STATE OF ART IN THINKING OF BIM COMPETENCE

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ABSTRACT

Building Information Modeling(BIM), today is considered a real milestone in the construction industry as BIM can be used widely throughout project lifecycle for various purposes and has a positive influence on increasing the productivity of the construction sector. It is considered as a method for generating and handling the digital representations of building from the designing phase through construction phases till the operations and maintenance phases. Thus, BIM education plays an important role in engineering studies. It serves as the foundation for reframing the engineering education as it helps to generate various kinds of skills and knowledge required for the construction industry and thus provides technology-enabled, process-driven and policy-encouraged advances in engineering studies.

The aim of this Bachelor's thesis was to build a better understanding of BIM skills requirement for the construction industries and to help in implementing the BIM skills oriented subjects in the educational curriculum. The Study also dealt with the industry thinking about BIM competencies and collected a different kind of competence needed for individuals and organizations. A literature review was carried out where were explored previous studies on BIM and its benefits, importance and barriers. Study on the internet and scientific journal papers and conference papers were also reviewed. Through the literature review, a set of BIM skills was generated. A survey through questionnaire was conducted to validate the skills and to match it with the industry inception toward BIM skill requirements for engineering graduates. A critical analysis of the literature review and the questionnaire survey results were discussed.

This study provides reliable results and defines various BIM skill sets required for individuals as well as different BIM professional positions that could easily be adapted to be integrated into educational curricula.

Keywords BIM, BIM Competences, BIM Skills.

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Manish Yakami

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LIST OF ABBREVIATIONS

BIM	Building Information Modeling
AEC	Architecture, Engineering, and Construction
NIBS	National Institute of Building Sciences
CAD	Computer Aided Design and Drafting
MEP	Mechanical, Electrical, and Plumbing
2D	Two-Dimensional
3D	Three Dimensional
VDC	Virtual Design and Construction
IFC	Industry Foundation Class
RR	Response Rate
CIFE	Center for Integrated Facility Engineering
OOCAD	Object-Oriented CAD
LOD	Level Of Development

CONTENTS

1 INTRODUCTION

1.1 Building Information Modeling

Building Information Modeling (BIM), today is considered a real milestone in the construction industry. BIM, however, is perceived differently by different trades within the construction sector. Different people from design, construction, and financial management field experience BIM in various ways. BIM today refers to a product (building information model- a structured dataset describing a building), an activity (building information modeling the act of creating a building information model), and a system (building information management- business structures of work and communication that increase quality and efficiency) (National Institute of Building Sciences (NIBS), 2007, p.1).

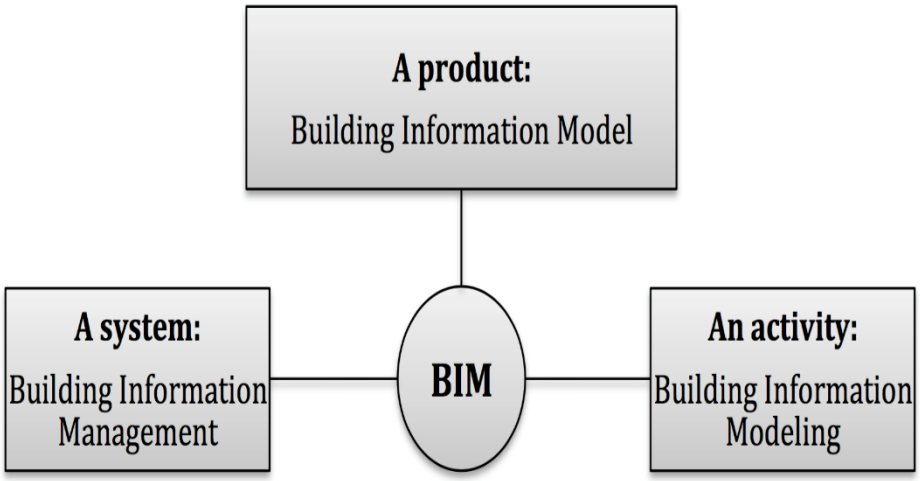


Figure 1. BIM definitions

Various definitions have been put forward for BIM. One of the most followed is by Eastman et al., 2008 in "BIM Handbook", it defines BIM" *as a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital, machine readable documentation about a building and its performance, design, construction, and operation".* The use of BIM in projects has a significant impact on improving quality, better resource management and reduction construction time and cost with better management of information amongst the stakeholders. As per research conducted by Center for Integrated Facility Engineering (CIFE) in 2007, financial benefits in BIM-based projects during design and construction phase yields the following results:

- 7% reduction in project completion time
- 10% of cost saving
- 40% elimination of unbudgeted changes

- 80% time reduction to generate cost estimate
- 3% cost estimation accuracy within 3%

BIM is widely used throughout the project lifecycle for various purposes and aids in increasing the productivity of the construction industry. *Figure 2* shows various BIM uses during different project phases.

Figure 2. What is BIM? (www.thenbs.com)

BIM serves construction stakeholders in various ways. BIM is a developed form of object-oriented computer aided system (OOCAD). BIM is a technological innovation in the construction industry and is considered modelling of the information required for the projects. A "single file concept" in BIM integrates various tools, disciplines, and processes. Subject specific building information models need plenty of objects and information. It incorporates all the physical components and its information.

National Institute of Building Sciences (NIBS) states "*A Building Information Model or BIM utilizes cutting edge open standard digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project/life-cycle*

information, and it is intended to be a repository of shared information for the facility owner/operator to use and maintain throughout the lifecycle of a facility."

Digital representations of the products in construction projects have varied largely from early phases of technological developments as shown in *Figure 3*. Today BIM technologies can interpret those objects as real architectural elements along with the required information stored within them

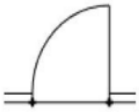
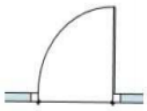
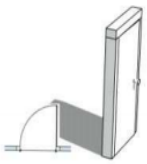
	Method	Human interpretation	Computer interpretation
	Drawing (Scanned)	Door	Pixels
	Drawing Information model	Door	Lines / Arcs
	Geometry Information Model	Door	Surfaces / Elements
	Building Information Model	Door	Door

Figure 3. Difference between a human and a Computer Interpreting data (translated version, Hietanen 2005, p.30)

BIM is not only recognized as a product or a solution solving software; it is a combined mechanism produced on coordinated reliable information from the designing phase through the construction phases until the operations and maintenance phases. BIM is not a product that only architects can use. BIM can be and has been used in types of projects like roads and highways, heating and plumbing and mechanical designs. The assistance given by BIM has been experienced by engineers in the same way as architects have been entertained.

Building Information Modeling (BIM) has come up innovative solutions by acknowledging the various problems and necessity specific to construction that was not delivered by CAD and paper-based traditional processes. The term BIM has been known for almost 25 years. The outlining of the BIM

principles occurred around 1975, but the rapid adoption started within the last decade. (Eastman et al.,2008: xi)

BIM is a method for generating and handling the digital representations of a building's spaces, elements, and systems combining their dimensional, functional, temporal and economic characteristics. As in 3D CAD, it represents volumetric environment and has different possibilities of producing desirable ways to visualize the building in detail. (Eastman et al., 2008: 13). BIM can also help in extensive engineering calculations during the design, including the early conceptual design phase. This type of system also contributes combining 3D data and other construction and engineering data from different technical departments. (Eastman et al., 2008:18)

