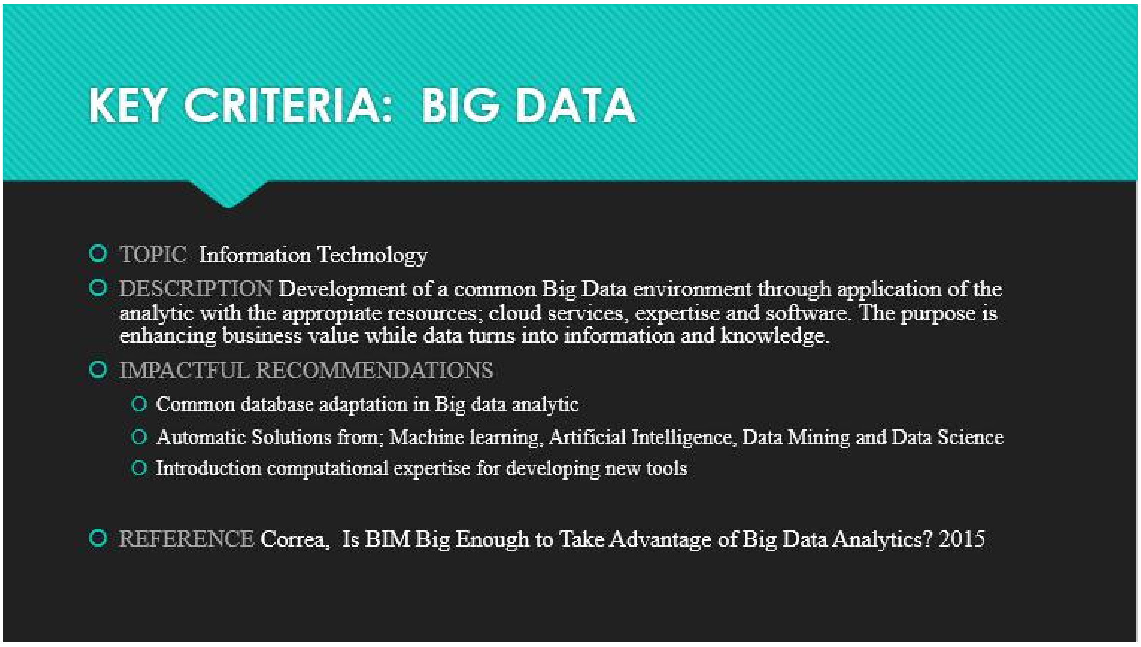

Figure 31) 5.2.6 Key Criteria no 6 (Own design)

Figure 32) 5.2.7 Key Criteria no 7 (Own design)

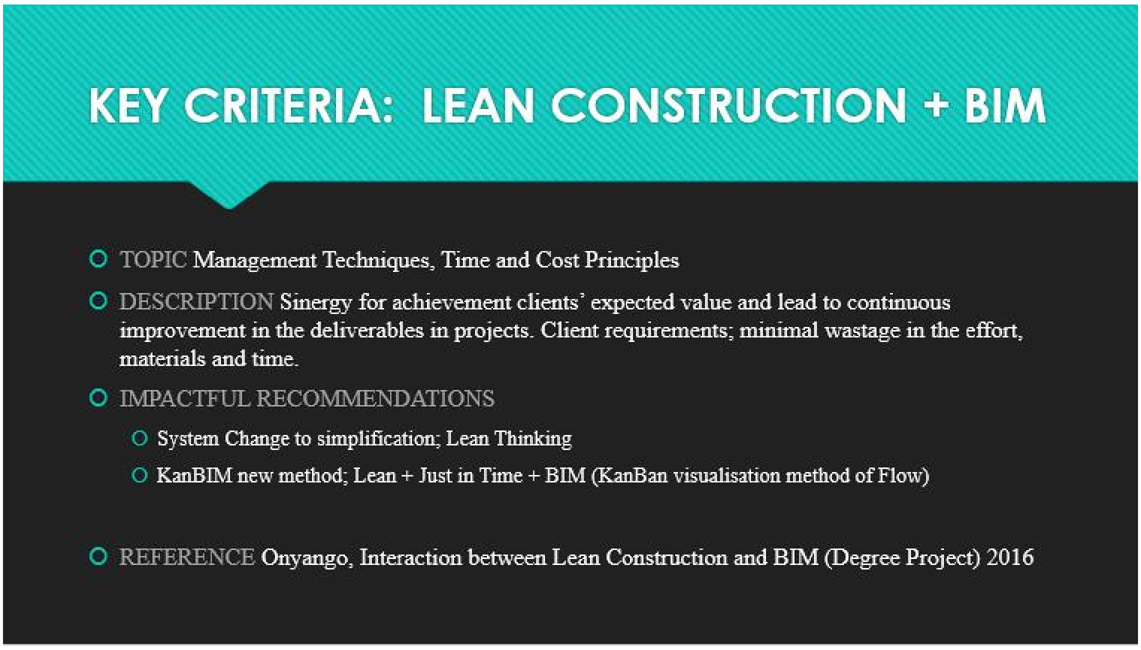

Figure 33) 5.2.8 Key Criteria no 8 (Own design)

STEP THREE_ CONTRAST OF HYPOTHESIS

The analysis of BIM uses is an essential part for an effective implementation
True. After this study, the analysis of BIM is one of the first steps for its implementation. For a basic knowledge, companies should critically analyse what BIM suppose inside the organization.

The use of BIM can be introduced in the employer's information requirements
True. Employer's information requirement belongs as a condition to a contract. The client may require for BIM in the project, but, from now, Public Administrations' expectations have to be accomplished with the new technologies and methodologies, and BIM already is considered as a part of it in the BIM protocol.

The public administration procedure is not as effective as expected about BIM implementation
True. Despite all the initiatives, there is still a long way to upgrade a fully-complete implementation. Recommendations and guidelines are established for years, but there are many companies that do not know about how to start implementing.

European Commission does not show United Kingdom as a BIM country reference
False. United Kingdom's initiatives, protocols and documentation have been promoted by several means, like BIM Task Group. As a reference, UK's protocol is one of the awarded propositions in European Commission.

AEC industry is taking BIM implementation as a very low process
False. Development is now making exponential progress if it is compared years ago. Literature review makes apparent that a lot of resources are being used and promoted in many events, conferences and innovative meetings where implementation has still a long way to go, but it is spreading out with the modern technologies and means of communication.

The decision of BIM implementation should be in the hands of the Governments.
False. Governments have the power to promote BIM, but private firms have their own professional interest that may differ from Governments'. The scope of a project is one factor to start implementing BIM, also a personal decision to change the company's mentality, despite sooner or later the obligatory nature will be a fact.

CONCLUSIONS

The investigation methodology of "Conclusions" finally ends up with a series of limitations, contribution for the thesis, and the suggestion of future lines for future studies. It is displayed in the next figure;

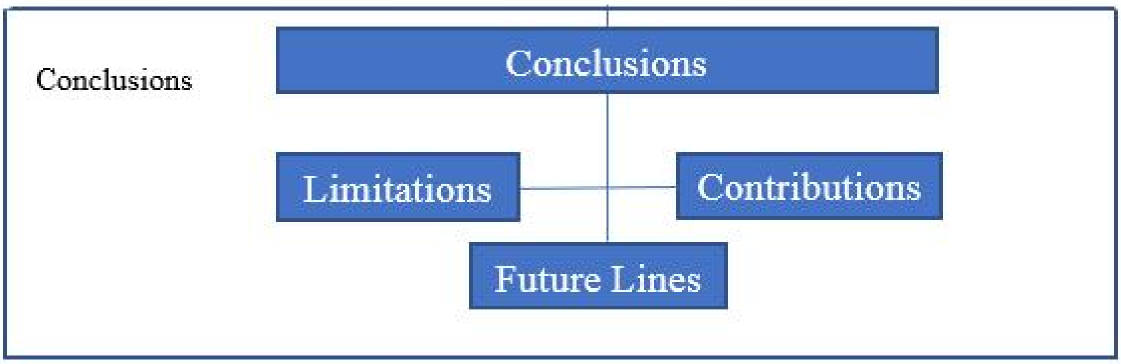

Figure 34) 6.0.1 Conclusion diagram (Own design)

In this chapter, several conclusions have been achieved after the study of the theoretical framework, since the parametric research until the elaboration of the literature review, key point for the understanding of the project life-cycle perspective. Other conclusions have been considered after the analysis of the scope of this thesis; procurement and contracting environment, and BIM usages. From those analyses, a methodology was proposed to get specific results for, at least, the answer the aimed hypothesis and accomplishing the specific objectives.

The achievement of the hypothesis was presented in the chapter of "Discussion of Results", but it can be taken into account as a contribution point in the study. Also, it is though for including some statements as for a future line. The main objectives made a broad outline about the direction of the study and they can be commented because some limitations rise at the present time. There has been a concern about the specific objectives, that have been successfully fulfilled. From their outcomes, they might become future lines for further research.

Bearing in mind the main objectives, the main factors were linked to the scope of the project, whose environment is the European AEC industry. After the development of the investigation, survey methodology and discussion of the results, the conclusions are;

-There have been many investigations about BIM application in several countries, with different social contexts in each one. Their aim factors differ from the present study, which it has been focused on establishing criteria implementation, according to European requirements and standardisation context.

-In this bibliometric research, barely commented in these papers, new findings of innovations have been discovered in the official academic research websites that they suppose a huge contribution for the review of the literature research. Despite many of them did not write about the basic information about contracts and procurements methods, the information was accurate for the "Theoretical framework". The objective of the understanding of lifecycle project phases where BIM is used was achieved in the Introduction chapter.

-The literature review has been a keynote for the development of the theory. The conception of the factors that comprise the problem formulation and the answer in BIM as a solution to the presented obstacles has a concern about the many virtual and innovative procedures in procurement, one of the general objectives to reach.

-In the "Theoretical Framework", several elements cover the different points that make BIM as a significant role for the whole life asset period, despite the topic is in the design phase (conception, development, and technology). Another of the general objectives, the enhancement of acknowledgment of BIM standardisation, was reached while it was analysed, after establishing BIM environment and its influence in Europe. Also, the first specific objective, assessing the concept of BIM, was successfully accomplished at the beginning of the chapter.

-The chapter of "Methodology" was the most intense one, considering the chosen procedures for its execution. The number of the answer of the survey are unexpected, so do the opinions. The period for the getting the responses was short, but enough for the conditions that the author was facing. The minimum number, 30 responses, was acceptable by the author for having a discussion. The conditions depended on the time and deadlines, quality of the responses (8 were invalid), and the level of understanding of the participants about the topic and content of the survey.

-The comprehending of the topic and the survey was a critical factor for the participants, some of them wanted to take part in, but they did not have an idea if BIM was a software that they were working on in the companies. After explaining to some of them the purpose, content of the survey, and even the concept of BIM through direct messaging, the conclusion of better quality than quantity was clear. Public posting for getting more responses was not successful, so pointing at potential participants through professional social media or mailing was the most effective way to obtain results.

-The survey dissemination and interpretation of the results were widely-though with the help of statistical analysis. The numbering of the results, further than likert satisfaction scale into percentages, was considered for getting more accurate outcomes, that is why the central limit theorem was chosen for a deep statistical analysis and interpretation of the survey results.

CONTRIBUTIONS

After the main conclusions, the following contributions have been ascertained below;

-Eight key criteria for BIM practical implementation have been developed from the analysis of the uses of BIM focused on procurement and contracting environment. Performed by international companies and organizations through a questionnaire survey of satisfaction, a set of criteria has been set up for this project. All each one of the key criteria has just been justified in explanatory cards with the survey results, standardisation guidelines and orientation documentation as a background insight. The criteria results are the final deduction which replies some of the outlined hypothesis and offers improvement propositions, constraints and, also, future lines as a contribution to the world of BIM now.

-The explanatory tickets conclude with a circle of influences about several topics; socio-cultural topics like Collaboration, Attitude and Networking prowess can enhance the AEC Industry to the change needed for better procurement methodology system. Modern technologies also play an essential role in the set of criteria; e-Procurement for virtual tendering is the unbeatable bet for the European Commission for Public Administration, Big Data is another criterion which brings the future common virtual environment through new developing tools for BIM. Nothing better than the implementation while being involved in the last innovations, with the best and suitable software, which best fits for a company by the time for the bid.

-Other encouraging proposes as input for the conclusions are Project pilots, the best excuse to start the practical training; while following similar case studies that companies are involved, it helps to develop their knowledge about what is BIM concept, deeply than theory. The same practical training and techniques focused on time and cost are linked into the criteria, like a formula, Lean construction and BIM addition, including in the implementation a synergy as a solution for management uses. The last criteria address the European context about Management and Execution Plans, key guidelines for the project preparation of documentation in BIM language.

There is no other evidence of contribution than the set of criteria made after this investigation. The results that confirm that the proposition will be involved in the general BIM outlook are still unknown in the future, but the contributions have a future impact somehow in the previous chapter. Straightforward recommendations in the criteria that are considered as possible contributions for following protocols and manuals might be the attitude and networking that the company can get the change to implementation. Refreshing or updating will help the companies to rapidly adapt or introducing BIM, it is a key point in the criteria which basically connects with many of other points, such as the introduction of the figure of the BIM Manager or its development and advantage in Big Data environment.

LIMITATIONS AND FUTURE LINES

LIMITATIONS

The next statements are the evidence of the constraints that have been showing up in the thesis;

-The process of the dissemination was an arduous task. Although there were many instruments to spread the survey, the interest of the potential participants was a huge obstacle to face. In expert and virtual social groups, the probability of understanding of the topic was on the top. Unfortunately, the interest of participating in a thesis' survey was not reflected as the time was going.

-Despite the dissemination of the survey was worldwide to many means, messaging social media, diverse platforms, the number of the sample was small. The quality of the responses and the short understanding of some of the participants that made the author put more attention and time in some participants to reply properly the survey, it was considered that is was better few replies but good ones, than plenty of them but with inadequate quality.

-The perception of the participant's opinions might not be equivalent to the reality of the general opinion of European AEC Industry. Despite the representation is not conclusive for considering the final indications as characteristic for the industry, it is a significant sample to contemplate the contributions the study has given and, also, to suggest future lines to further studies without the obstacles weighed in this chapter.

FUTURE LINES

The succeeding lines of investigation are proposed, based on this study;

-The set of criteria proposed might be used for the total integration of CAD/BIM with Geographical Information System (described as a framework of a Smart City). To develop and to adapt all criteria within every software in the market. Every possible tool used in BIM can be under examination and develop the use of the criteria.

-New BIM uses that might be developed upcoming and added, can also contribute the upgrading of the criteria.

-A real advance in the subject could be the expansion of BIM in all lifecycle stages, design-evaluation-planning, construction, operation, maintenance, and demolition and retrofit. From this progress, it will make the most in new software innovations and methods under development, contemplated since the design phase.

-Another future improvement like citizen participation in BIM simulation processes that they are involved in would ensure a positive influence for the Industry.

-Considering Value Engineering Idea Bank proposal within BIM**,** but with its implementation in the BIM criteria discussed. How to cross or to compare the BIM-based VE Idea Bank's evaluation criteria with this thesis' criteria set is a current idea that would encourage a growth in BIM environment.

-Taking the idea of the implementation in other disciplines, in this case, would not differ from its goal. With a budget background established, the set of criteria can have another kind of expansion, specifically in BIM concept growth. "City Information Modelling" (CIM) is going further than a building performance project, and with that, the development of the goal of this project into other fields or spheres from the same domain.

REFERENCES AND CITATIONS

AEC UK Industry (2015) *AEC (UK) BIM Technology Protocol. Version 2.1.1 Practical implementation of BIM for the UK Architectural, Engineering and Construction (AEC) Industry.*

AENOR Asociación española de Normalización y Certificación (2016) Estándares en apoyo del BIM. Informes de normalización. Comité Técnico de Normalización CTN-41 Construcción, pp 1-16.

Alreshidi, E., et al. (2017) Factors for effective BIM governance. School of Engineering, Cardiff University, Cardiff, UK. School of Computer Science, Hail University, Hail, Saudi Arabia, Journal of building engineering, 10, 89-101.

Barnes, P. & Davies, N. (2014) *BIM in principle and practice.* U.S.A. Institution of civil engineering, U.S.A. ICE Publishing.

Bell, G., Rochford, L. (2016) Rediscovering SWOT's integrative nature: A new understanding of an old framework. Labovitz School of Business and Economics, University of Minnesota, Duluth, USA. The International Journal of Management Education, 14, 310-326.

Bew, M., Richards, M., (2008-2016). Bew-Richards BIM Maturity Model.

Bradley, A., et al. (2016). BIM for infrastructure: An overall review and constructor perspective. School of Engineering, Cardiff University, Queens Building, the Parade, Cardiff, UK. Automation in Construction, 71, 139–152.

BuildingSMART (2007), National Building Information Modelling Standard Version 1 - Part 1: Overview, Principles, and Methodologies. National Institute of Building Sciences.

BuildingSMART (2017) [online] URL: http://www.buildingsmart-tech.org [Consulted 1st June 2017].

Butcher, S. (2016) Recognising women in BIM. [online] URL: https://www.linkedin.com/pulse/introducing-women-BIM-su-butcher [Consulted 8th July 2017).

Česnik, J., (2016). Analiza potenciala uvajanja BIM za javna naročila. Master Thesis. Ljubljana, University of Ljubljana, Faculty of civil and geodetic engineering. (supervisor Cerovšek, T.): 132 pp.

Chen, P.H., Nguyen, T.C. (2016) Integrating BIM and Web Map Service (WMS) for Green Building Certification. Department of Civil Engineering, National Taiwan University. Taiwan. Procedia Engineering, 164, 503 – 509.

Ciribini, A.L., Bolpagni, M., Oliveri, E. (2015) An innovative approach to e-public tendering based on Model Checking. University of Brescia, Bescia. Construction Technologies Institute-National Research Council, San Giuliano Milanese (MI), Italy. Procedia Economics and Finance, 21, 32-39.

Computer Integrated Construction Research Program (CICRP). (2010). “BIM Project Execution Planning Guide – Version 2.0.” April 16, 2010 The Pennsylvania State University, University Park, PA, USA, pp 126.

Correa, F. (2015) Is BIM Big Enough to Take Advantage of Big Data Analytics? Escola Politécnica, University of Sao Paulo, Brazil. ISARC Proceedings, pp 8.

Directive 2014/24/EU of the European Parliament and of the Council. of 26 February 2014 on public procurement and repealing Directive 2004/18/EC Text with EEA relevance.

Directive 2013/34/EU of the European Parliament and of the Council of 26 June 2013 on the annual financial statements, consolidated financial statements and related reports of certain types of undertakings, amending Directive 2006/43/EC of the European Parliament and of the Council and repealing Council Directives 78/660/EEC and 83/349/EEC Text with EEA relevance.

Dziadosz, A., Rejment M. (2015) Risk analysis in construction project - chosen methods. Institute of Structural Engineering, Poznan University of Technology, Poznan, Poland. Institute of Building Engineering, Wroclaw University of Technology, Wroclaw, Poland. Pro**ce**dia Engineering, 122, 258 – 265.