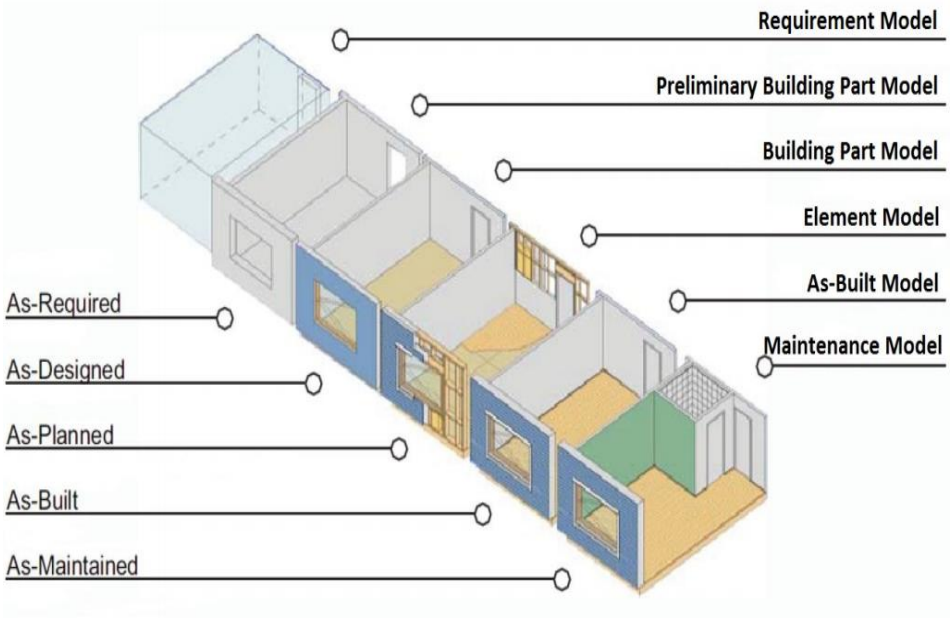


Figure 4. BIM in different phases (Penttilä, Nissinen, and Niemioja 2006, P.28)

BIM is known to deliver numbers of benefits and significant productivity advancement in the Architecture Engineering and Construction (AEC) industry. In AEC industry, BIM has been playing an important role in the increment of the quality of construction by facilitating support on decision making and coping towards the long-term performance of the buildings. BIM not only decreases the cost of the project while in construction but aids contributing better results for the whole life cycle processes by serving as a necessary project data repository and by allowing the usage of advanced life-cycle analysis tools.

A building model can be symbolized in four different ways:

- *Building Components/real architectural objects*- an object represented with the attributes and indicating what they are for. For example, a door is a door which can be attached to a wall.

- *Consistent and non-redundant data*- changes made in one prospect will also be performed in another prospect.

- *Component*- data which had included define how they act as for analyses and working action. e.g. energy simulations.

- *Coordinated data*- all views available in the model are represented in a coordinated way.

BIM way of working requires active collaboration and communication between the project participants. The use of coordination and collaboration of the design between the professionals has been today's need of the AEC industry. Different people from different disciplines need the data from the BIM model and BIM professional's/engineer's duty is to provide/extract the type and the content of the required data from the BIM models depending on the intent of use. BIM technologies provide various possibilities of internal and external collaboration and various platforms for sharing and exchanging the building data of a model inside and outside of the office. Industry Foundation Classes (IFC) has been developed as a standard for such collaboration and coordination to transfer smooth data exchange between different disciplines and their tools. Besides IFC, BIM applications support various file formats as shown in *Figure 5*. This aids to allow the BIM program to communicate with other applications like structural analysis, energy analysis, and clash detection programs required for various analysis for construction projects.

Figure 5. Different file formats possibilities for data exchange from BIM applications (ArchiCAD tutorials, Graphisoft)

These possibilities of two ways data exchange support active collaboration and cooperation of people working in different fields. *Figure 6* shows different stakeholders involved in construction projects and highlights the need of smooth data exchange between the participants. A dedicated BIM engineer/manager for the projects is seen as a requirement today and thus, BIM managers play a vital role in providing with the data on the current state of the design to all the project participants. As BIM technology and a single file concept is its mainstream, the successful BIM implementation is a result of integrated and active cooperation between the stakeholders. These cooperation activities have various benefits for all the project members.

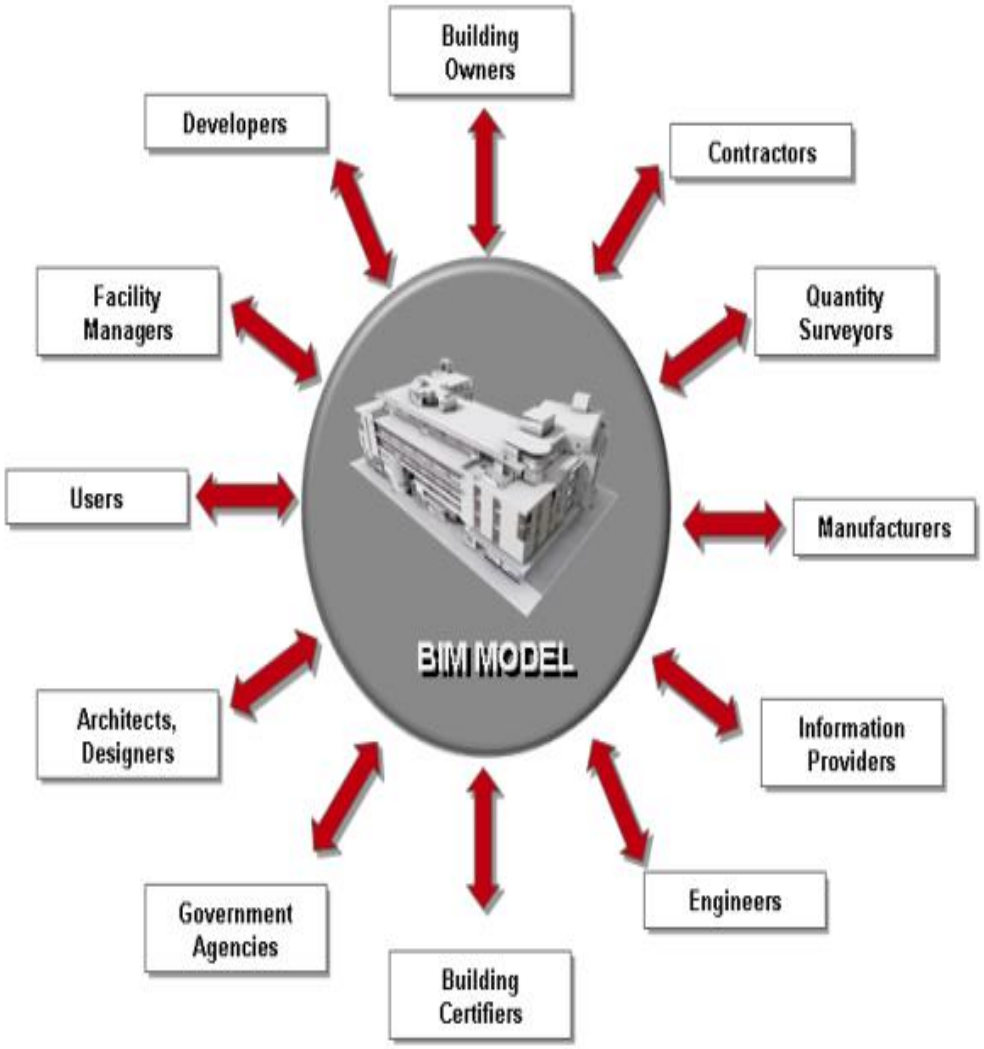


Figure 6. The BIM model as an information repository and Platform for Project Communication (ArchiCAD tutorials, Graphisoft)

Such versatile fields and uses require BIM know how and qualification for its utilization. BIM education today has been one of the key requirements in AEC education. A skilled graduate needs a de-facto BIM skill on one

hand and the education providers, on the contrary, should be able to provide quality BIM education.

1.2 BIM Education

It is expected that BIM will advance to change in the achievement of professionals in the Architecture, Engineering, and Construction (AEC) companies. In future, BIM will be the major aspects of the development of the construction industry. Educational Institutes will play a significant role preparing the graduates with the required skills needed for BIM tasks. Thus, BIM education plays a major role in engineering studies. It serves as the foundation for reframing the engineering education as it helps generate various kinds of skills and knowledge required for the construction industry. It provides technology-enabled, process driven and policy-encouraged advances in engineering studies. BIM education is the process where different skills and knowledge are generated to deliver the BIM-based skills and satisfy their respective requirements (Succar et. al., 2012). BIM education is the bridge to provide technology-enabled, process-driven and policy-encouraged advances in design, construction, and operation of facilities. BIM based training helps to empower the current and future generation of the construction industry professionals to accomplish in the increase in the productivity, waste reduction and the betterment of sustainable future. BIM education concentrates on both individuals as well as organizational learning. BIM Education handles all the ways of BIM learning such as tertiary courses, industry workshops, media and on-the-job training and so on. BIM education figures out learning environment of the BIM learners regarding the topics and the needed materials the learners need to educate others.

In the AEC industry, there is a need for the personnel with BIM know how and knowledge. Most of the time teaching about BIM at the undergraduate level helps to get the required need of BIM skilled staff. In most of the developing and also in some of the developed countries industries are still using the old 2D method of drafting and designing. One of the main reasons is that most of the teachers are experts in 2D drafting and some of them are in 3D modelling but there are relatively few professionals who can teach BIM. Even though some experts are available they are not enough for providing the knowledge of BIM to all the professionals. Companies which are currently using BIM are looking for students who are capable of and comfortable with BIM processes, but also one who do not require software expertise.

Different kinds of educational institutions in the AEC industry are exploring the ways of teaching BIM applications in their curricula and also struggling to integrate them into other courses. Most of the schools who are wishing to apply BIM in their curriculum mostly face problems as they need to integrate it into different areas of the school curriculum. Implementing BIM education in academia is one of the difficult change processes like most of the major change processes. Different kinds of problems and challenges exist. Some of them are already crowded courses in the curriculum,

difficulties in introducing the new course into already accredited degree programs, lack of BIM educators, the unfamiliarity of BIM, traditional ways of working, the unwillingness of existing teachers to get trained in new topics. The implementation of BIM in the AEC education curriculum will be critical for the preparation of future employees for the industry as the educational institutions currently lack incentive plans and abilities to familiarize the advantage of BIM into present and future coursework efficiently. (Clevenger et al. 2010).

Penn State University, Georgia Tech University, University of Southern California, Montana State University and the University of Wyoming are some of the identified leading institutions for BIM education in the world. BIM implementation at an undergraduate level in the University curriculum is an ongoing and increasing process around the world with the objectives to prepare students for a technology based working environment and for the improvement of global learning through comprehensive design. Usually, BIM educational institutions have an option of adapting the existing curriculum to include BIM for the teaching purpose, or they can include BIM as a separate course or both.

The integration of BIM at an undergraduate level not only serves the increasing demand for BIM skilled professionals but also creates new opportunities for the students in their future professions. Educational institutions should go into the path for producing professionals with BIM know-how and competencies rather than creating professionals for software. As for BIM integration, however, some teachers have implemented it into course curriculum, knowing that students should master it in the future. Numerous BIM relevant courses are being taught as a technology training without any idea of the collaborative learning environment. However, industry values the training more collaboration as a dominant skill in the possible future employees. As we take a profile of the AEC industry, their present expectation from the graduates is with the skills of both technical and non-technical competencies. (Ahn, Pearce, & Kwon, 2012). Two kinds of critical needs in the modern construction education are identified: the development of information technology and attention to it, and proper application of collaborative practices.

The present generation of students are supposed to be much more competent in 3D, but the school focuses them first on 2D and focuses on 3D with a limited number of teaching hours. Most of the schools around the world still stick to the old method of curriculum teaching CAD, mainly AutoCAD.The problem of this is due to partly of modernity of the technology as there has been a lack of people who are capable of teaching and also partly in the dilemma of teaching an application or teaching the technological concept.

1.3 Aim and Objectives

In the future of the AEC industry, there will be a consensus that the professionals will need to acquire knowledge and skills in the BIM environment. The aim of this thesis is to build a better understanding of the

BIM skills for future AEC industries engineers. Also, it deals with the BIM skills which industry expects in the future employees that could serve as the requirements for BIM education during the engineering studies. Two types of research methods will be used i.e. a literature review and survey analysis. The literature review is done by studying different academic journals that are published by various authors in scientific repositories. The survey analysis will be done with the AEC industry personnel through an online survey questionnaire. More details about the study method are presented in the following chapter.

1.4 Research Question

The research questions that are to be answered in this thesis are:

i. What does the construction industry think about BIM Competency?

ii. Is BIM competency required for engineering graduates?

iii. What type of BIM competencies should the graduates have?

iv. What kind of BIM competencies are needed for individuals and organizations?

2 STUDY METHOD

Two methods were chosen as research methods. One is a literature review, and the other is survey analysis. The literature review was conducted to gain information related to BIM and its importance in the industry as well as to gather information about competency and skills required for today's construction projects. Various sources were explored, such as articles, international conference papers, research papers and the materials available on the internet and various scientific data repositories. The literature review provided necessary information on BIM, BIM skills, and the BIM education. The survey questionnaire was drafted based on the review. The survey questionnaire research method was used to better understand state of the art in BIM competency among the AEC industry. The primary objectives of the survey were designed to obtain experts' opinions on the subject matters in the areas of BIM competencies.

2.1 Literature Review

A literature review was done through the scientific repositories available from Emerald Publisher (www.emeraldinsight.com); ProQuest (www.proquest.com); ScienceDirect (www.sciencedirect.com); and IEEE Xplore Digital Library (www.ieeexplore.ieee.org). At first, the search was carried out with "BIM" as a keyword in all the repositories sites. Then the keyword "BIM Skills" was used again in the sites. In *Table 1*, the results that were searched for are presented. The results obtained were analyzed

after going through the "title" and the "abstract" of the repositories. A total number of 11 papers through the review of the title and abstract were selected for further study regarding the "BIM Skills" that showed the potential relevance of this research

Table 1. Search Results from the different scientific repositories

	Keyword- "BIM."	Keyword- "BIM Skills."	Selected
Emerald	714	4	1
ProQuest	1131	24	6
ScienceDirect	370*	12	3
IEEE Xplore	325	6	1
*Limited to Automation in Construction			

Amongst the repositories, ProQuest with a total number of 1131 results suggests that this is mostly used by researchers for publishing BIM-based articles and similarly Emerald has the second highest number of results. The relevancy of the papers was scanned through the title and abstract of papers and only relevant papers to this thesis were selected as shown in *Table 1*.

The academic database was found to be limited to the BIM skills topic in the present context. So, a broad internet database search was done with Google and Google scholar. As on 15th May 2016, while the search was done through Google it resulted out "around 9,350 results in 0,38 seconds". However, through Google Scholar the results were "around 218 in 0.05 seconds". The search result for each year has listed out in *Table 2* below with the available material related to Building Information Modeling (BIM) and the papers related to this research were selected.

Table 2. Research paper searched in Google Scholar

Google scholar search with keyword- "BIM skills."			
Year	**Results**	**Available Materials**	**Selected**
2016	18	10	2
2015	73	47	9
2014	29	15	4
2013	39	18	6
2012	12	7	2
Until 2011	42	*	

* were not taken into account.

The results of the search indicate that BIM skills as a topic is of growing interest and various researches are currently being undertaken for active integration with engineering studies. These studies highlight the need of BIM competent workforce.

2.1.1 BIM Competence

Any unique skills which are required for performing a given task, activity or role successfully or efficiently can be considered as competence. BIM competency is one of the included qualification needed in the procurement process. *Individual BIM competencies are the personal traits, professional knowledge and technical abilities required by an individual to perform a BIM activity or deliver a BIM-related outcome. These abilities, activities or outcomes must be measurable against performance standards and can be acquired or improved through education, training, and/or development.* (Succar et al. 2013).