Eadie, R. et al. (2013) *BIM implementation throughout the UK construction project lifecycle: An analysis*. School of the Built Environment, University of Ulster, United Kingdom. WDR & RT Taggart, Architects and Engineers, Belfast, United Kingdom. Automation in Construction, 36, 145–151.

Elshakour, H. (2015) Types of construction contracts Report. Construction Management department, King Saud University, Riyadh, Saudi Arabia. Chapter 2, 19-41.

EUBIM TASK GROUP (2017)- *Handbook for the introduction of Building Information Modelling by the European Public Sector. Strategic action for construction sector performance: driving value, innovation and growth*. European Union [online] http://euBIM.eu/handbook [Consulted 15th July 2017].

European Commission (2017) Public Procurement. The European Single Market. [online] URL: https://ec.europa.eu/growth/single-market/public-procurement_en

Farr, E., et al. (2014) BIM as a generic configurator for facilitation of customisation in the AEC industry. New School of Architecture and Design, San Diego, California, USA. School of Environment and Technology, University of Brighton, Brighton, UK. Automation in Construction, 45, 119-125.

Grilo, A., Jardim-Goncalves R. (2011) *Challenging electronic procurement in the AEC sector: A BIM-based integrated perspective*. Faculdade de Ciencias e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal. Automation in Construction, 20, 107-114.

Hardin, B., McCool, D. (2015) - *BIM and Construction Management. Proven Tools, Methods and Workflows [2nd Edition]*. U.S.A. & Canada. SYBEX John Wiley & Sons.

Hore, A., McAuley, B. & West, R. (2017) BIM in Ireland 2017, BIM Innovation Capability Programme, CitA Ltd.

Isikdag U., Zlatanova, S. "A SWOT analysis on the implementation of Building Information Models within the Geospatial Environment". Independent Consultant, Turkey. GISt, OTB, TUDelft, The Netherlands. Urban and Regional Data Management, 15 – 32.

Kreider, R. et al. (2010). Determining the frequency and impact of applying BIM for different purposes on projects. Engineering Unit A, State College, Pennsylvania, USA., 1-10.

Luo, Y., Wu, W. (2015) Sustainable Design with BIM Facilitation in Project-based Learning. California State University, Fresno, USA. Procedia Engineering, 118, 819 – 826.

Martinez, AM., (2015) *BIM y las repercusiones en la calidad de los procesos constructivos. Análisis sobre la influencia de esta metodología en las etapas del proceso constructivo (Master tesis*). Departamento de Construcciones Arquitectónicas. Escola Técnica Superior d'Arquitectura. Universitat Politécnica de Catalunya, Spain. 70 pp.

McGraw-Hill Construction. (2010). THE BUSINESS VALUE OF BIM: Getting Building Information Modelling in Europe to the Bottom Line in the United Kingdom France and Germany. "Smart Market Report". New York, NY, USA.

McGraw-Hill Construction. (2014). *The business value of BIM for Construction in Major Global Markets: How contractors around the world are driving innovation with Building Information Modelling*. "Smart Market Report". Massachusetts, MA, USA 64 pp.

Mehran, D (2016) *Exploring the Adoption of BIM in the UAE construction industry for AEC firms.* Department of Energy, Geoscience, Infrastructure and Society, School of Construction Project Management, Herriot Watt University, Dubai, UAE. Procedia Engineering, 145, 1110 – 1118.

Miettinen, R., Paavola, S. (2014). Beyond the BIM utopia: Approaches to the development and implementation of building information modelling. Centre for Research on Activity, Development, and Learning (CRADLE), Institute of Behavioural Sciences, University of Helsinki, Finland. Automation in Construction, 43, 84-91.

Migilinskas, D., et al. (2013) The Benefits, Obstacles and Problems of Practical BIM Implementation. Vilnius Gediminas Technical University, Civil Engineering Faculty, Vilnius, Lithuania. Procedia Engineering, 57, 767 – 774.

NATSPEC (2011-2016) National BIM Guide. Construction Information System Limited ABN 20 117 574 606 URL: www.natspec.com.au

NBS-RIBA (2016) The Periodic table of BIM. [online] URL: https://www.thenbs.com/knowledge/periodic-table-of-BIM [Consulted 10th July 2017].

Neary, R. et al. (2010) The VA BIM Guide v1.0. U.S. Department of Veterans Affairs, Office of Construction & Facilities Management. Washington, U.S. URL: https://www.cfm.va.gov/til/BIM/BIMGuide/

NEC3 (2013) Procurement and Contract Strategies. NEC Thomas Telford Ltd. Institution of Civil Engineers (ICE). Cabinet Office UK, pp 1-23.

Niu, S., et al. (2015) A BIM-GIS Integrated Web-based Visualization System for Low Energy Building Design. Department of Civil Engineering, The University of Hong Kong, Hong Kong, China. Procedia Engineering, 121, 2184 – 2192.

Nyström, J., et al. (2016) Degrees of freedom and innovations in construction contracts. Swedish National Road and Transport Research Institute (VTI), Stockholm, Sweden. Transport Policy, 47, 119–126.

Onyango, AF. (2016) *Interaction between Lean Construction and BIM (Degree Project)*. Department of Real Estate and Construction Management. KTH Royal Institute of Technology, Stockholm, Sweden.

Park, C.S., et al. (2017) BIM-based idea bank for managing value engineering ideas. Department of Architecture Engineering, Chung-Ang University, Seoul, Republic of Korea. Korea Institute of Civil Engineering and Building Technology, Gyeonggi-do, Republic of Korea. International Journal of Project Management, 35, 699–713.

Porwal, A., Hewage, K. (2013). Building Information Modelling (BIM) partnering framework for public construction projects. Candidate, Civil Engineering, University of British Columbia| Okanagan; University Way, Kelowna, Canada. Civil Engineering, University of British Columbia| Okanagan; University Way, Kelowna, Canada. Automation in Construction, 31, 204–214.

RIBA Enterprise (2013) RIBA Plan of Work. [online] URL: www.ribaplanofwork.com [Consulted 10th March 2017].

Serpell, A. et al. (2015). Assessing the client's risk management performance in construction procurement and contracting: Case studies. Department of Construction Engineering and Management, Pontificia Universidad Católica de Chile, Santiago, Chile. Procedia Engineering, 123, 510 – 518.

Smith, P. (2014) *BIM & the 5D Project Cost Manager*. International Cost Engineering Council (ICEC) & University of Technology Sydney (UTS), Australia. Procedia - Social and Behavioral Sciences, 119, 475 – 484.

The Joint Contracts Tribunal Limited (2011) Practice Note: Deciding on the appropriate JCT Contract. London, UK. Sweet & Maxwell Publisher.

Toth, T., Sebestyen, Z. (2015) Time-varying risks of construction projects. Budapest University of Technology and Economics, Budapest, Hungary. Procedia Engineering, 123, 565 – 573.

Trinkūnienė, E., Trinkūnas, V. (2014) Knowledge management in composition of construction contracts. Vilnius Gedimino Technical University, Vilnius, Lithuania. Entreprenurial Business and Economics Review, 2(4), 101-112, DOI: http://dx.doi.org/10.15678/EBER.2014.020407

Ustinovicius, L. et al. (2006) Verbal Analysis of Financial Risk Elements in Construction Contracts. Department of Construction Technology and Management Vilnius Gediminas Technical University. Vilnius, Lithuania. pp 1-8.

Vargas, R. (2008) *Estadística II. Programa Administración Pública Territorial*. Escuela Superior de Administración Pública, Bogotá, Colombia, pp. 88.

Virtual Viewing (2016) BIM Solutions Virtual Viewing Ltd, United Kingdom. [online] URL: http://www.virtualviewing.co.uk/slimBIM/

Won, J., Lee, G. (2016) How to tell if a BIM Project is successful: A goal-drive approach. Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong, China. Department of Architectural Engineering, Yonsei University, Seoul, Republic of Korea. Automation in Construction, 69, 34-43.

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ADDENDUMS

ADDENDUM ONE_ ABBREVIATIONS, INITIALS AND ACRONYMS

AEC Architecture, Engineering and Construction

BAS Building Automation System

BIM Building Information Modelling

CAD Computer-Aided Design

CEN Committee for Standardisation

CICRP Computer Integrated Construction Research Program

CIM Civil Information Modelling

CMAA Construction Management Association of America

COBie Construction Operations Building Information Exchange

CPL Cost Led Procurement

CRC Cooperative Research Centre

DBB Design Bid Build

DK/DA Does not know. Does not answer

DWF Design Web Format

EIR Employer's Information Requirement

EU European Union

FM Facility Management

GDP Gross Domestic Product

GIS Geographic Information System

GML Geographic Mark-up Language

GMP Guarantee Maximum Price

ICT Information Communication Technology

IFC Industry Foundation Classes

IPD Integrated Project Delivery

IPI Integrated Project Insurance

ISO International Standards Organization

ITeC Technologic Institute of Construction of Catalonia

LEED Leadership in Energy and Environmental Design

NATSPEC National Specification System of Australia

MEP Mechanical, Electrical, and Plumbing

OGC Open Geospatial Consortium

PA Project Alliancing

PDF Portable Document Format

PMBOK Project Management Body of Knowledge

PPP Public Private Partnership

RICS Royal Institution of Chartered Surveyors

ROI Return on Investment

SME Small and Medium Enterprise

SLAM Simultaneous Localisation and Mapping

SWOT Strengths, Weaknesses, Opportunities, Threats

UK United Kingdom

US United States

USACE United States Army Corps of Engineers

VE Value Engineering

WMS Web Map Service

XML Extensible Mark-up Language

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USES OF BIM

This survey is intented to be part of the analysis of the BIM uses in order to be an important requirement in future building contracts. The assestment of this survey in the project will promote the creation of a set of contractual criteria from a procurement method analysis which fits with BIM environment.

* Required

Name of the company/organization

Your answer

Type of Company/organization *

- Client/Realtor
- Surveyor
- Design
- Contractor
- Maintainer/Management
- Academic/Scientist
- Others

Size of the company *

- Micro < 10 people
- Small 10 - 49 people
- Medium 50 - 249 people
- Large 250 or > 250 people

Period the company has been using BIM *

- Not using
- < 1 year
- 1 -2 years
- 3 - 5 years
- 5 - 10 years
- > 10 years

BIM USES

Please, choose that clearly reflexes your opinion about the level of significance of each BIM use in construction projects , according to your satisfaction from your experience.

*

	1 - Very low level	2 - Low level	3 - DK/ DA	4- High level	5 - Very high level
3D Visualization and coordination	○	○	○	○	○
Augmented Reality	○	○	○	○	○
Virtual reality	○	○	○	○	○
Geographical information	○	○	○	○	○
Daylight simulation	○	○	○	○	○
Record modelling	○	○	○	○	○
Existing Conditions Modelling	○	○	○	○	○

	1 - Very low level	2 - Low level	3 - DK/ DA	4- High level	5 - Very high level
Digital fabrication	○	○	○	○	○
4D building maintenance scheduling/planning	○	○	○	○	○
Risk planning (disaster scenario)	○	○	○	○	○
Urban planning and design	○	○	○	○	○
Site utilization planning	○	○	○	○	○
Programming	○	○	○	○	○
5D cost estimation	○	○	○	○	○
Quantity Take-off (Material and cost estimation)	○	○	○	○	○
Clash detection	○	○	○	○	○
Construction process tracking	○	○	○	○	○
Safety Management	○	○	○	○	○
Space Management (conflict detection, tacking)	○	○	○	○	○
Risk management	○	○	○	○	○
6D Facility Management (Operation and maintenance)	○	○	○	○	○
Asset management	○	○	○	○	○
Design authoring	○	○	○	○	○
Quality control	○	○	○	○	○
File version control	○	○	○	○	○

	1 - Very low level	2 - Low level	3 - DK/ DA	4- High level	5 - Very high level
3D laser scanning monitoring	○	○	○	○	○
Design checking and assessment	○	○	○	○	○
Supply integration	○	○	○	○	○
Data integration	○	○	○	○	○
Additional information integration	○	○	○	○	○
Issues analysis integration (way-finding, crowd behaviour)	○	○	○	○	○
Design and fabrication integration	○	○	○	○	○
Engineering analysis (Structural, energy, lighting)	○	○	○	○	○
7D LEED sustainability analysis	○	○	○	○	○
Code Validation	○	○	○	○	○
Site analysis	○	○	○	○	○

ADDENDUM FOUR_GRAPHICS OF GENERAL RESULTS

VISUALIZATION USES

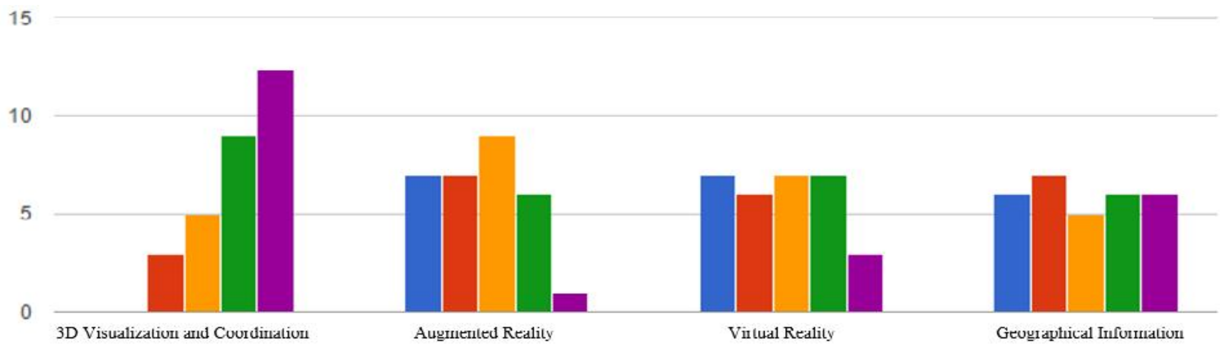

Figure 35) Visualisation Uses Graphics (1)

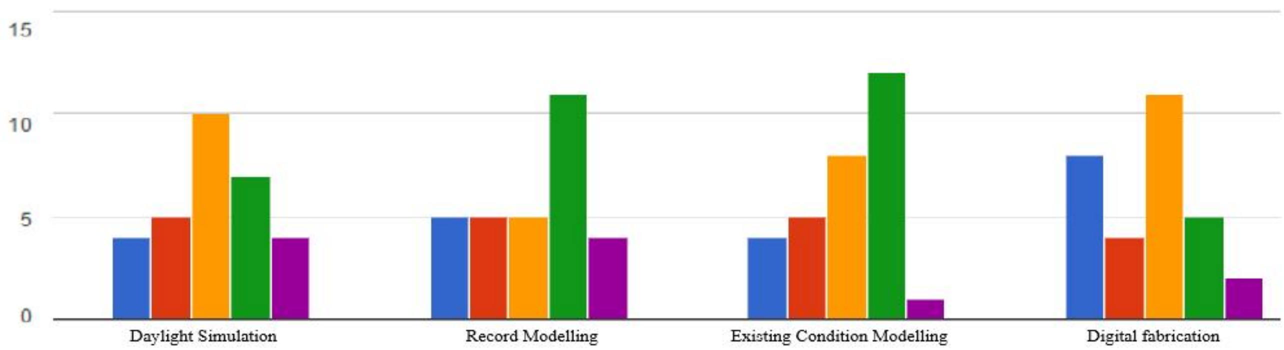

Figure 36) Visualisation Uses Graphics (2)

PLANNING USES

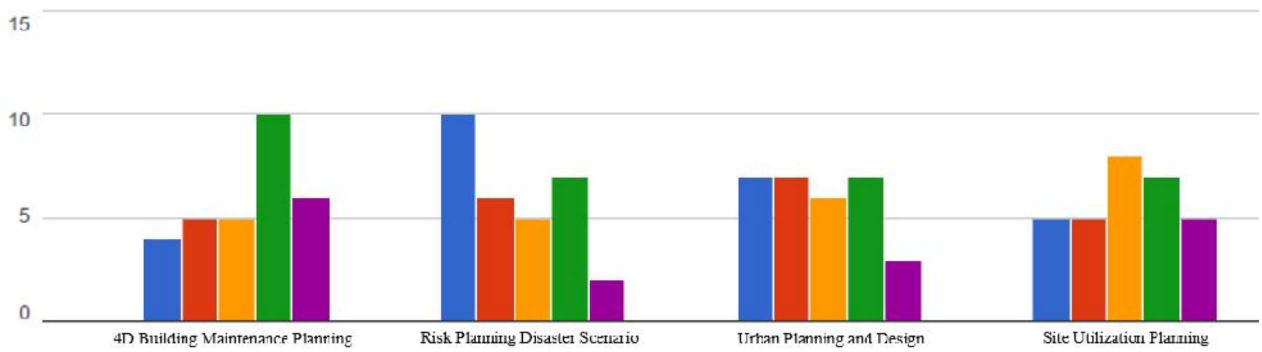

Figure 37) Planning Uses Graphics

PROGRAMMING AND ESTIMATION USES

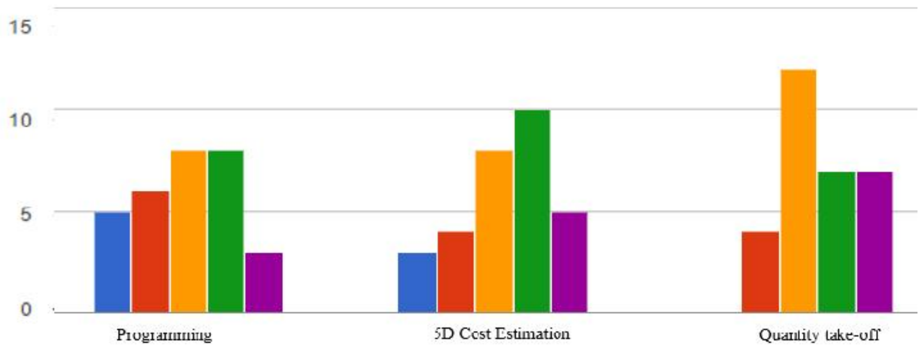

Figure 38) Programming and Estimation Uses Graphics

DETECTION AND MANAGEMENT USES

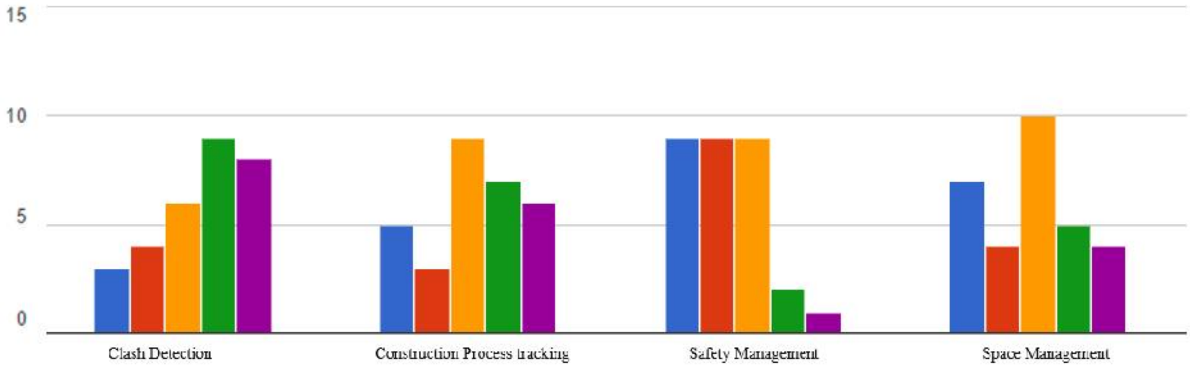

Figure 39) Detection and Management Uses Graphics

MANAGEMENT USES

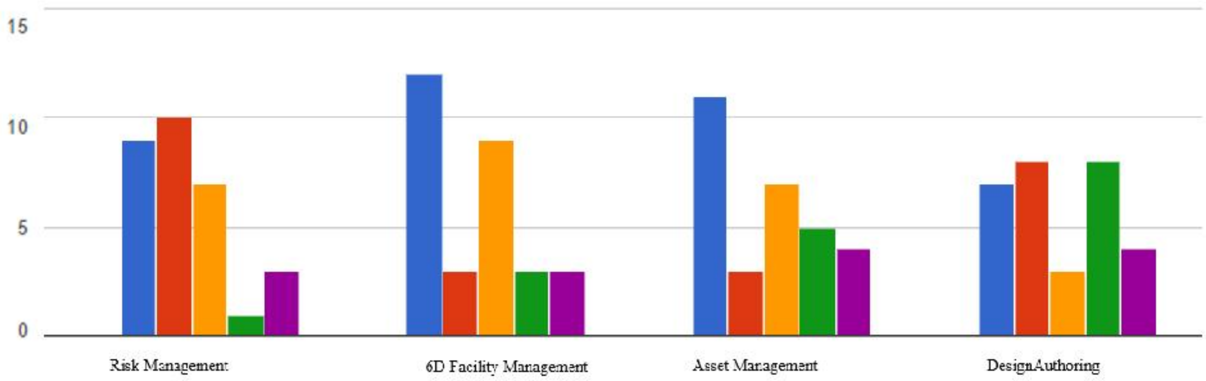

Figure 40) Management Uses Graphics

CONTROL USES

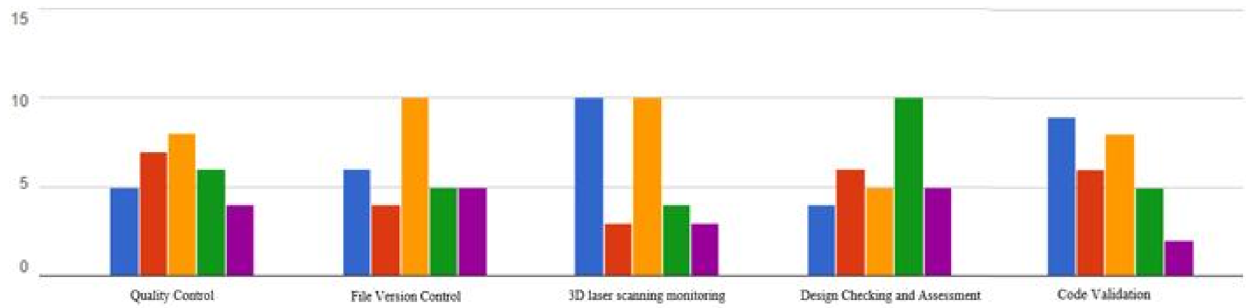

Figure 41) Control Uses Graphics

INTEGRATION USES

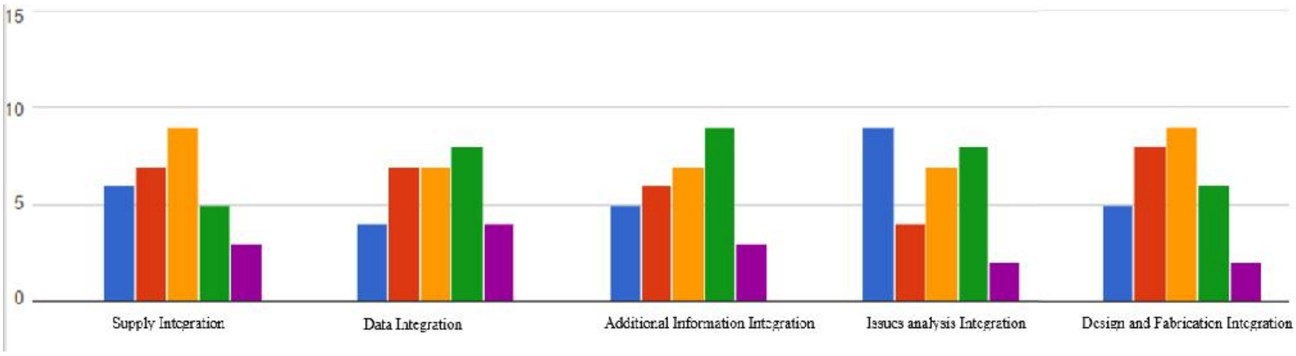

Figure 42) Integration Uses Graphics

ANALYSIS USES

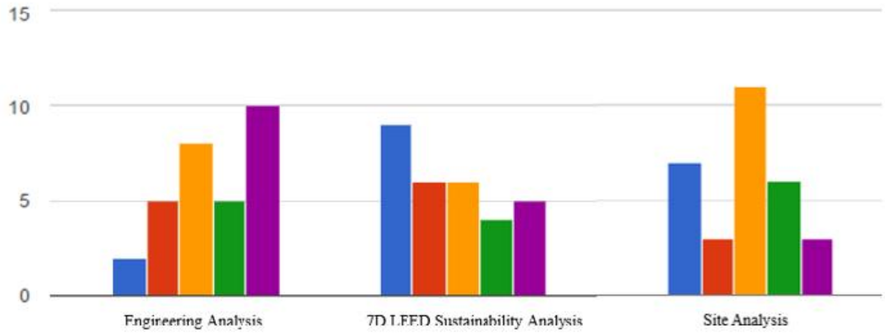

Figure 43) Analysis Uses Graphics

ADDENDUM FIVE_GRAPHIC OF ANALYSIS OF RESULTS

1º- 3D visualisation and coordination

According to type of Company

Figure 44) 3D Visualisation (Type Company) Analysis Results

According to Size of the company

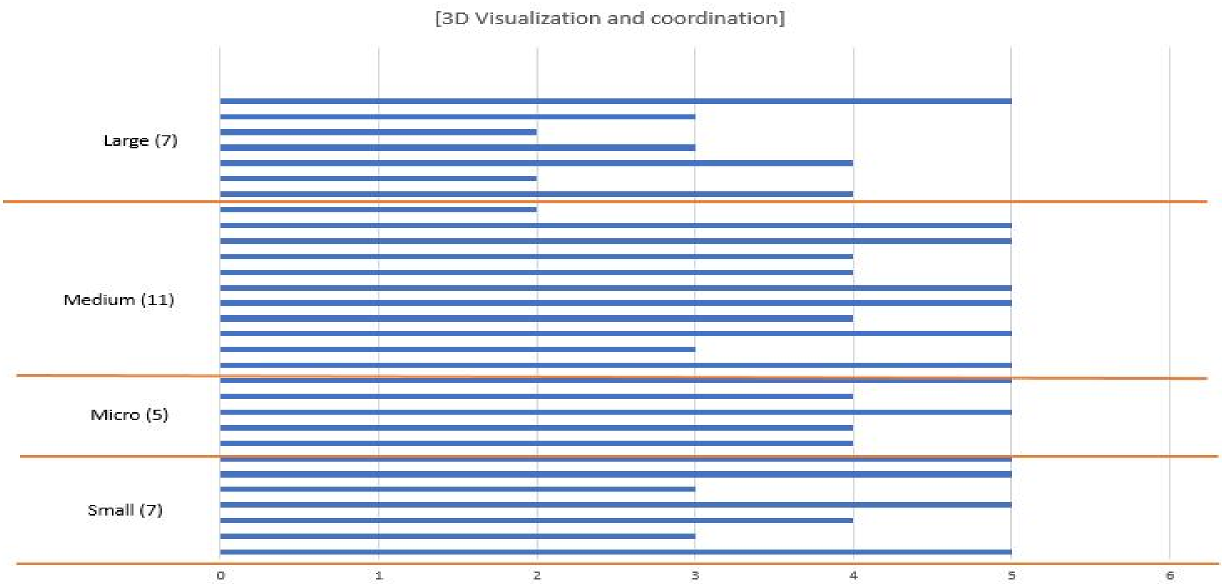

Figure 45) 3D Visualisation (Size Company) Analysis Results

According to period BIM has been used

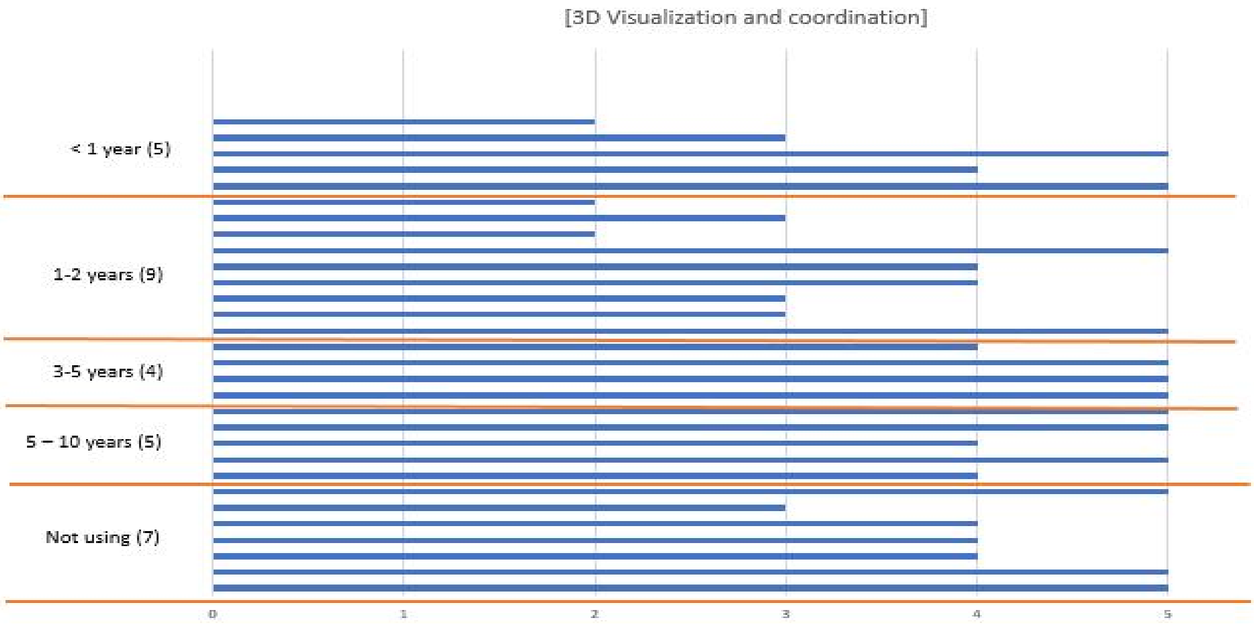

Figure 46) 3D Visualisation (Period Company) Analysis Results

2º - Geographical information

According to type of Company

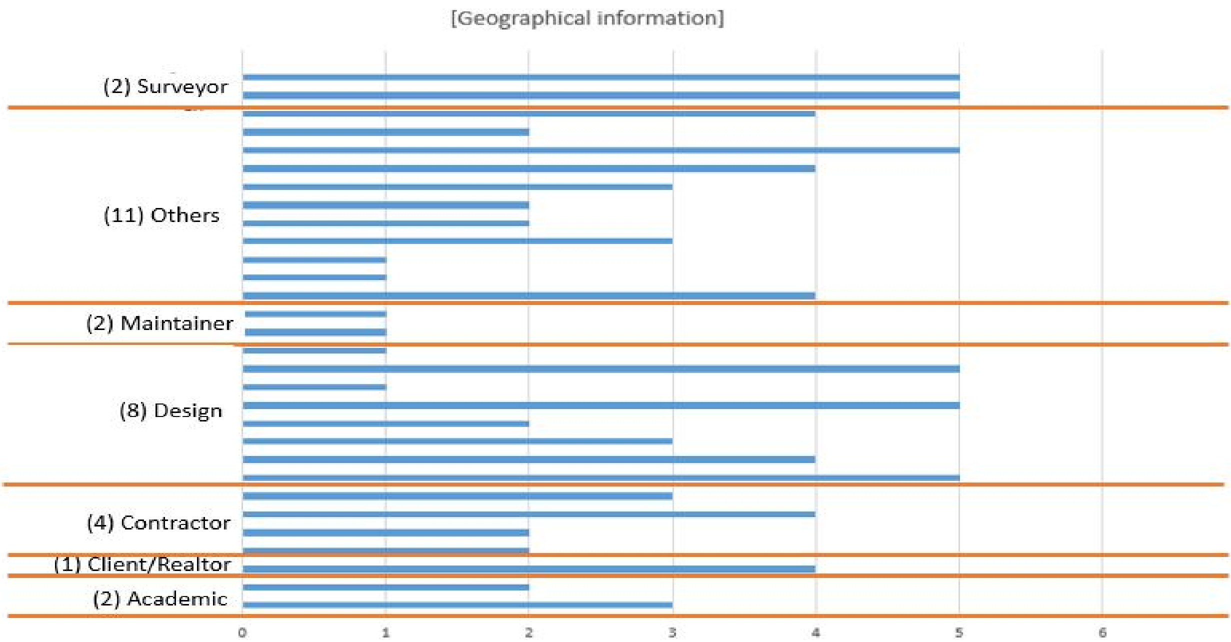

Figure 47) Geographical Information (Type) Analysis Results

According to Size of the company

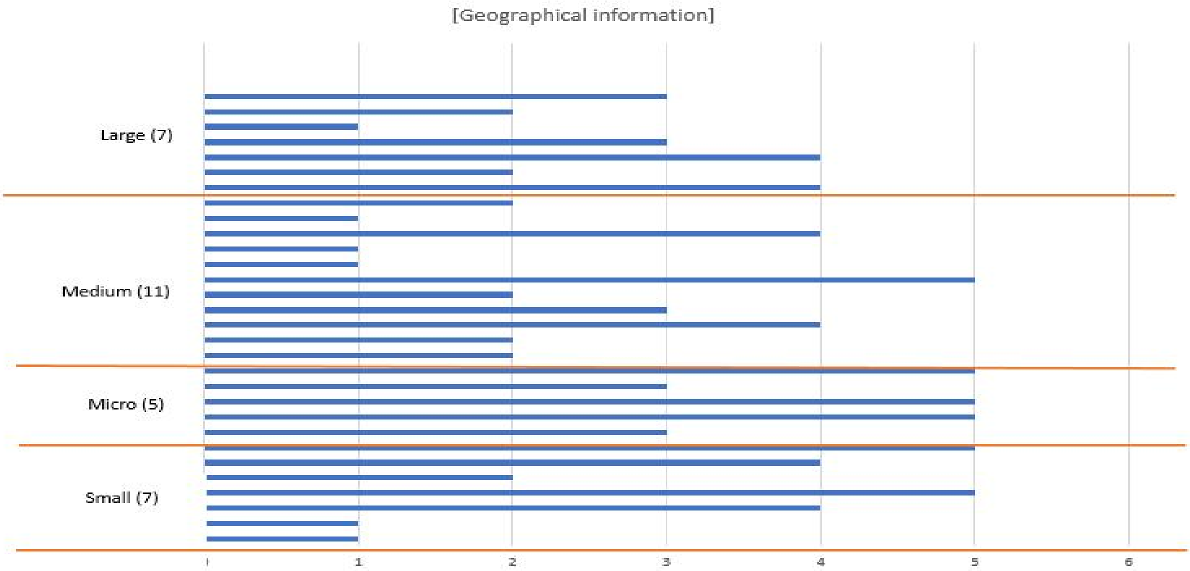

Figure 48) Geographical Information (Size) Analysis Results

According to period BIM has been used

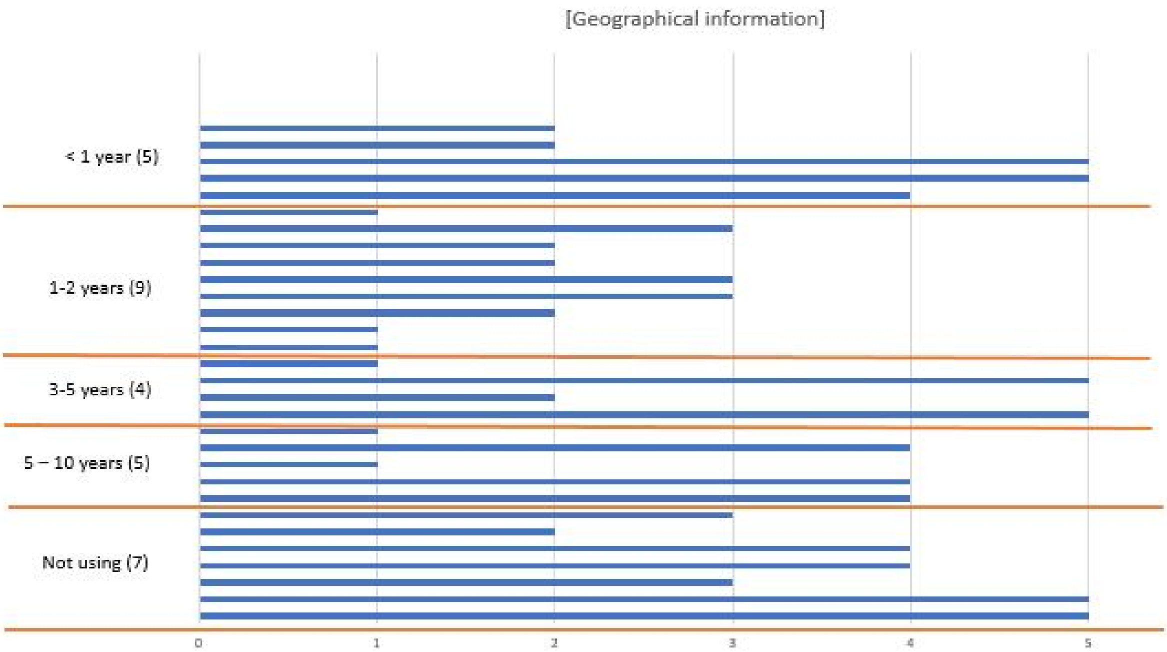

Figure 49) Geographical Information (Period) Analysis Results

3º- Existing Conditions Modelling

According to type of Company

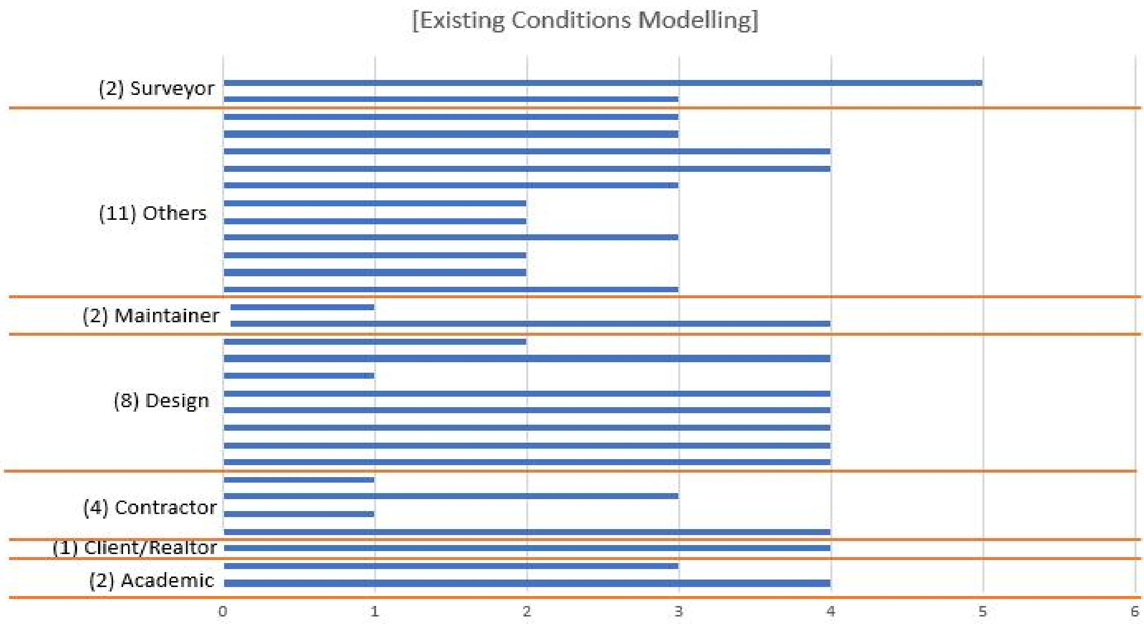

Figure 50) Existing Conditions Modelling (Type)