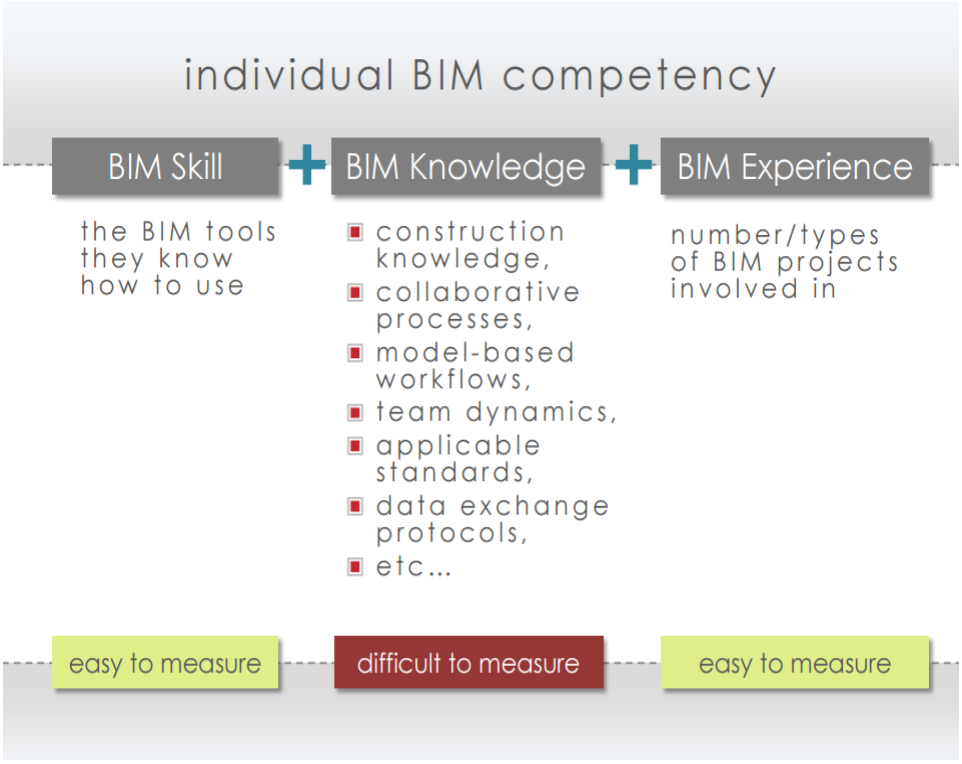


Figure 7. Individual BIM Competency (BIM performance measurement and improvement, Succar 2013
https://www.academia.edu/3529511/BIM_Performance_Measurement_and_Improvement_presentation_slides_)

2.1.2 Findings From Literature Review

The literature review highlights the need for BIM skills for the construction industry. Fan et al., (2014) highlight that there should be a relationship between the skill level of a person who had engaged in design and modelling with the BIM software and project field should have the understanding intricacies of the field project for which the modelling is done. In this context, the modeller should have a BIM skilled related competency which helps them to follow up the model and which will assist them to get rid of the model and also to cause less rework needed to be done in the field. Due to a lack of high degree of BIM competency, it was seen that there was the effect of reducing field productivity. Mohd et al., (2013) mention that skilled BIM workforce in the industry helps in the cost reduction and also in the better time management through clash detection between different disciplines. The authors also state that BIM implementation requires a lot of time investment at the beginning to be profound and efficient to get the actual benefits out of it. Wu and Issa (2014) anticipate BIM education as a solution to brisk up the BIM skills learning curve which may help a company to hire ready-made graduated BIM personnel. However, they mentioned that the learned competencies that the graduate gets from the institution are not enough or will not be able to satisfy the workforce demand for BIM. So the industry still needs to shape BIM competencies of the personnel as per the organizational need. The learning curve of the BIM, however, can be neglected to a certain level if the graduates are already BIM competent.

Yarmohammadi & Ashuri (2015) discuss the issues of BIM competency regarding the coordination process for Mechanical, Electrical and Plumbing (MEP) in the construction industry. How the person with the BIM competency in the team leads with an experience has major impacts on the progress of a project using coordination competency. The authors also state that due to the coordination process the clashes produced were grouped together into similar specific batches which help to reduce additional discussions in the team and finally add to the increment of unit production rate. Taiebat & Ku (2010) state that the construction industry prefers their future employees with a deep conceptual knowledge of BIM rather than to hire those only with BIM application skills.

A growing trend of new positions in the industry like BIM professor, BIM manager, BIM modeller shows the increasing need for BIM competent workforce for the industry. Various studies have shown that project managers in the sector are likely to have a role as BIM managers. However, Rahman et al., (2016) state that an individual's skill sets needed for the project managers and the BIM managers differ. Moreover, the author defines BIM expertise and its co-related skills which help in getting the title of ‘project manager’ and ‘BIM manager.' Authors also highlight that skills like teamwork and communication skills that are required for the collaboration in the projects need to be provided by the academic community through an implementation in their curricula to prepare the students for the future BIM skilled personnel that can work efficiently as a team member. The authors furthermore state that there is a limited

opportunity for the BIM managers as the construction industry is not so much aware of the skills and expertise that BIM managers provide.

The research conducted by Dossick et al., (2014) states that the focus on BIM for graduate curriculum was done regarding the understanding the computer application concepts and BIM processes than to the mastering the BIM tools. The study was done by Davies et al., (2015) has focused on the soft skills like collaboration and communication, negotiation, teamwork, leadership and conflict management which are required for the BIM project team. However, the authors also highlight that the soft skills are not the ones which can be learned quickly as it comes from the personality, experience, and training. It is identified that the graduate students tended to have a better technical knowledge in BIM and are limited to the knowledge of BIM skills as compared to the experienced professionals who are richer in discipline-specific skills. The authors also mentioned that in current practice technical skills regarding BIM are kept in details but the soft skills that are critical are not so much elaborated Soft skills are used to provide the solution for the conflicts and help to provide healthy relationships. Regarding the BIM competence, notably most of the companies hire a candidate with personal traits rather than the BIM-technical skills as it is considered to be one of the least important skill sets. Developing the employees with BIM competencies rather than just BIM-technical skills are more prominent as the company's expectations and values are carried out through the process.

Individual competencies such as aptitude, qualifications, skills/abilities, knowledge and attitude were taken into account by Barison and Santos (2011). The authors highlighted a BIM manager and how he can be competent. The authors mentioned professional needs for the position in both foundational and functional ways. Essential skills like communication skills, ability to handle multiple BIM software, teamwork, leadership skills were also pictured as some of the intellectual abilities to understand the updated knowledge of BIM. The author even states that these qualities are not enough unless the person works with a positive attitude.

The importance of BIM competencies varies depending upon the organizational needs. Based on the literature review essential skills required for the graduates are listed below in *Table 3.*

Table 3. Literature review on the BIM Skills as Authors stated in peer-reviewed Journal

Authors	***BIM Competencies***
Rahman Rahimi A., et al.(2016)	*Teamwork skills, Communication skills, Understanding BIM standards and BIM workflow.*
Succar, B, et al. (2012)	*Leadership, Quantifying and estimation, Documentation and detailing, Model Management.*

Eadie Robert et al.(2014)	*Collaborative skills.*
Wu Wei et al.(2014)	*3D Coordination, Record Modeling, Design Review, Site Utilization Planning.*
Murphy M.E.(2014)	*Technical Knowledge, Planning, and Administration, Strategy, and Policy, Programme Management.*
Dossick Carrie Sturts et al.(2014)	*Coordination and Collaboration*
Davies Kathryn et al.(2015)	*Conflict Management, Communication Skills, Negotiation Skills, Teamwork and Leadership skills.*
Barison M. B, et al. (2011)	*Teamwork, Leadership, Analytical thinking skills, Ability in handling BIM applications, creative*
Succar, B & Sher, W(2014)	*Leadership, Collaboration, Facilitation, Organizational Management.*

The BIM skill sets developed from the literature review show varying BIM skills and know how as a requirement of the industry. A questionnaire survey was furthermore conducted to validate the above skills mentioned in *Table 3.*

2.2 Survey Analysis

2.2.1 Description of the Survey

A survey questionnaire (Appendix 1) was designed with two sections: 1. BIM questionnaire and 2. BIM skills and competencies. All the questions in the survey were mandatory to be answered. In the BIM questionnaire section, the marginal questions like the genre, age, were avoided. After asking the role, they were prompted to select their professional background. The rationale behind this question was to find out the personnel background of respondents usually implement BIM most.They were asked about their working experience in BIM. Question number 4 was about the definition of BIM, where the definition was provided by the author and the person can make a choice for the right definition. The need for BIM competent employees in the industry was the subject of the Question number 5. The requirement of national level BIM competency certification and the bodies which were responsible for the certification were the concerned matter for Questions 6 and 7. An open-ended question was provided in Question 8 about kinds of BIM competency concerning BIM skills related to fluency in BIM applications, BIM knowledge concerning the development of BIM

and BIM experience corresponding to the experience level using in BIM were provided for the participants. The question is supposed to be marked as the most important one or the least important one. i.e. 1, 2 and 3 where "1" is the most important and "3" is the least important. Question 9 is about the skills/competencies that the person should list out as per their knowledge

The second section of the survey continued with BIM skills and competencies. BIM skills for BIM managers, BIM coordinator, BIM designer and BIM team based on the literature findings were listed out by the author and the participant should mark the skills as to their importance to the respective position from a scale of 1 to 10 where "1" is the most important skills for the position and "10" is the least important one.These positions questions 10, 11, 12 and 13 respectively. Question 14 a list of skills was provided for the participants and requesting them to choose the skills that they presently have.

2.2.2 Results of Survey

Individuals who are from AEC firms and are involved with BIM and Virtual Design and Construction (VDC) were identified to receive a survey considering their better understanding in practice and trends in BIM. Around 105 emails were initially sent to the BIM professionals, with the participants of Aalto BIM summer school (2016) and the link to the survey was also posted in groups in the Linkedin.com. From the target of 120 responses, the survey received 27 answers within the first week.

For the first week, the response rate was:

$$\mathrm{RR} = \frac{\text{responses}}{\text{number of targeted people}} \times 100\%$$

$$= \frac{27}{120} \times 100\% = 22.5\%$$

A reminder was sent after a week of dispatching the previous emails. After the reminder and ending the survey 46 responses altogether were recorded. The survey was open for a week after the reminder. The final response rate after closing the survey questionnaire was:

$$\mathrm{RR} = \frac{46}{120} \times 100\% = 38.33\%$$

From the final response rate, it proved that the reminder was a useful tool to improve the rate of reply as it increased the total response rate by approximately 22.5% units to 38.33%.

2.2.2.1 Section 1: BIM questionnaire

The respondents were assured that all the data collected from the survey would be used for academic research and the identities of the respondents will be confidential. They were able to select their role between a Bachelor level student, Master's degree student, Researcher and in other as their current role as Project Managers, BIM specialists, BIM managers, Lecturers. The role in others and researchers were among the most answered question with 54% and 30%, and the least were on students with a Master's and Bachelor's level. *Figure 8* represents the roles of the respondents.

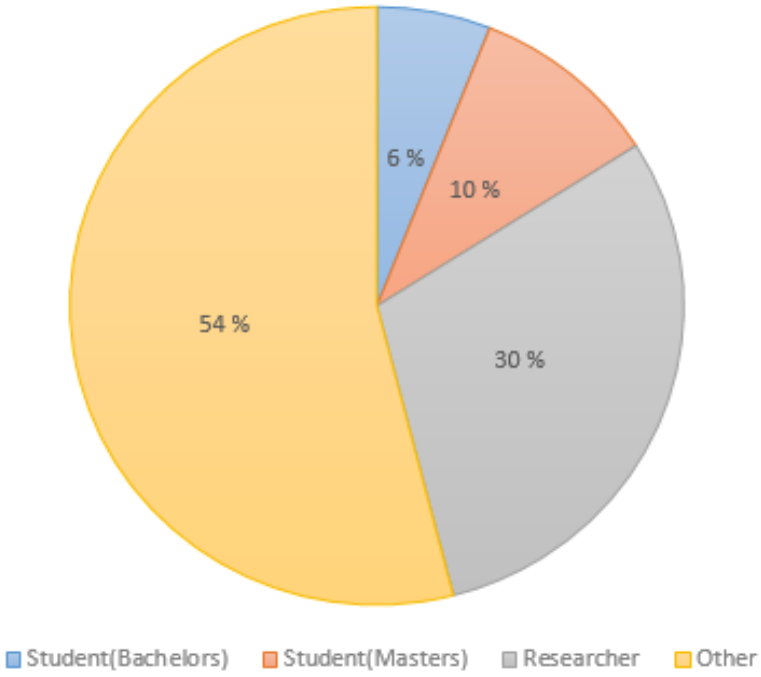


Figure 8. Role of the respondents

Respondents were asked about their professional background field, where it was possible to mark more than one option. Civil/ Structural Engineers with 42% and Construction/design/business managers with 33% were the most professional backgrounds that were recorded in the response. On the other hand, 14% were architects and the remaining 11% MEP designers as seen in *Figure 9.*

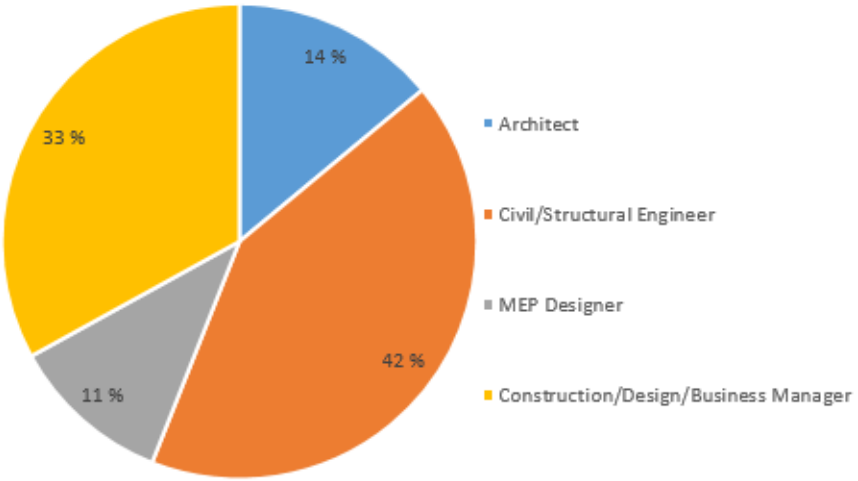


Figure 9. Professional background of the respondents

The aim of Question 3 was to identify whether respondents have experience in using BIM or not. The majority of the participants had an experience with BIM with 82% while 18% of the surveyed people had no experience with the BIM as shown in *Figure 10*. Through this question, it is shown that BIM has become popular in the field of construction industry.

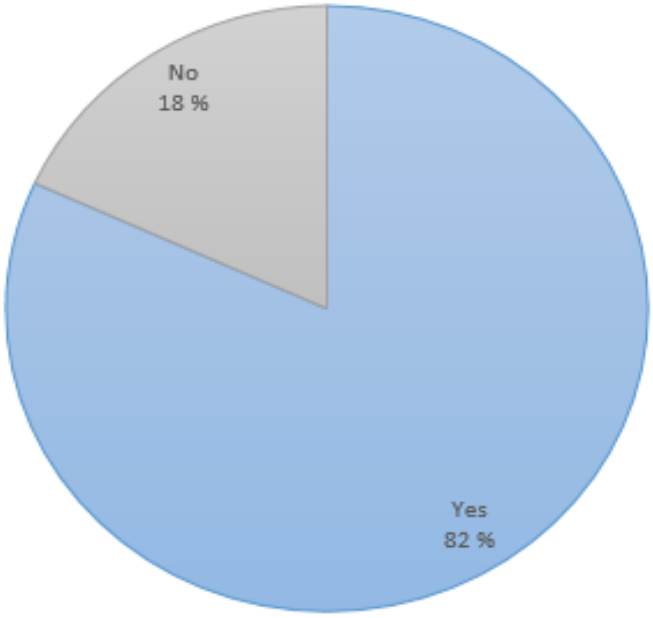


Figure 10. Experience of respondents working with BIM

Question number 4 was related to the definition of the BIM. The definitions provided in the options are listed as follows:

a. A 3D design with standards.

b. A process of generating and managing building data during its life cycle which involves representing a design as virtual objects, which carry their geometry, relations and attributes.
c. A combined mechanism produced on coordinated reliable information from the designing phase through the construction phases until the operation.
d. All of the above.