According to Size of the company

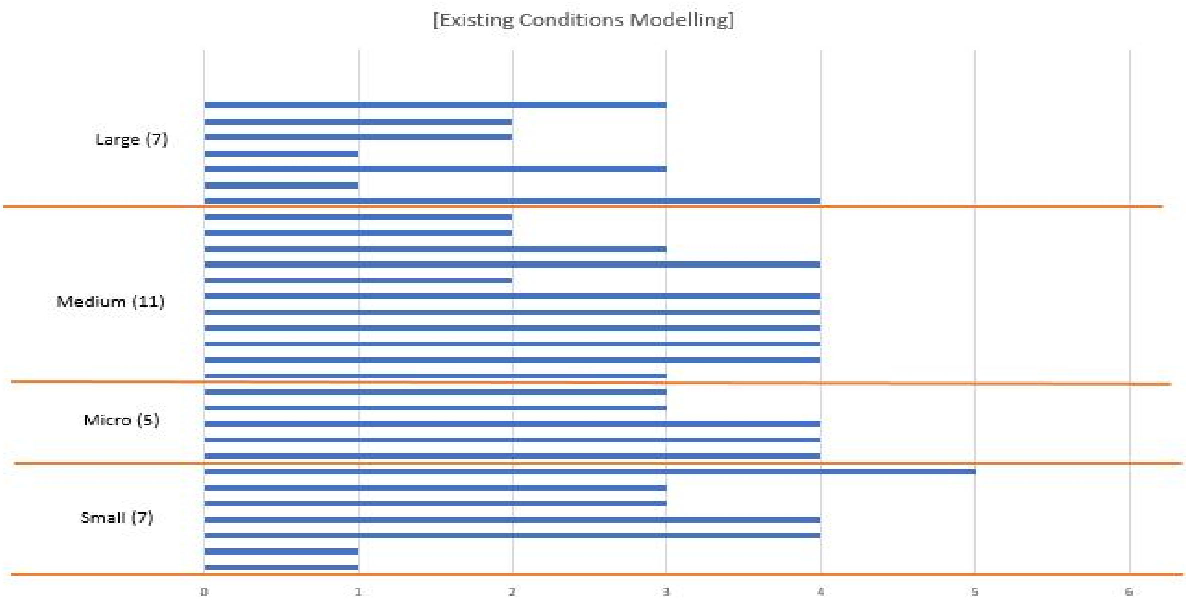

Figure 51) Existing Conditions Modelling (Size)

According to period BIM has been used

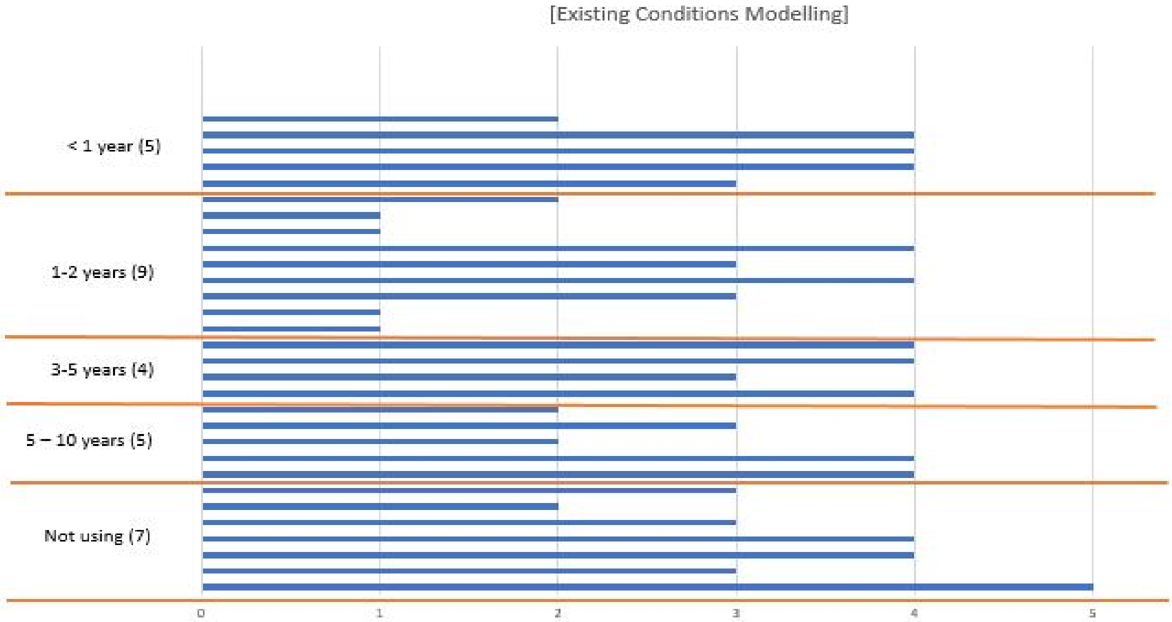

Figure 52) Existing Conditions Modelling (Period)

4º- Urban Planning and design

According to type of Company

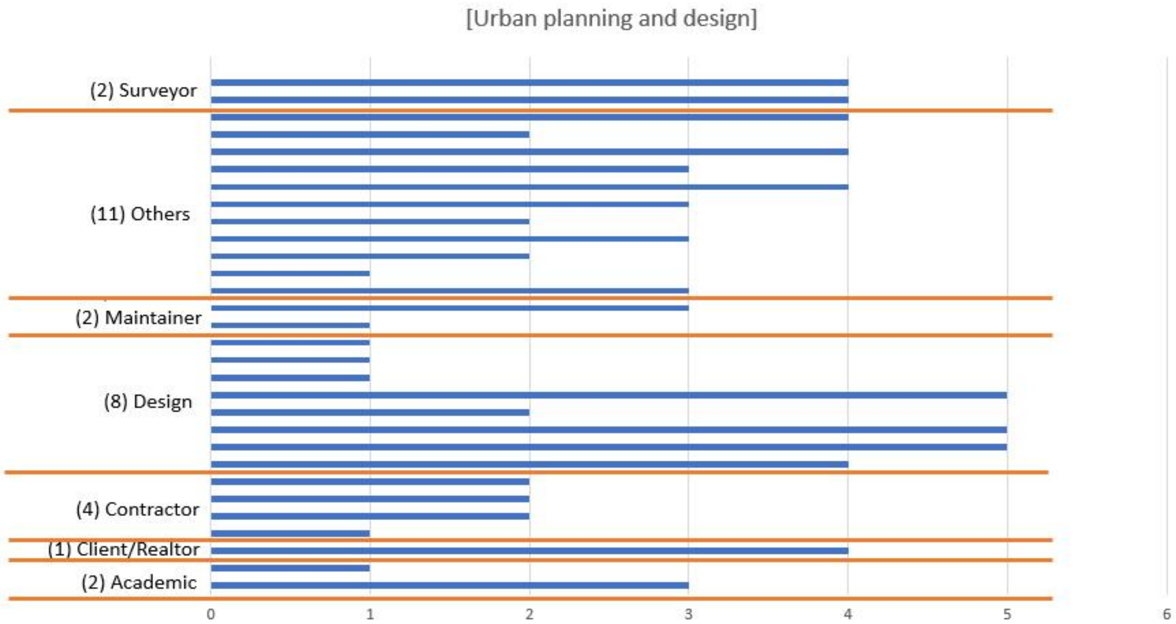

Figure 53) Urban Planning and Design (Type)

According to Size of the company

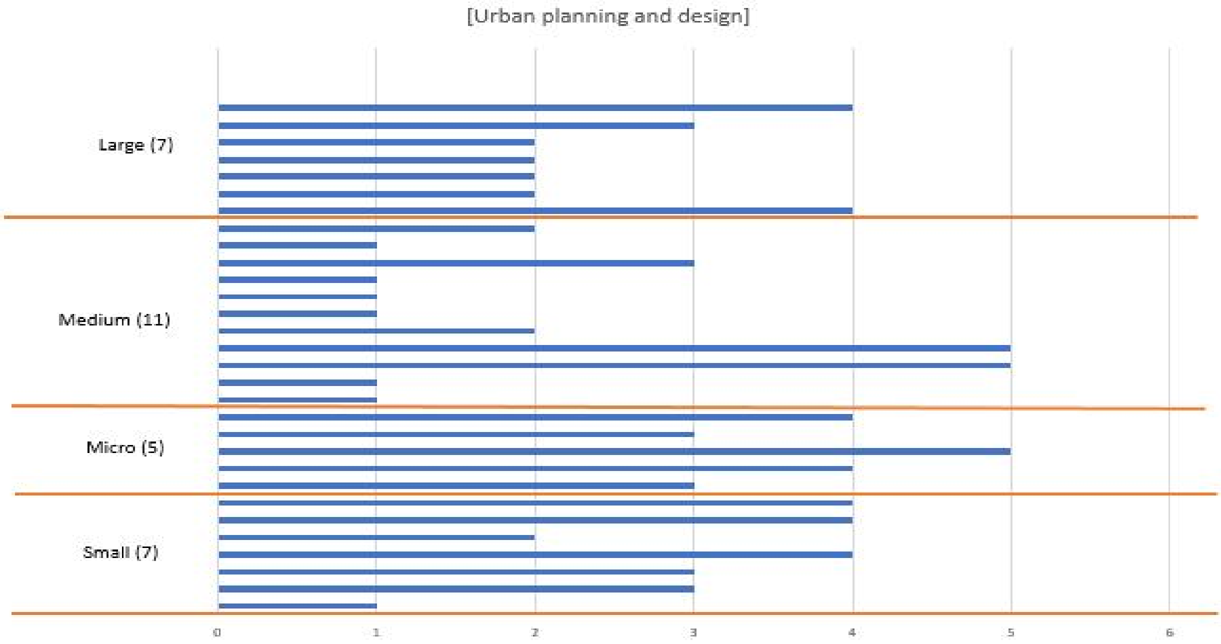

Figure 54) Urban Planning and Design (Size)

According to period BIM has been used

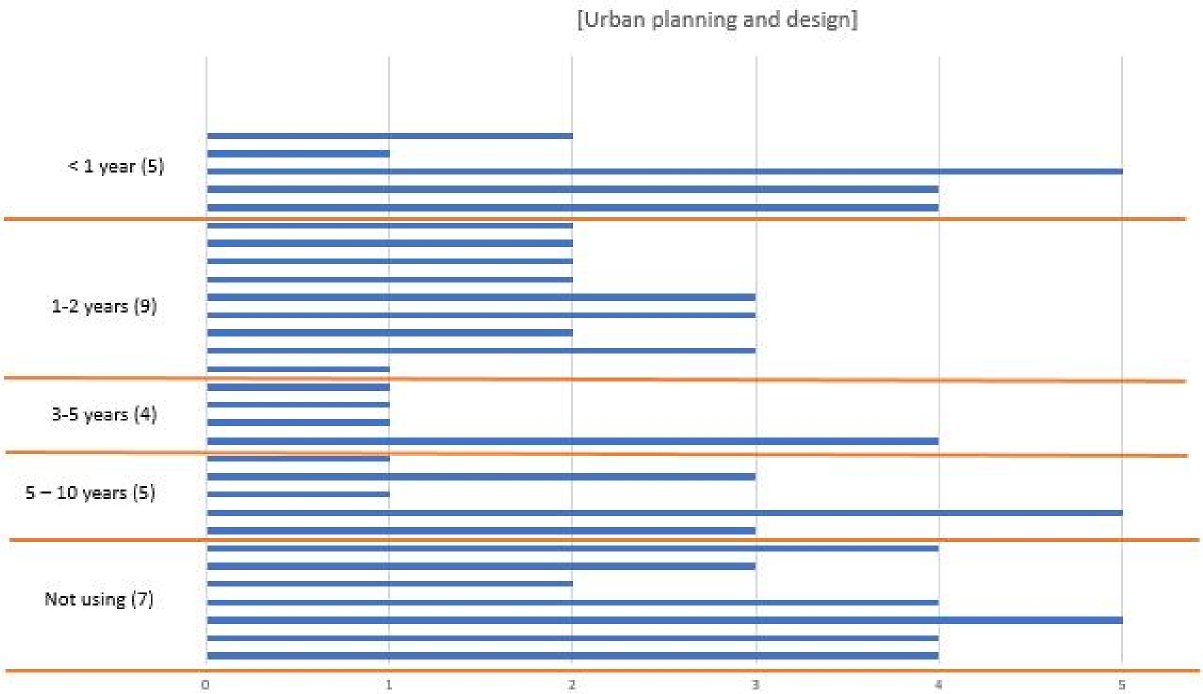

Figure 55) Urban Planning and Design (Period)

5º- Programming

According to type of Company

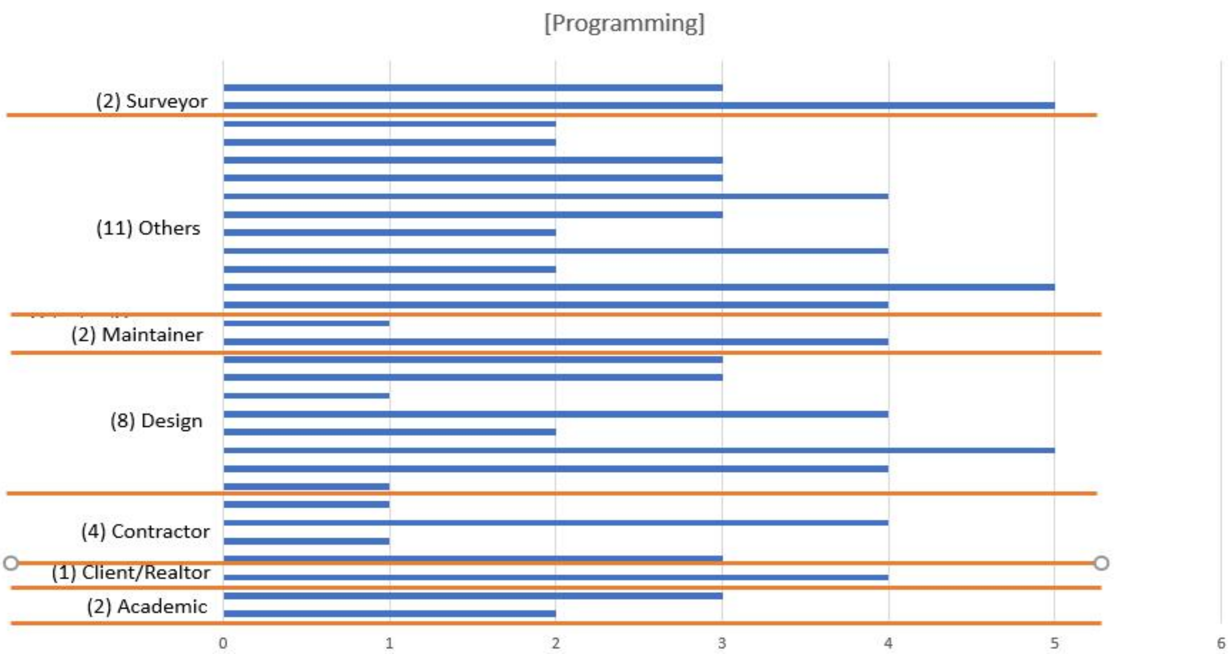

Figure 56) Programming (Type)

According to Size of the company

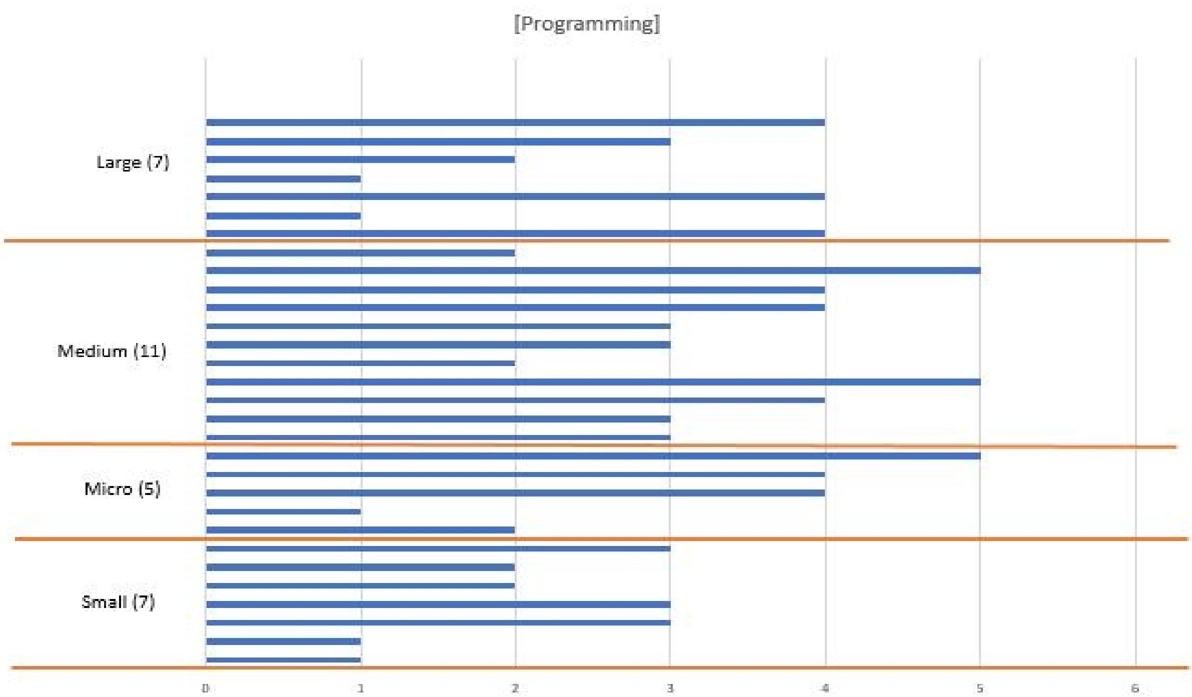

Figure 57) Programming (Size)