The participants picked the better option as per their views and with the multiple choice option they had the possibilities to choose more than one answer. As shown in *Figure 11* most of the people had selected the 4th option "d. all of the above" as all of the options were related to BIM definition or a part of BIM definitions. *Figure 11* shows the details of the results.

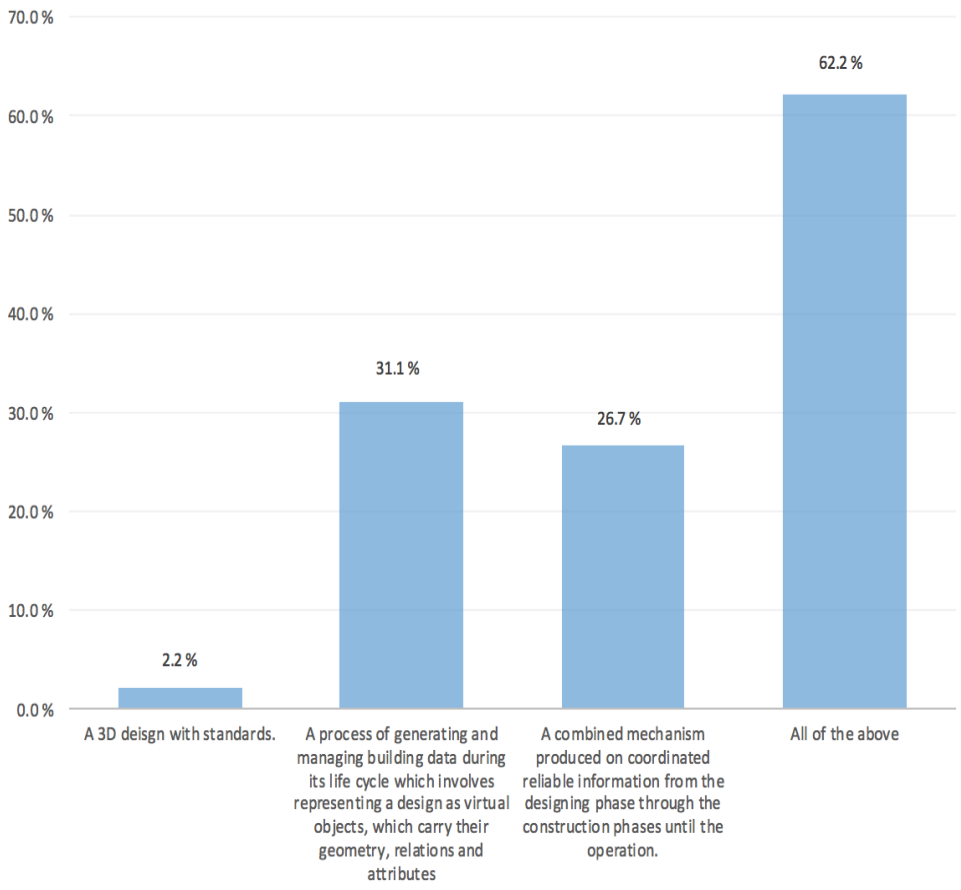


Figure 11. Questionnaire results on description of BIM

More than four-fifths of the respondents categorized the requirement of BIM competent professionals in the industry as shown in *Figure 12*. As per the result, it shows that the construction industry is in demand for BIM competent professionals and similar findings were reviewed through the literature review. The findings roughly show that around 8 out of 10 people see BIM competence as a needed skill for the professionals.

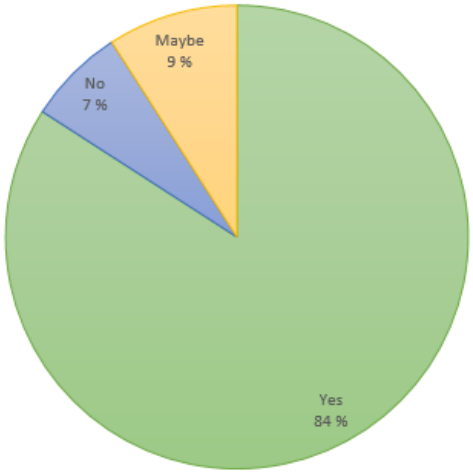


Figure 12. Requirement of BIM competent engineer

The certification of the competencies was also seen as a need during the literature review. A question was assigned about participants' perception of determining the requirements of National level BIM competency certification where more than half of the respondents believed in the necessity of certification systems whereas 16% of the respondents felt that it was not required as shown in *Figure 13.*

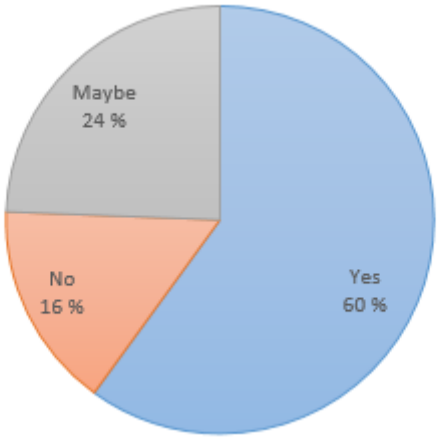


Figure 13. BIM competency certification requirements

The continued question referred to the organization's chain for certification. The participants suggested that educational bodies and engineering professional organizations should be liable for the BIM competency certification. Respondents also indicated that the certification could also be done through the local country organizations like RIL, FISE in Finland, BuildingSMART International. Some people also suggested the possibilities of regional level EU certification for BIM competencies.

Around 20% respondents believed that the BIM application vendors should be responsible for supervising competency certifications. The details of the survey results regarding this question can be seen in *Figure 14.*

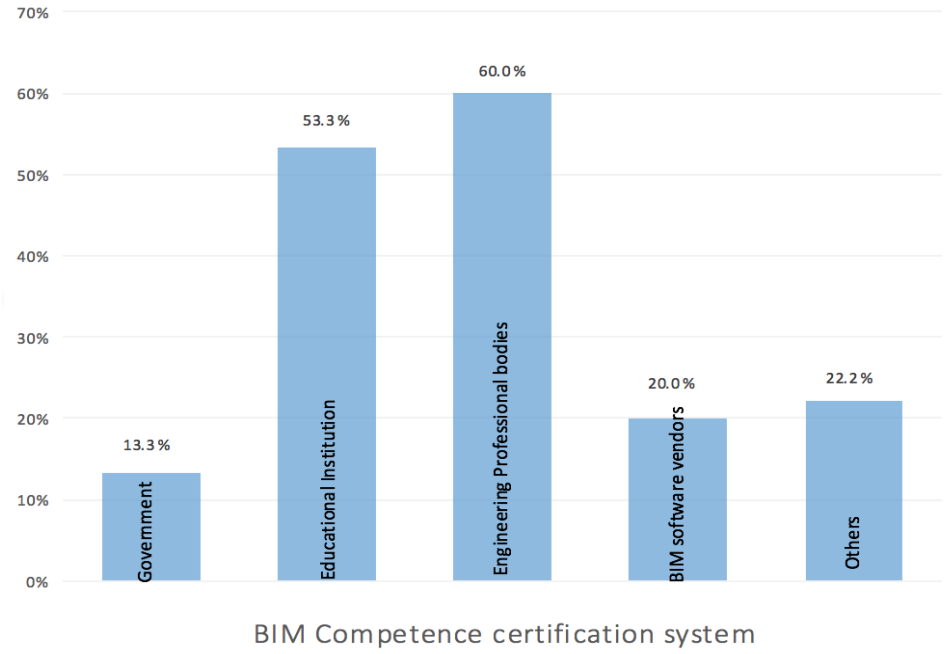


Figure 14. Organizations responsible for BIM competence certification

For Question 8, most of the participants considered BIM skills essential with 90% after that their concern lies in BIM knowledge with 70% and BIM experience with 78%. It shows that both BIM knowledge and experience along with fluency in the use of BIM applications is required. *Figure 15* shows the values of the most needed BIM competency for the construction industries.

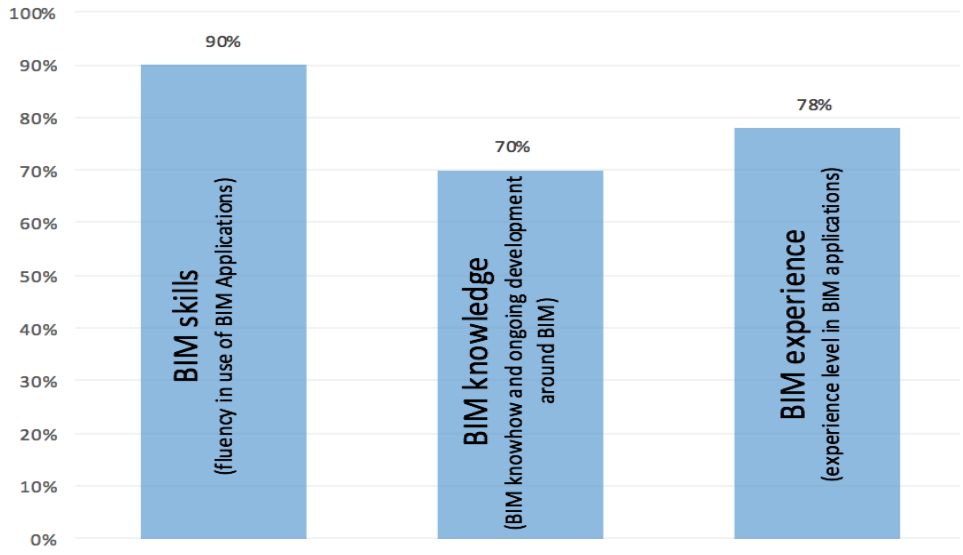


Figure 15. Need of BIM competency

In Question 9, respondents were asked to list out 10 important skills that are required for BIM professionals. They had suggested different kinds of skills needed for the BIM professional. The most common skills mentioned by the respondents are summarized in *Table 4* below.

Table 4. Suggested BIM skills by respondents

Communication	Problem solving capabilities
Leadership	Enthusiasm for learning
Collaboration and coordination	Interoperability
Process understanding	Time management
LOD concept	Negotiation skills
Application skills	Project management
Knowledge of BIM standards and National BIM guidelines	
Experience in use of VDC/Big room Method	
Understanding about working environment of another discipline(Architect, HVAC, Structural)	

2.2.2.2. Section 2: BIM skills and competence

Section two of the survey mainly focused on BIM skills questionnaire asking about the participants' opinions through listed skills where they need to scale the importance in the respective field. Although questions of this section are closed ended, the answers were not very different. For question 10, respondents were able to choose the essential skills that are needed for the BIM manager. *Figure 16* illustrates the skill sets for BIM manager as per importance for his position. According to the respondents' views, the most valuable skills for the BIM managers are "collaboration" with 84%, "knowledge about BIM development" with 82%, "fluency in BIM applications," with 80%, "Technical skills" with 78%. Remaining skills like "decision making," "quality and document management," "goal-oriented," "leadership skills," "communication skills" and "negotiation skills" were least scaled by the respondents.

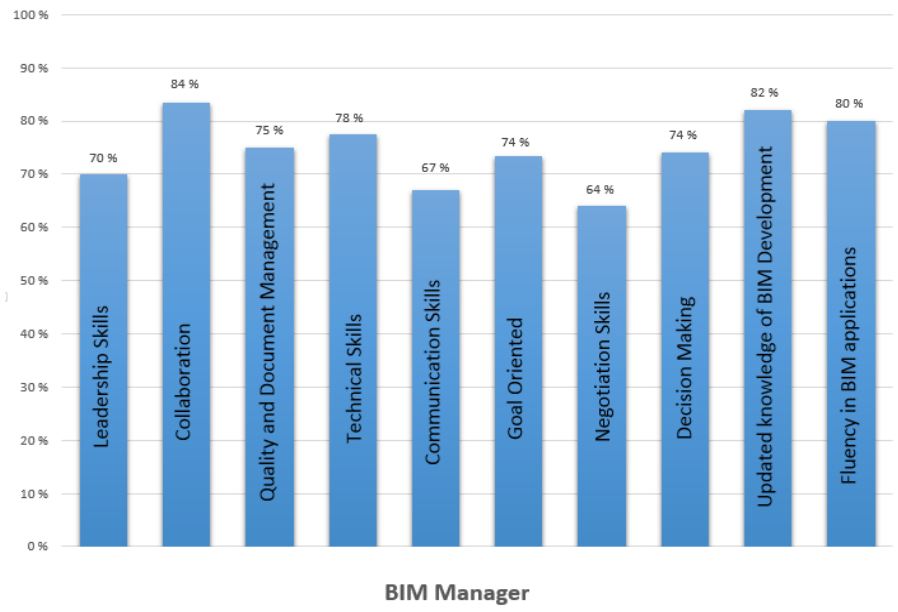


Figure 16. Skill sets as per their importance for BIM Manager

For a BIM coordinator, *Figure 17* demonstrates the most important skills for the position. From respondents, "knowledge of BIM standards," along with "updated knowledge of BIM developments" were the most preferred skills for 82% and 79% respectively. The skills that are important after those two are "leadership skills," "application skills" with both 76%. The least scaled as it is not critical for BIM coordinator are "communication skills" and "creativity" with both 65%.

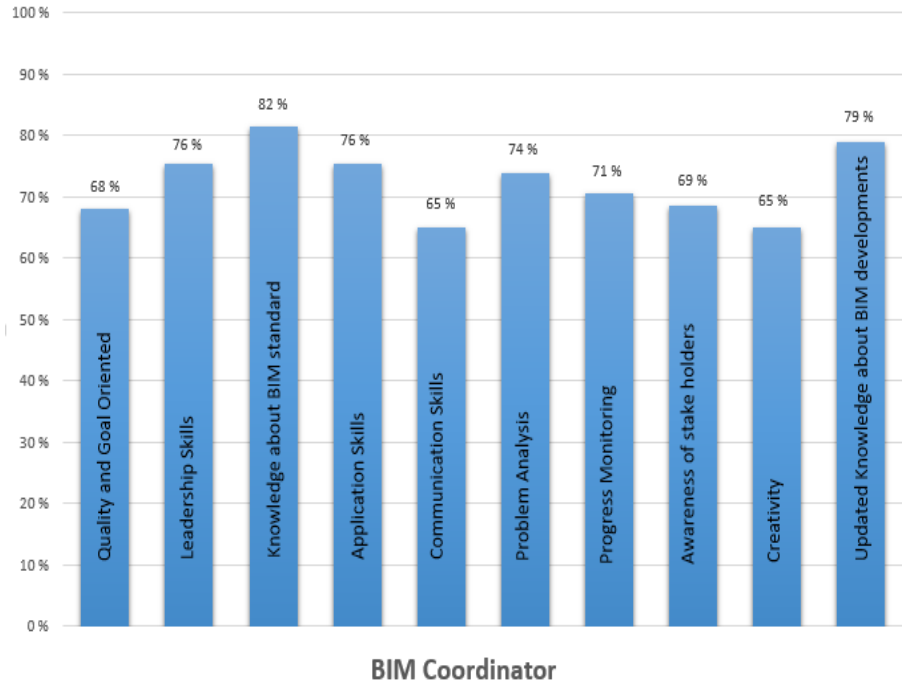


Figure 17. Skill sets as per importance for BIM Coordinator

Similarly for the BIM designer, skills like "updated knowledge of BIM development" with 81%, "application skills" with 82%, "knowledge of BIM standards" with 77% are the most preferred ones. The result shows that a BIM Designer is required with the competency of BIM skills and BIM knowledge. In *Figure 18*, the remaining skills are presented with their respective importance percentage to the position.