According to period BIM has been used

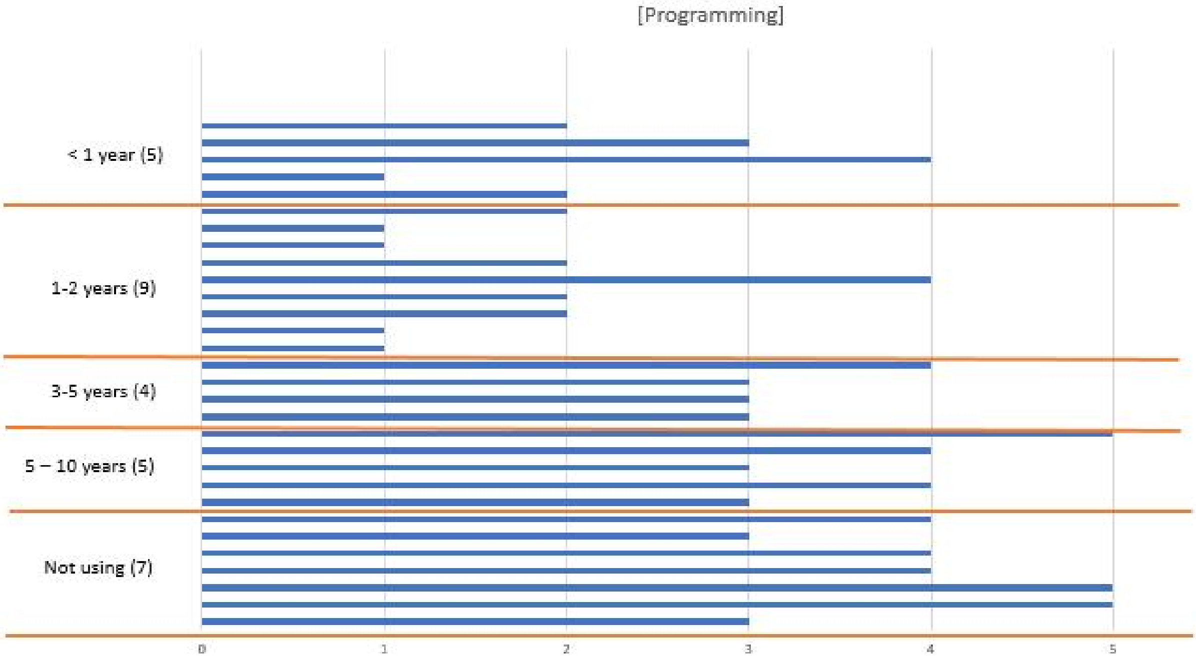

Figure 58) Programming (Period)

6º- 5D Cost Estimation

According to type of Company

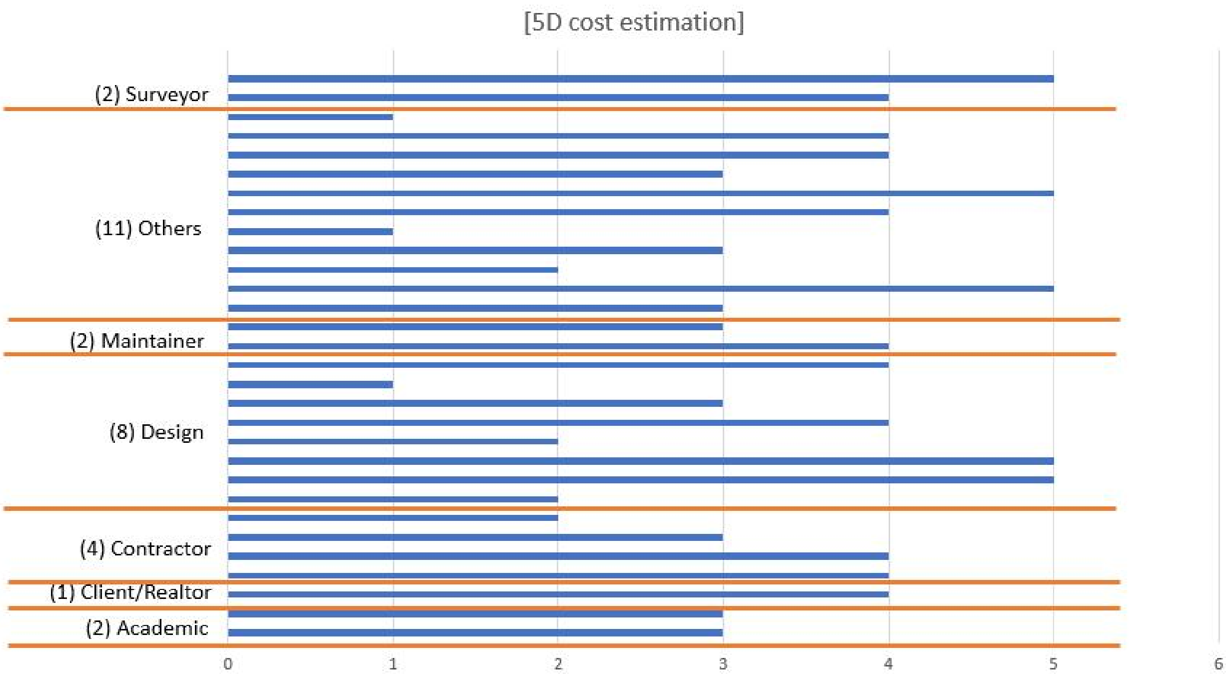

Figure 59) Cost Estimation (Type)

According to Size of the company

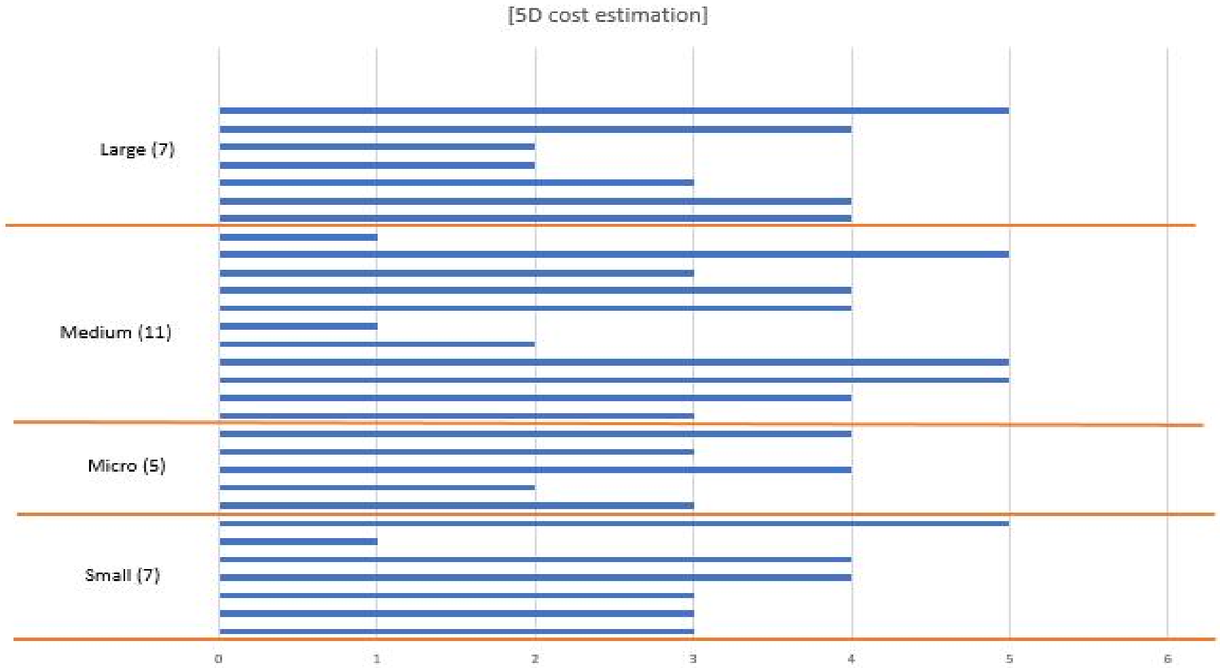

Figure 60) Cost Estimation (Size)

According to period BIM has been used

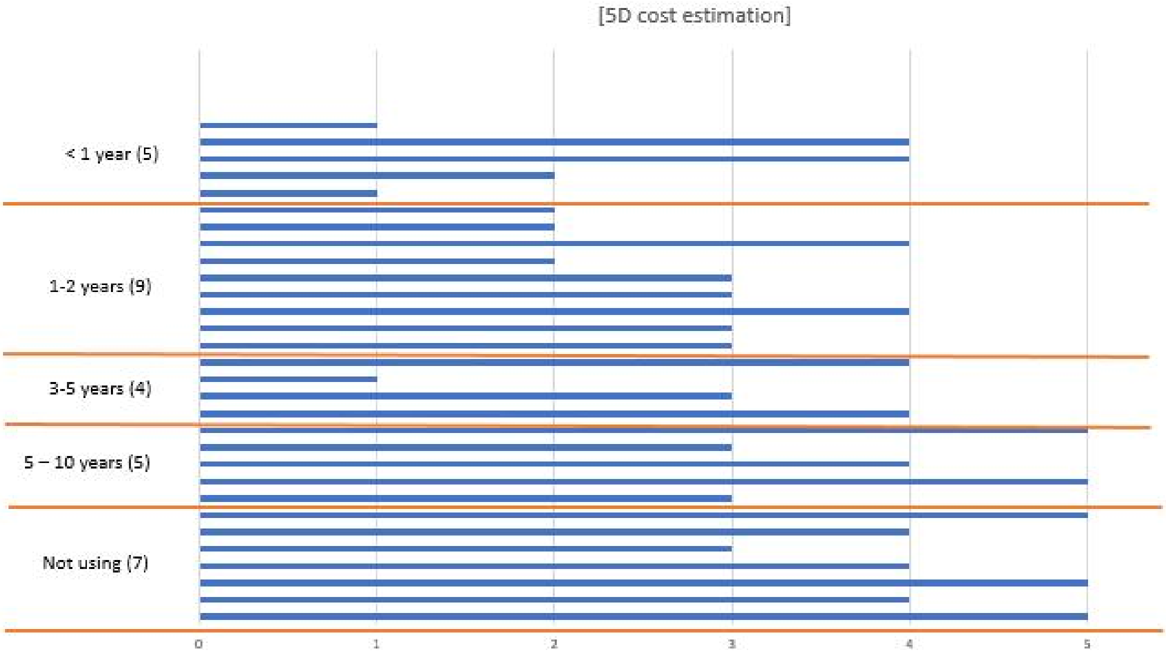

Figure 61) Cost Estimation (Period)

7º- Safety Management

According to type of Company

Figure 62) Safety Management (Type)

According to Size of the company

Figure 63) Safety Management (Size)

According to period BIM has been used

Figure 64) Safety Management (Period)

8º- Space Management

According to type of Company

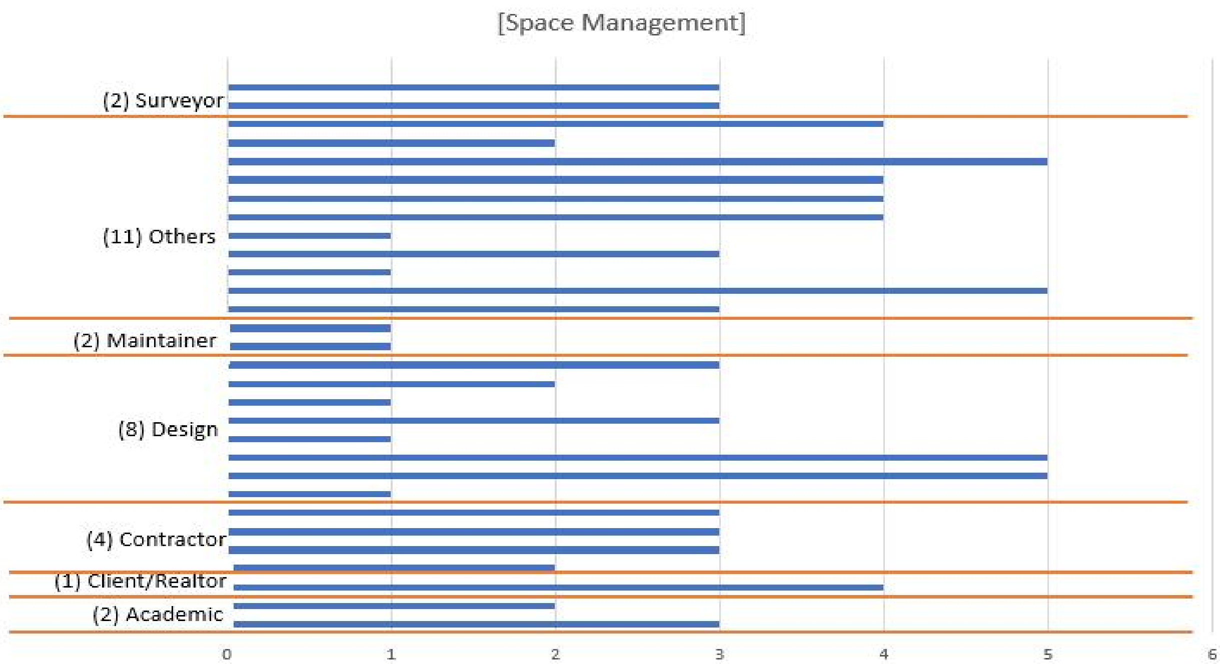

Figure 65) Space Management (Type)

According to Size of the company

Figure 66) Space Management (Size)

According to period BIM has been used

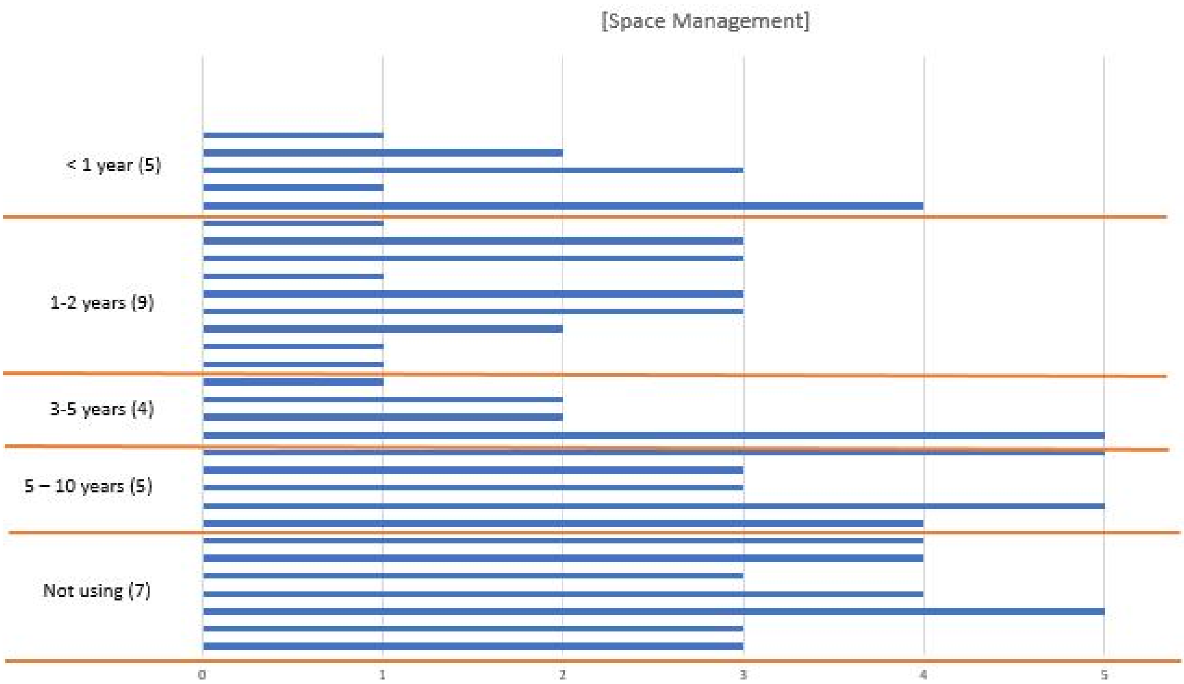

Figure 67) Space Management (Period)

9º- Risk Management

According to type of Company

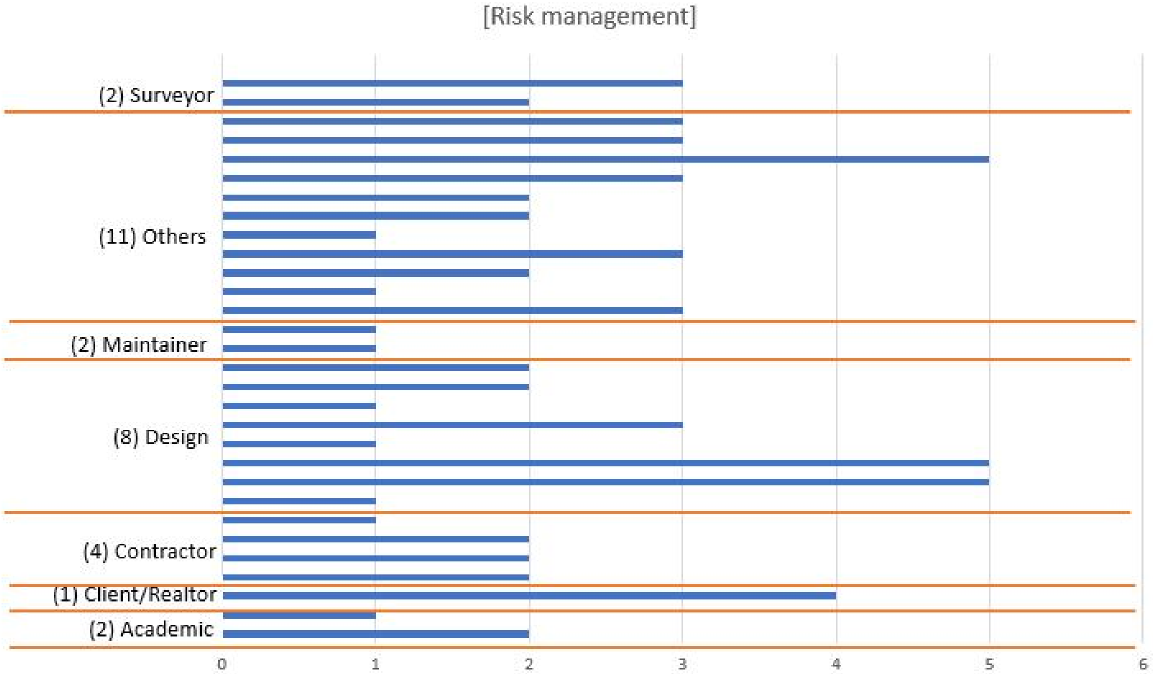

Figure 68) Risk Management (Type)

According to Size of the company

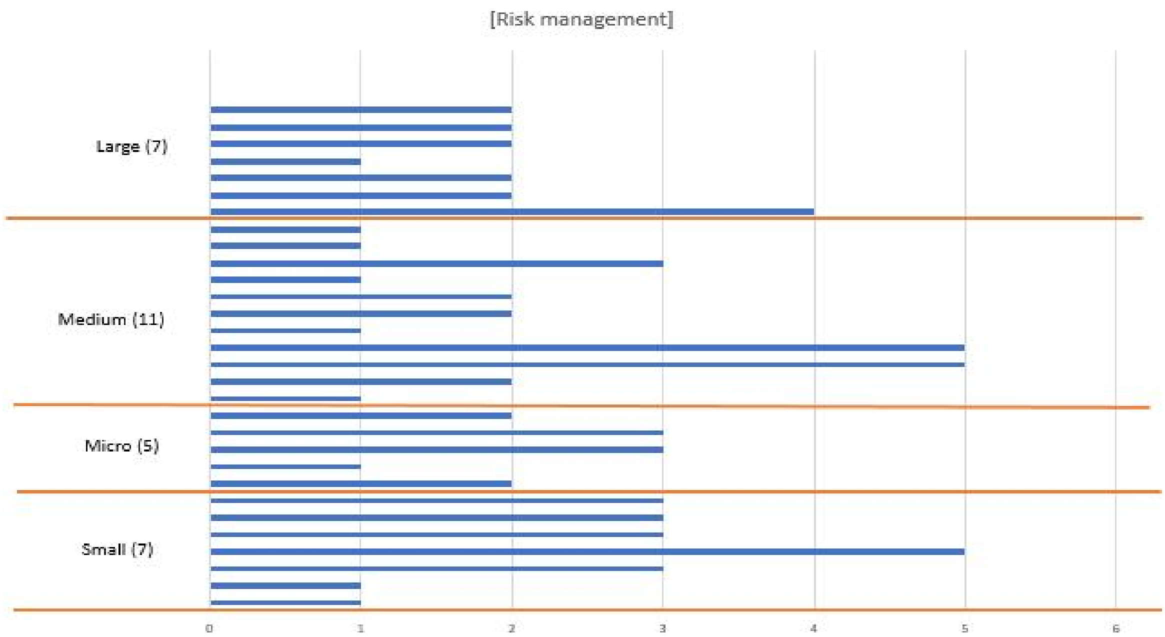

Figure 69) Risk Management (Size)

According to period BIM has been used

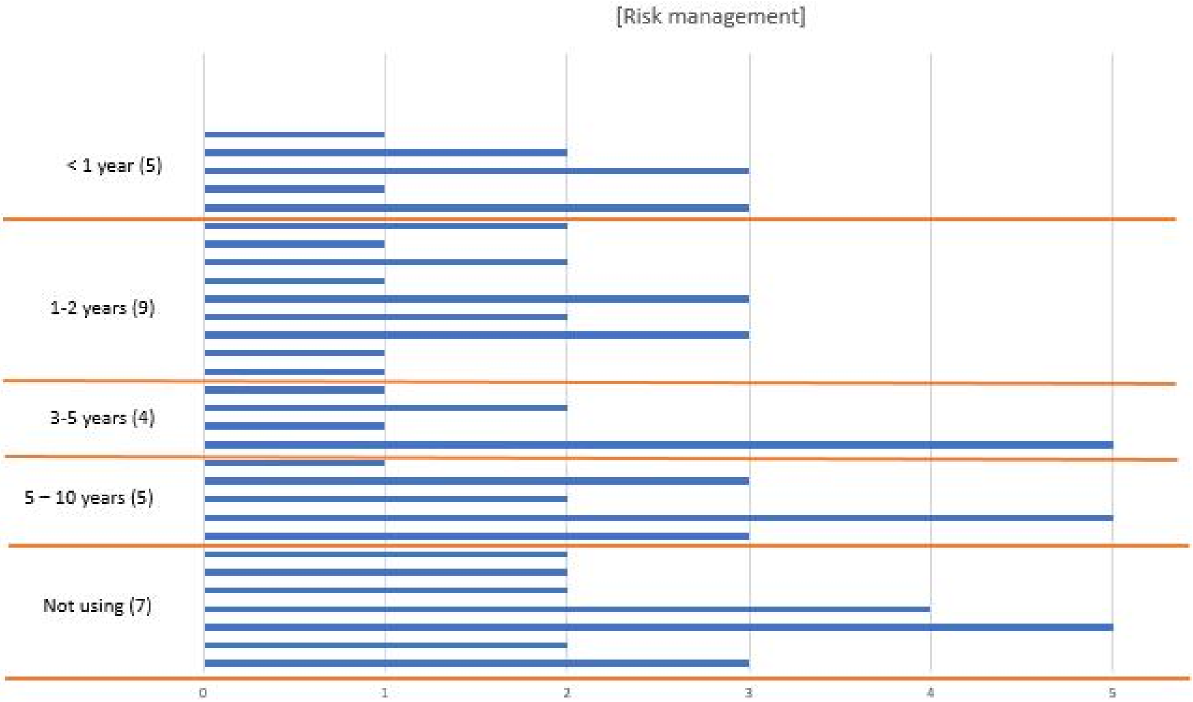

Figure 70) Risk Management (Period)

10º- Design Authoring

According to type of Company

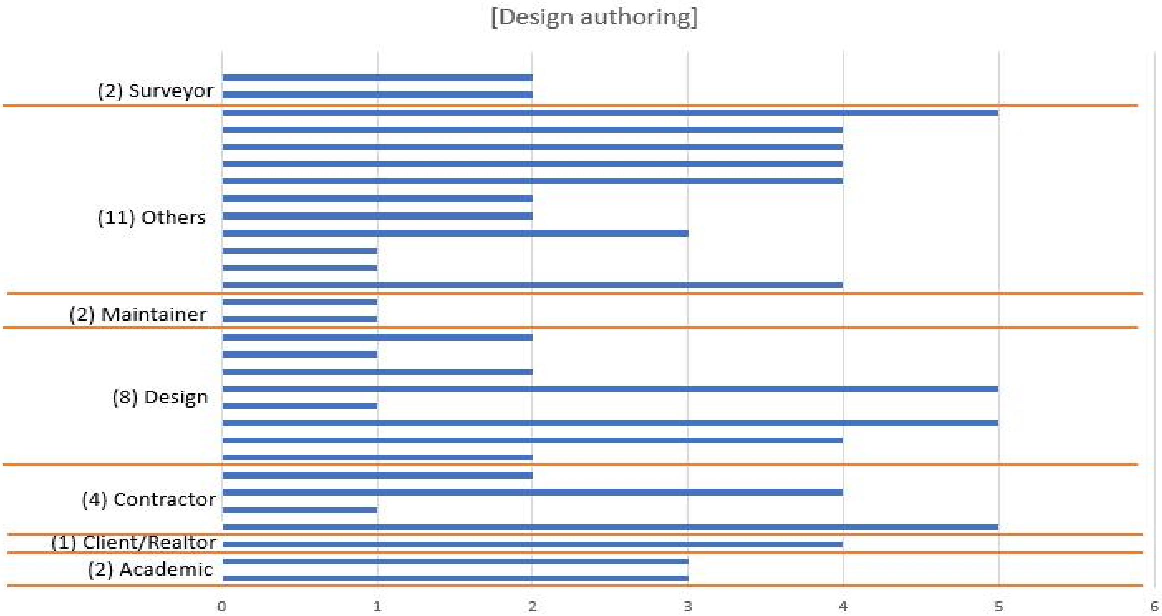

Figure 71) Design Authoring (Type)

According to Size of the company

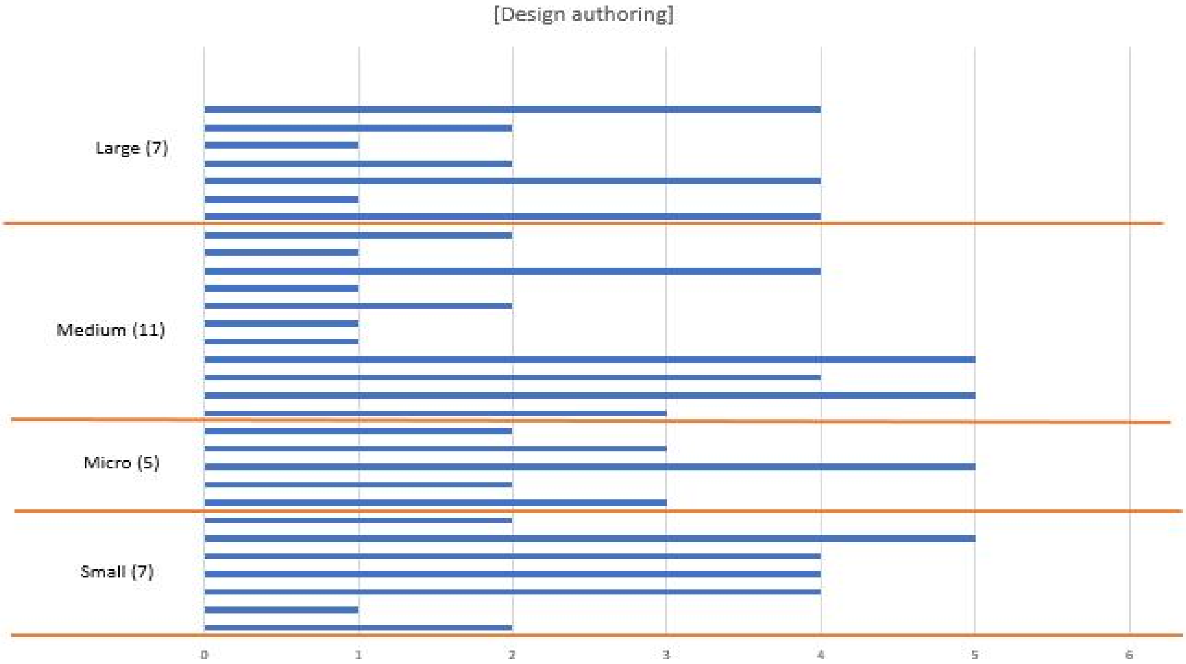

Figure 72) Design Authoring (Size)

According to period BIM has been used

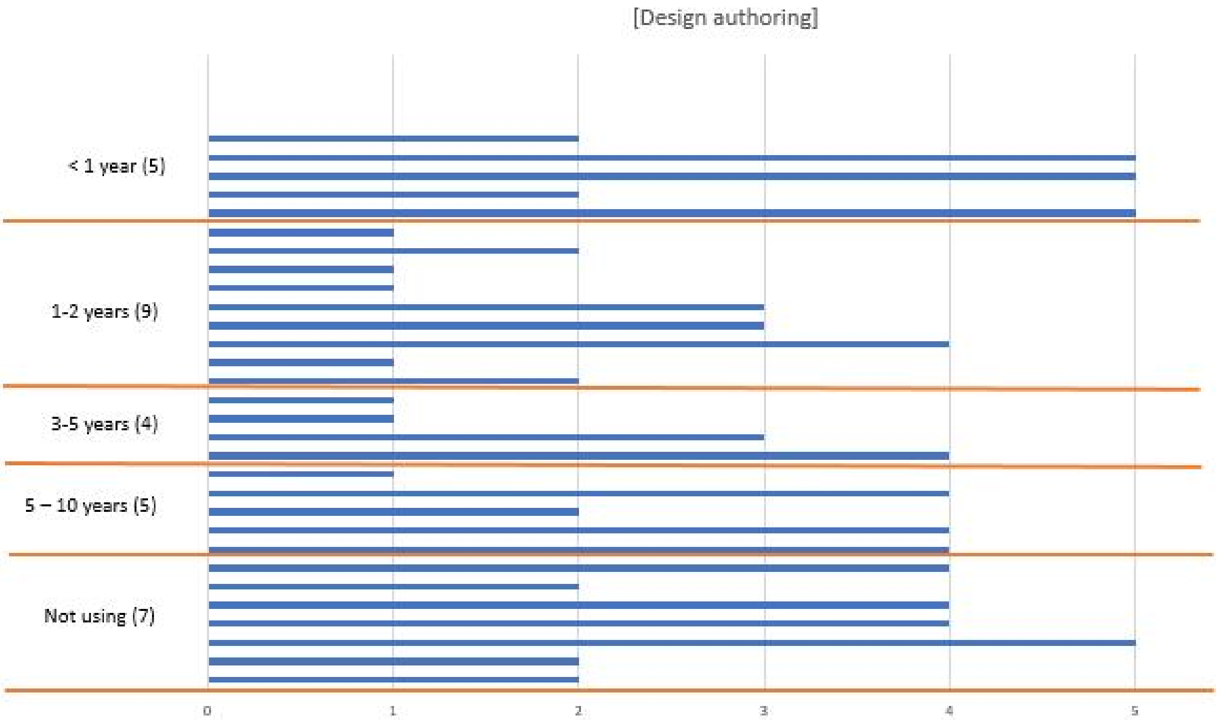

Figure 73) Design Authoring (Period)

11º- Design checking and assessment

According to type of Company

Figure 74) Design Checking and Assessment (Type)

According to Size of the company

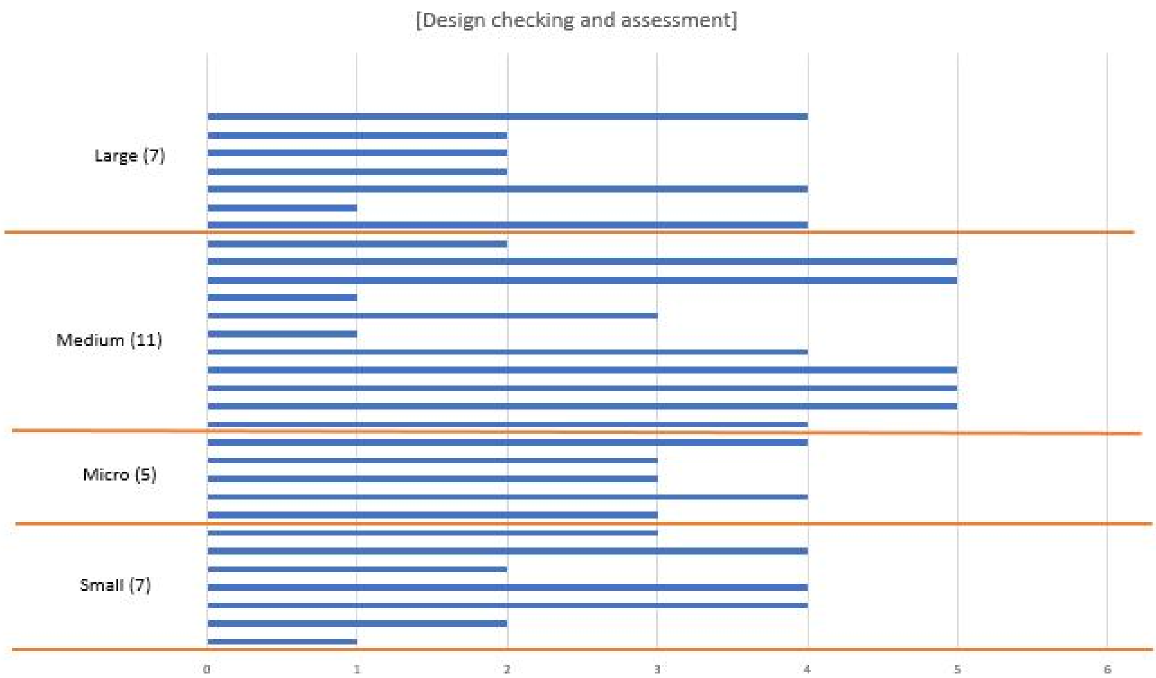

Figure 75) Design Checking and Assessment (Size)

According to period BIM has been used

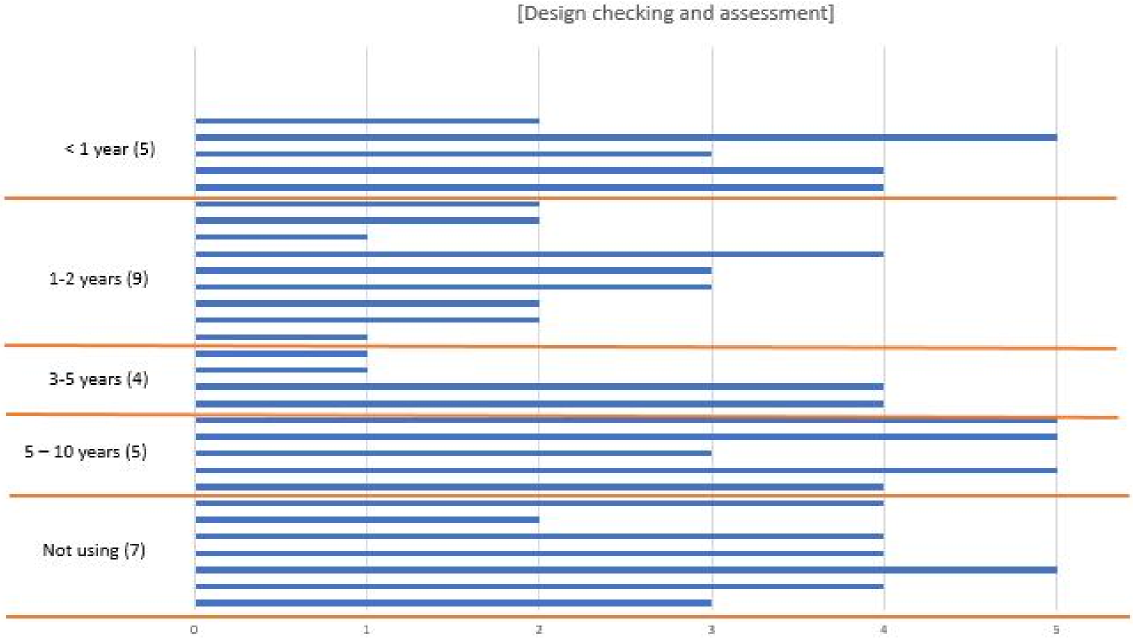

Figure 76) Design Checking and Assessment (Period)

12º- Code Validation

According to type of Company

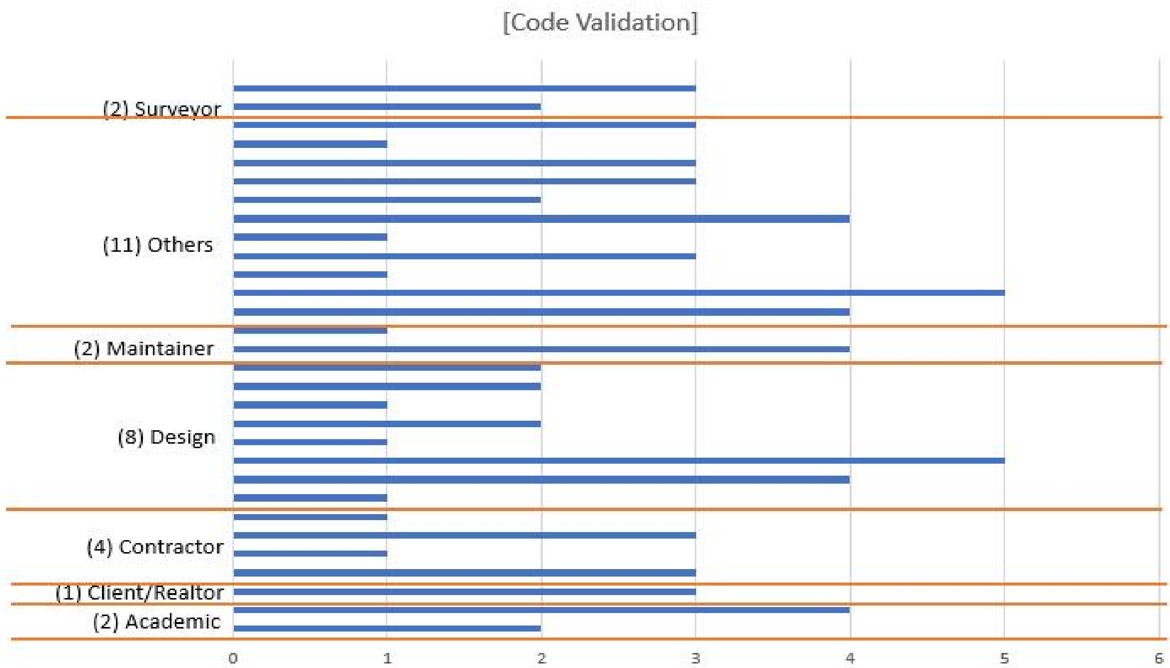

Figure 77) Code Validation (Type)

According to Size of the company

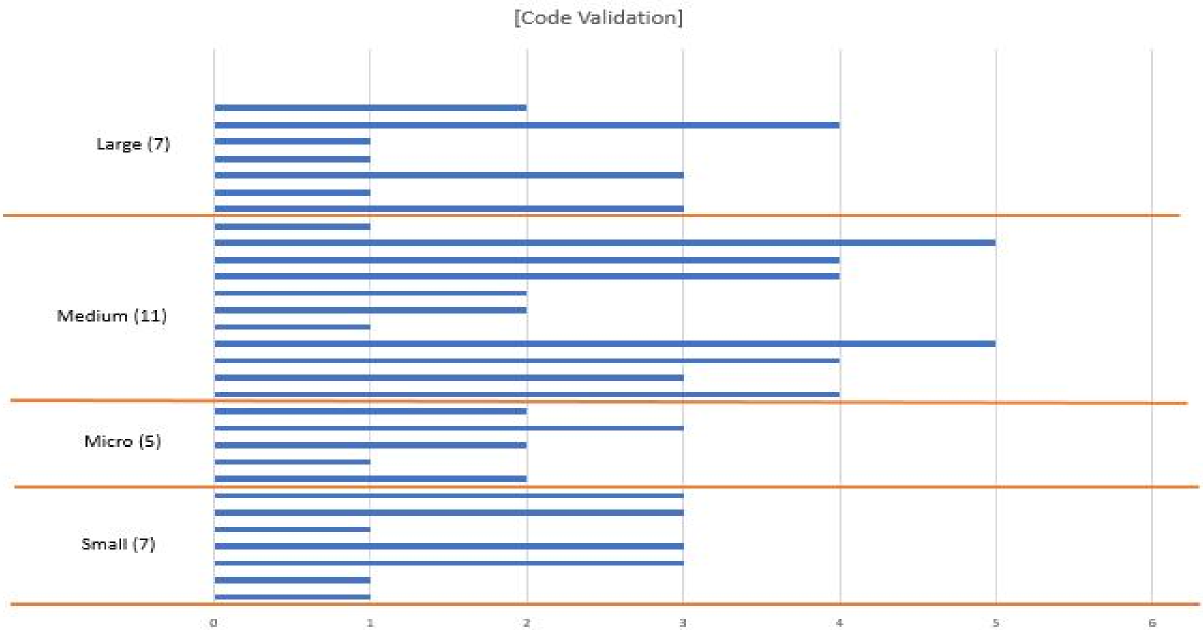

Figure 78) Code Validation (Size)

According to period BIM has been used

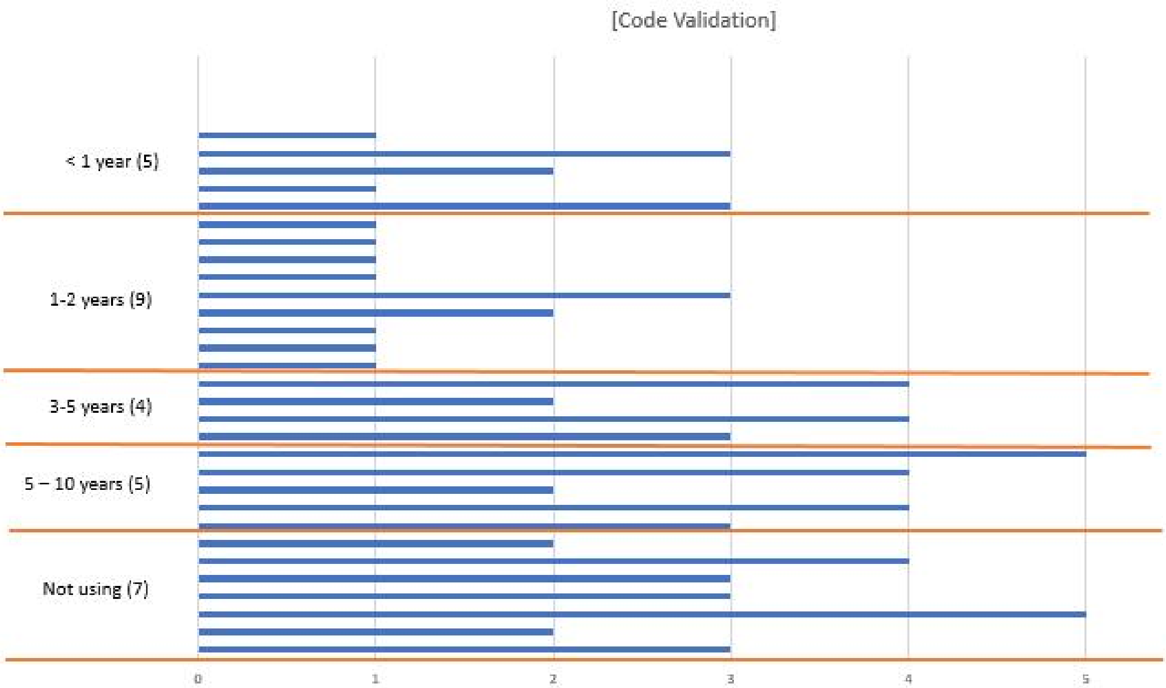

Figure 79) Code Validation (Period)

13º- Data integration

According to type of Company

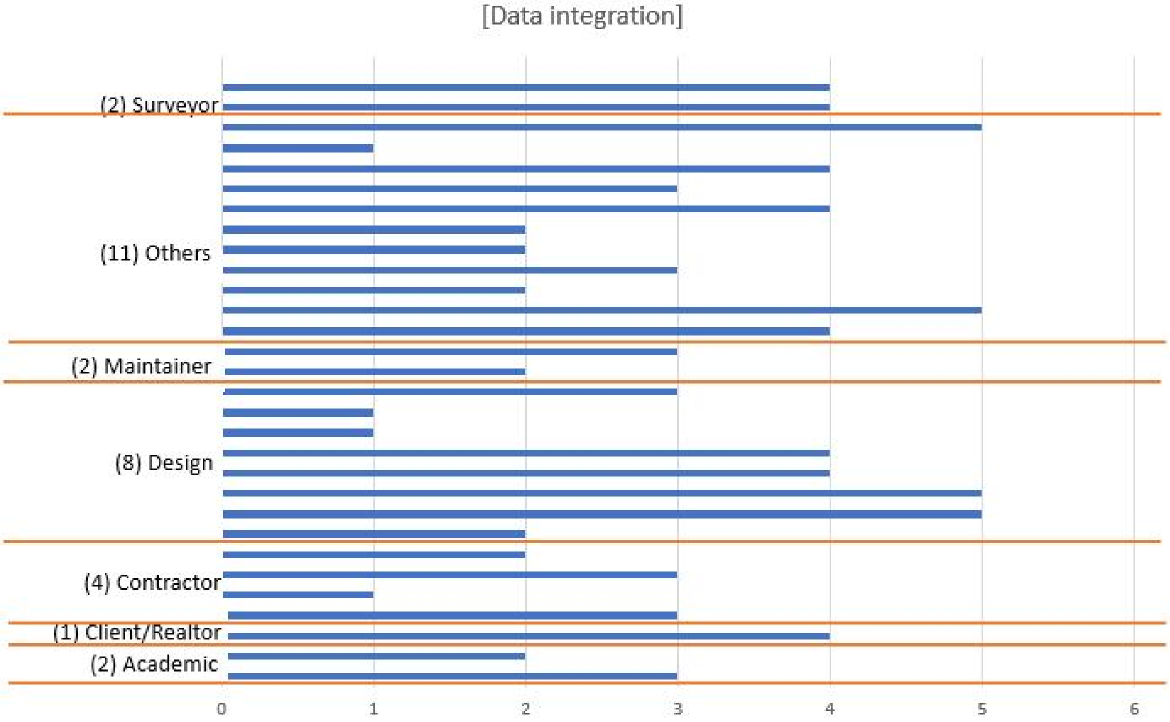

Figure 80) Data Integration (Type)

According to Size of the company

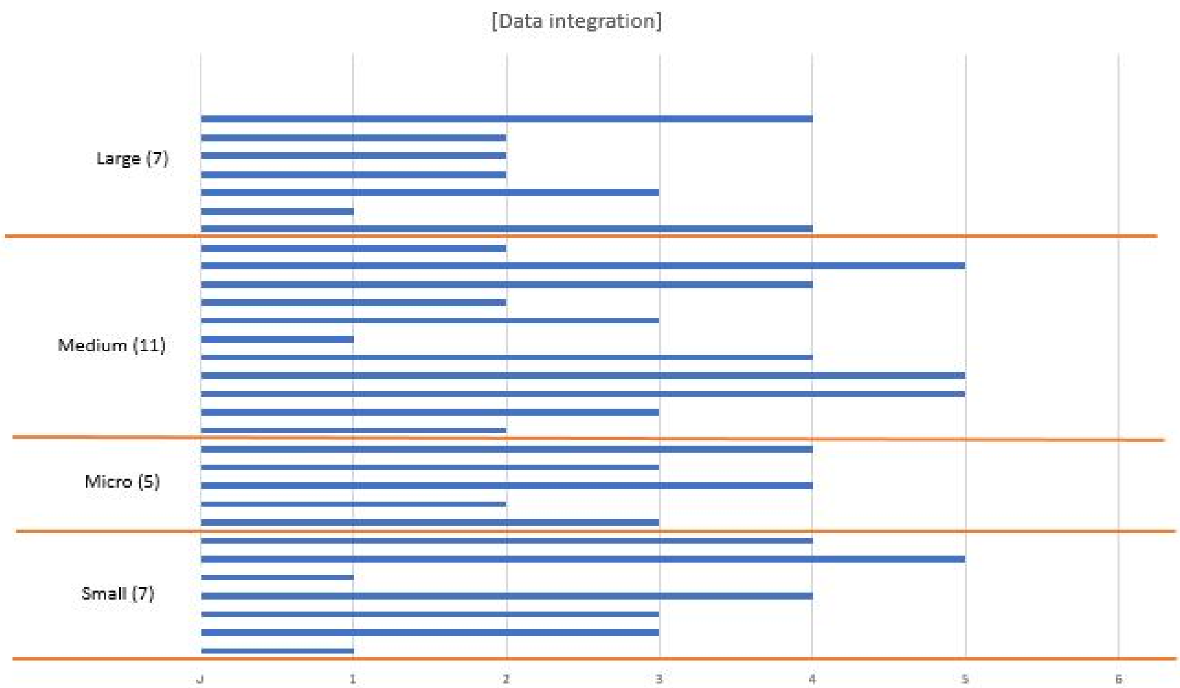

Figure 81) Data Integration (Size)

According to period BIM has been used

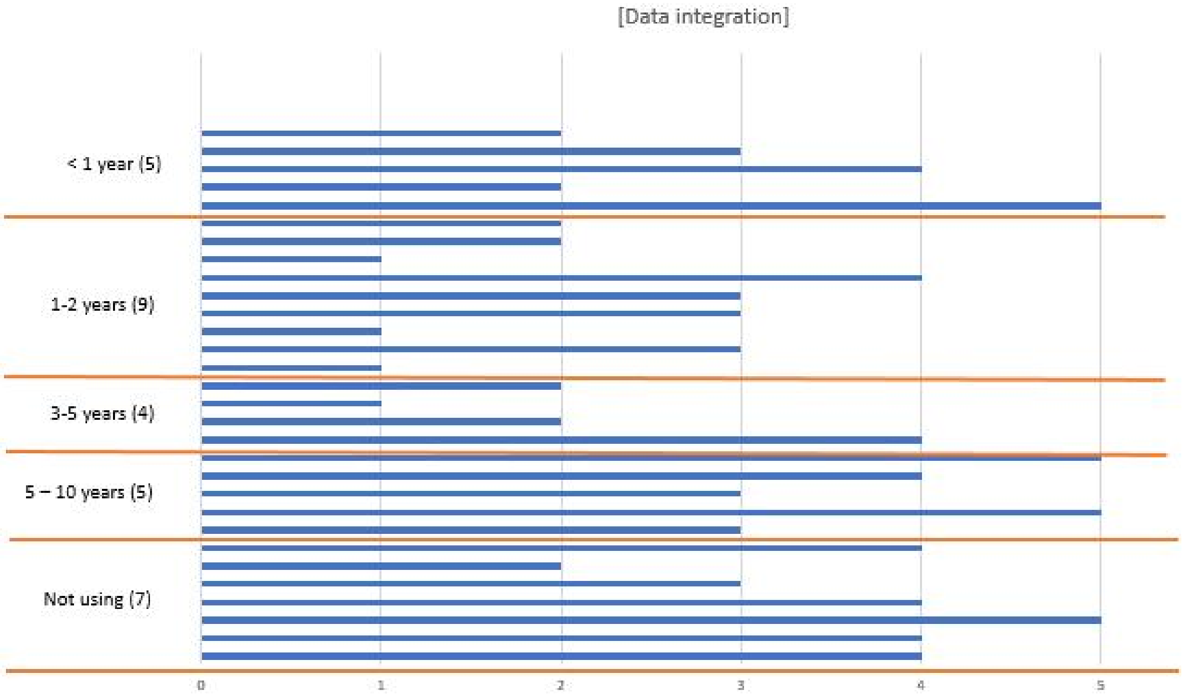

Figure 82) Data Integration (Period)

14º- Engineering analysis

According to type of Company

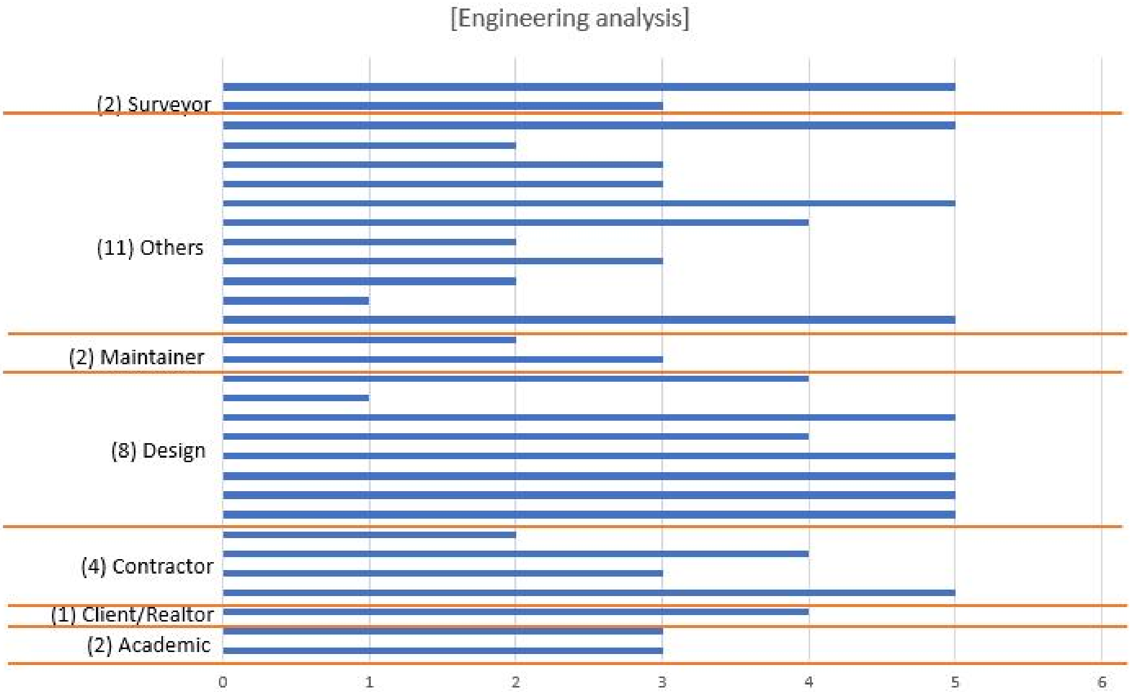

Figure 83) Engineering Analysis (Type)

According to Size of the company

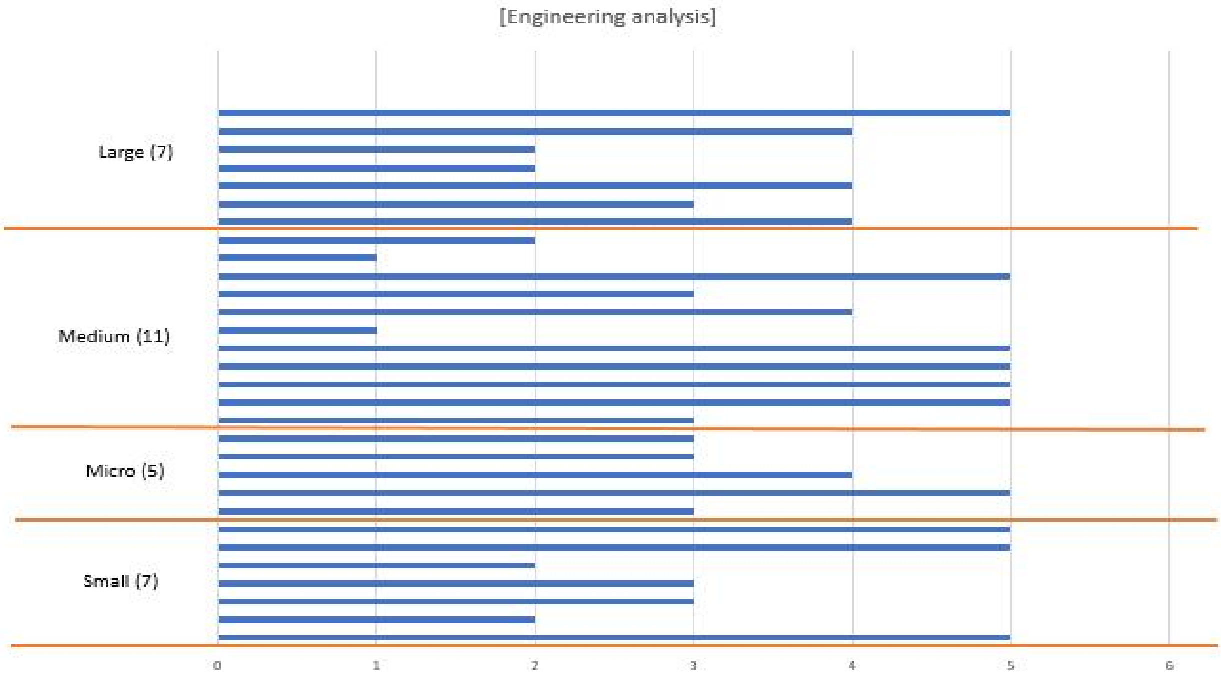

Figure 84) Engineering Analysis (Size)

According to period BIM has been used

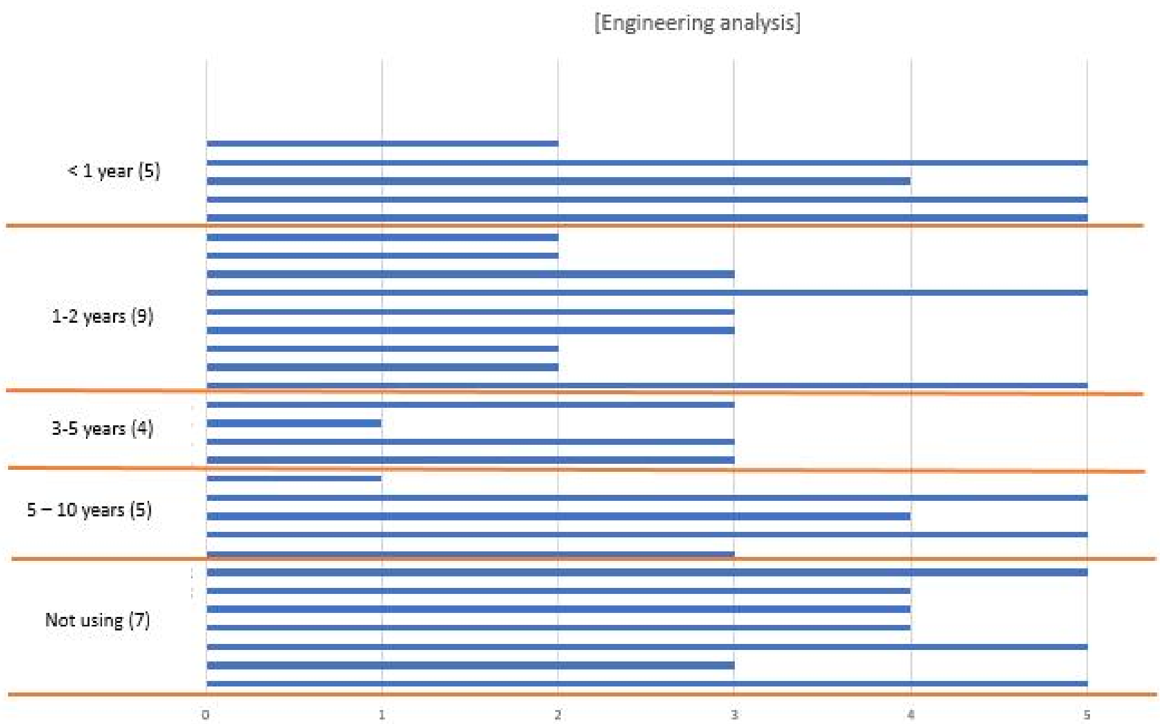

Figure 85) Engineering Analysis (Period)

15º- 7D LEED Sustainability Analysis

According to type of Company

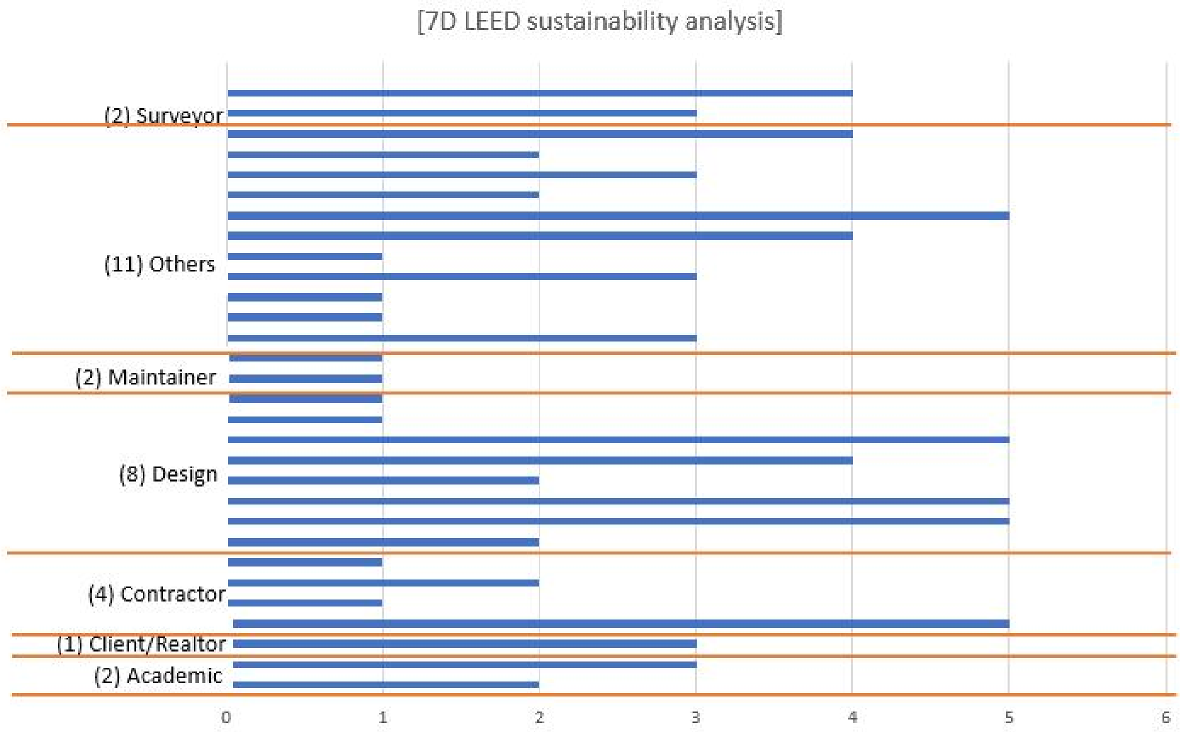

Figure 86) 7D LEED Sustainability Analysis (Type)

According to Size of the company

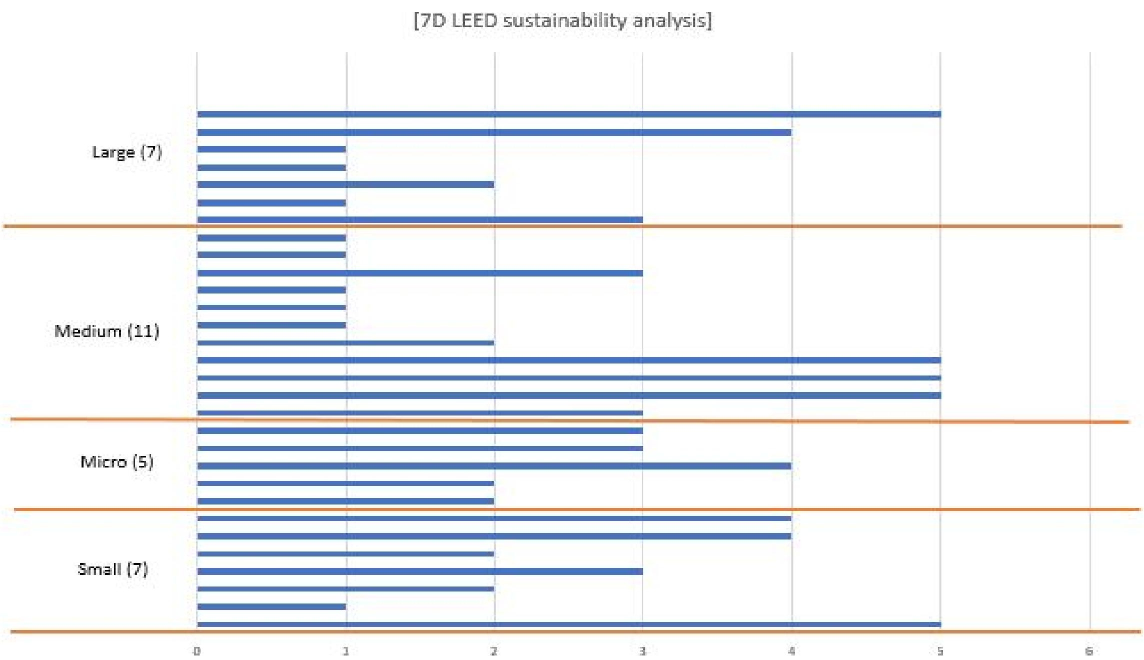

Figure 87) 7D LEED Sustainability Analysis (Size)

According to period BIM has been used

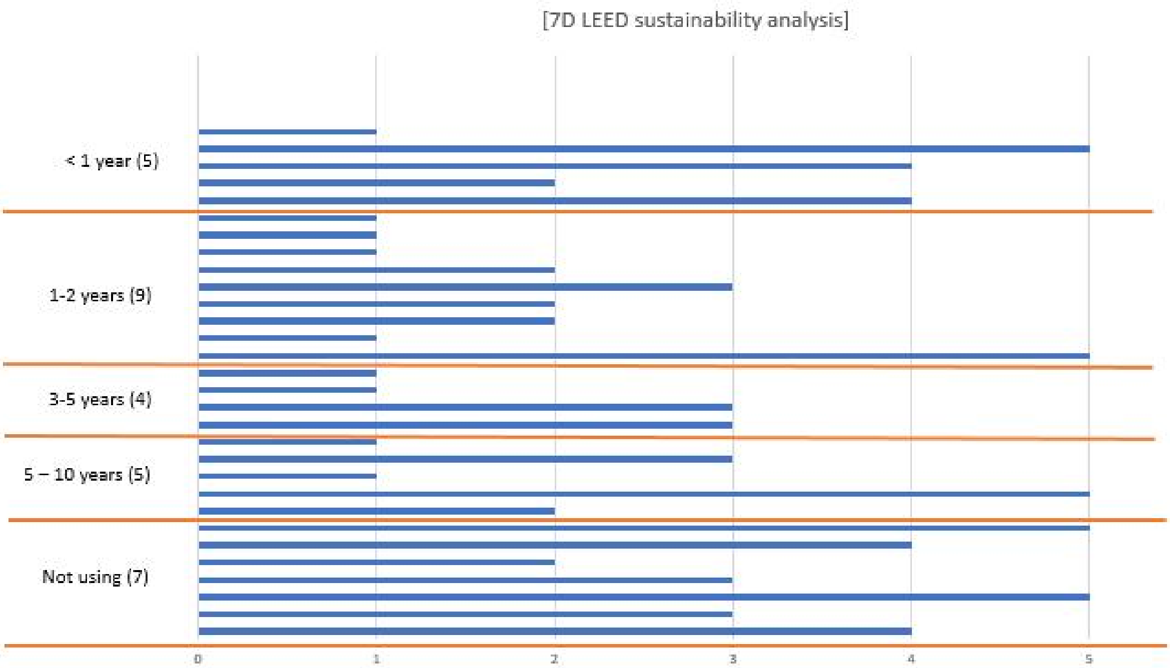

Figure 88) 7D LEED Sustainability Analysis (Period)

16º- Site Analysis

According to type of Company

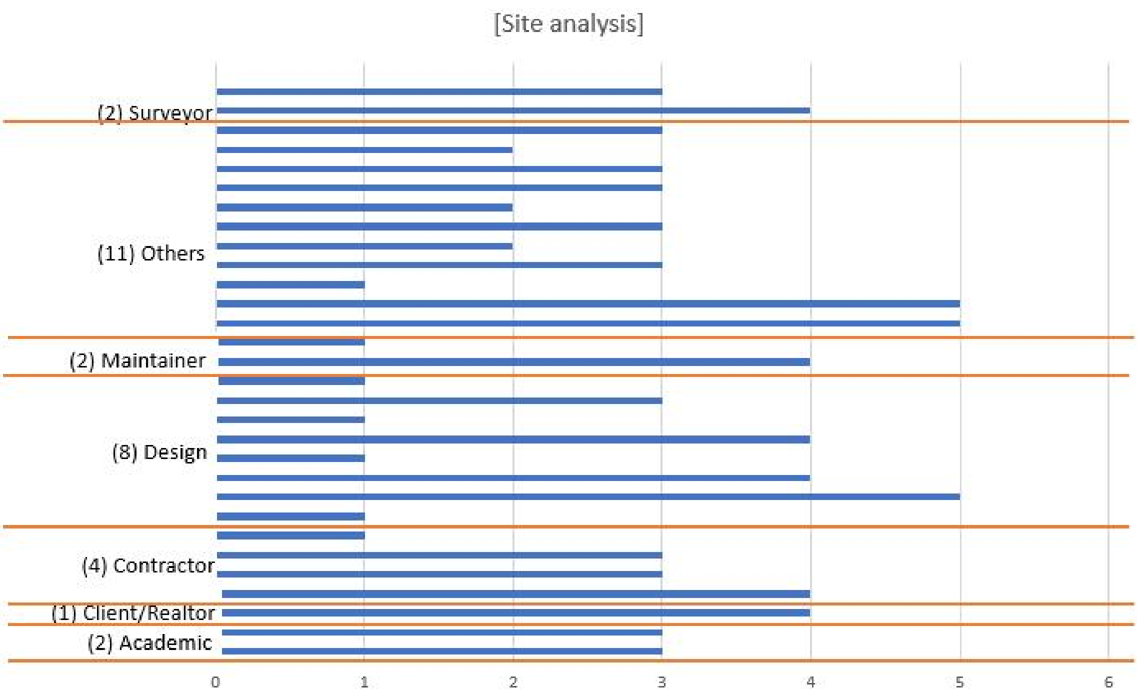

Figure 89) Site Analysis (Type)

According to Size of the company

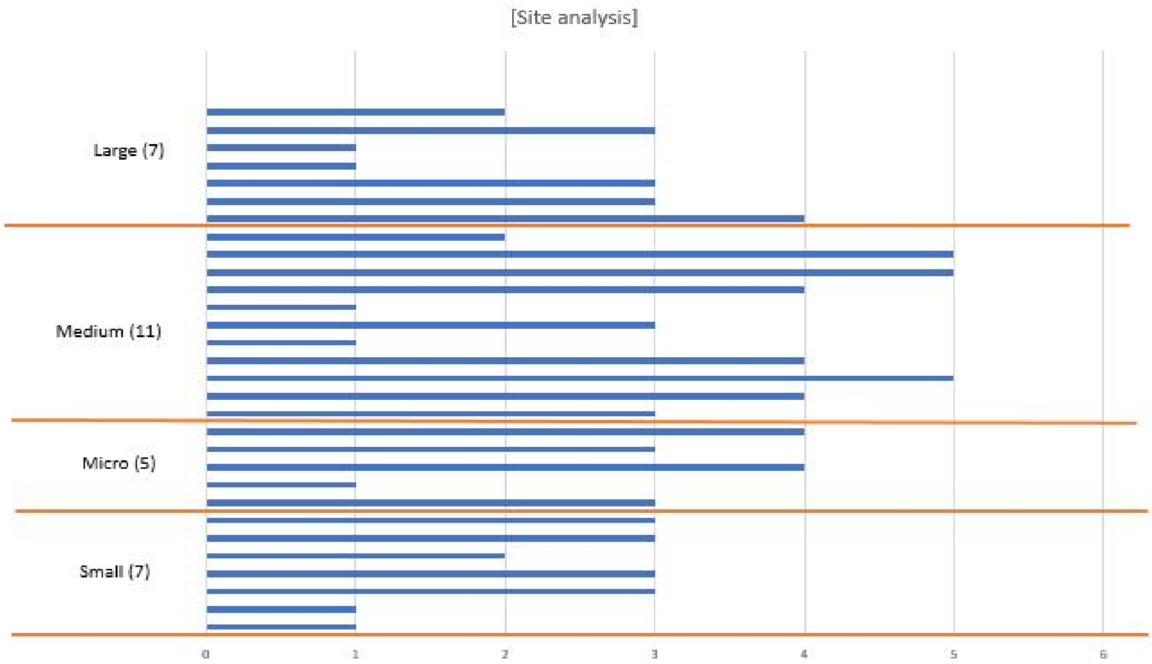

Figure 90) Site Analysis (Size)

According to period BIM has been used

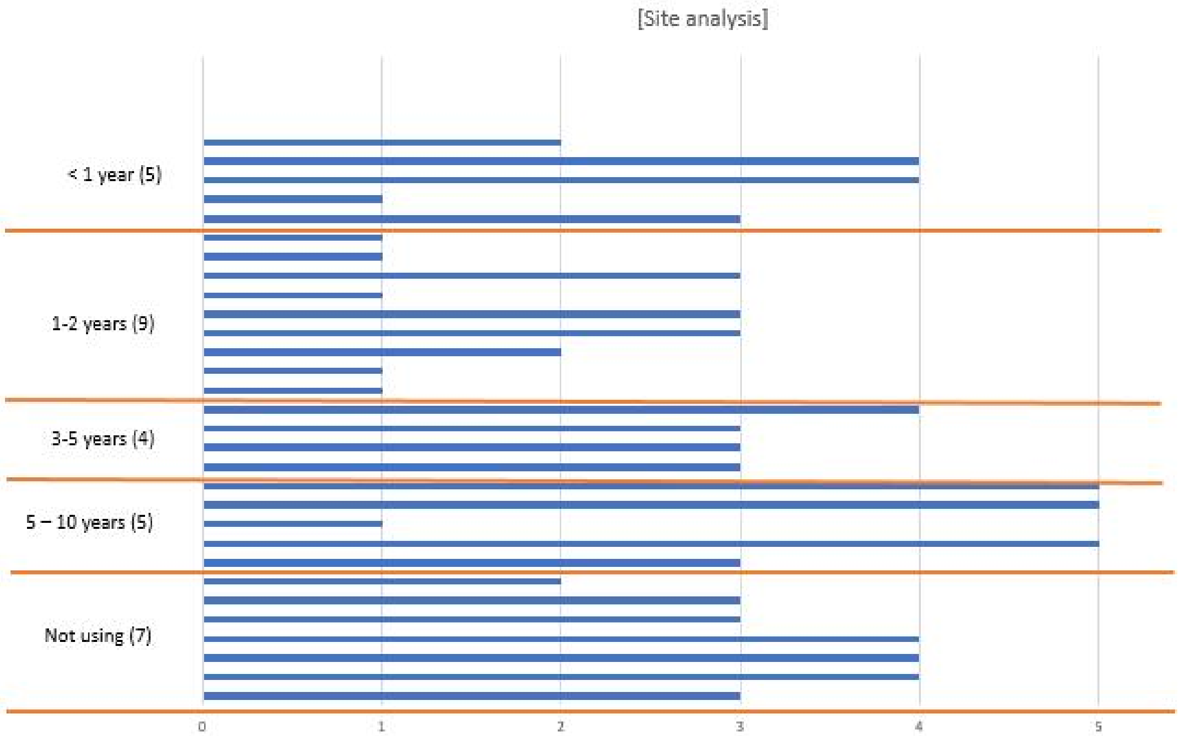

Figure 91) Site Analysis (Period)

ADDENDUM SIX_PERIODIC TABLE OF BIM