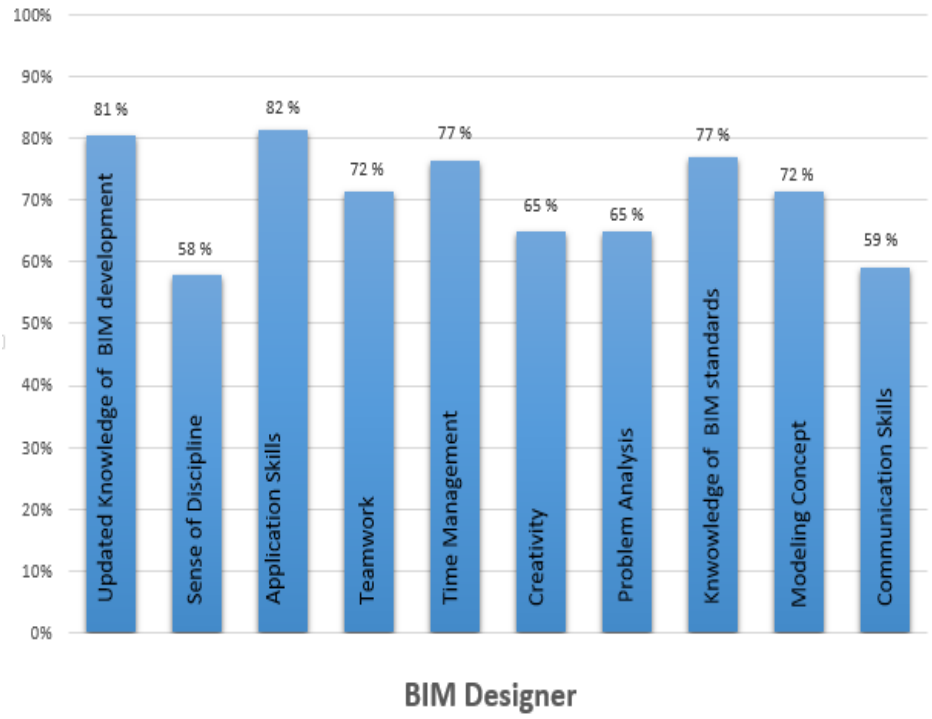


Figure 18. Skill sets for BIM Designer as per their importance

Skills required in a BIM team was the main focus in question number 13. This question was also a closed-ended question with skill sets shown in *Figure 19* provided by the author. From the survey response, the most important skills for the team is "coordination and collaboration" by 83%, "teamwork" by 84%, "knowledge of BIM standards" by 79%. These are followed by "problem analysis," "creativity," "project management," "BIM competence," "sense of discipline," "progress monitoring" and "vision" as shown in *Figure 19* below.

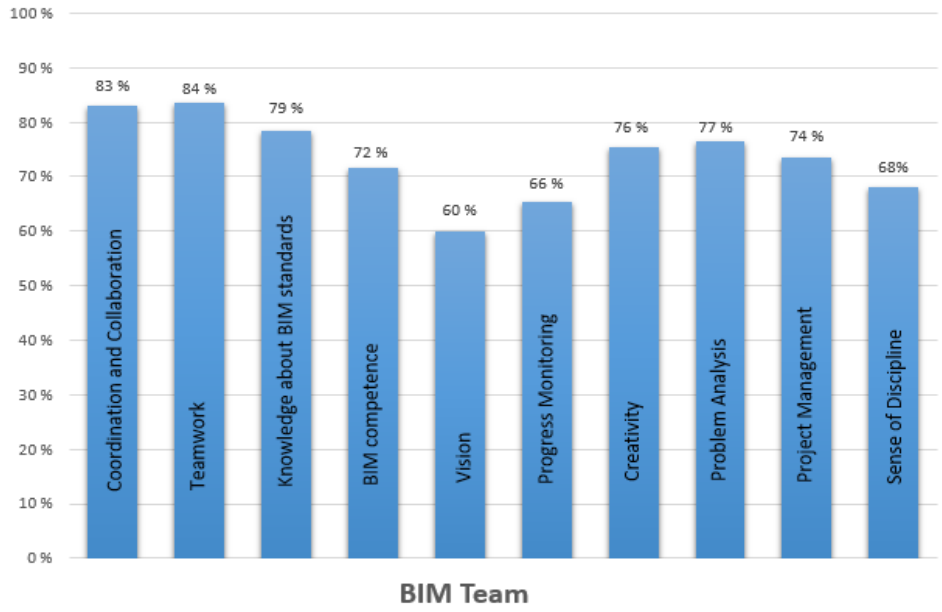


Figure 19. Important skills for BIM Team.

In the last question, the author intended to find out what kind of skills the respondents must have to be BIM professional Among the provided skills, "coordination and collaboration" with 80%, "teamwork" with 73.3%, "application skills" with 68.9%, "knowledge about BIM standards" with 60% and "modeling concept" with 51.1% were the most selected ones following with "problem analysis", "time management", "goal oriented" and "leadership skills". The least skills scaled by the respondents was "creative" with 33.3% as presented in *Figure 20* below. In *Figure 21*, we can see the average skills possessed by the respondents according to their discipline.

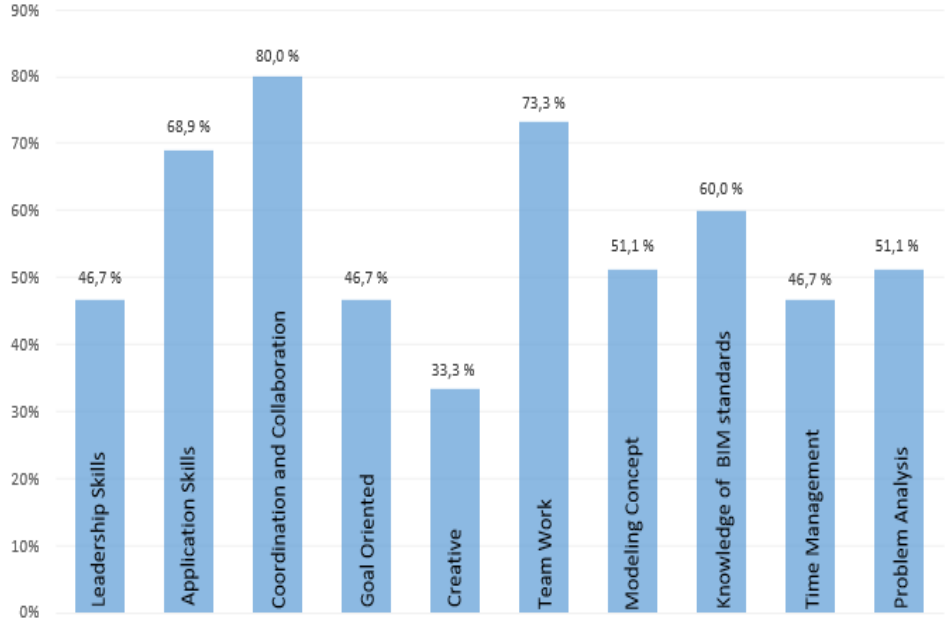


Figure 20. BIM skills possessed by the respondents

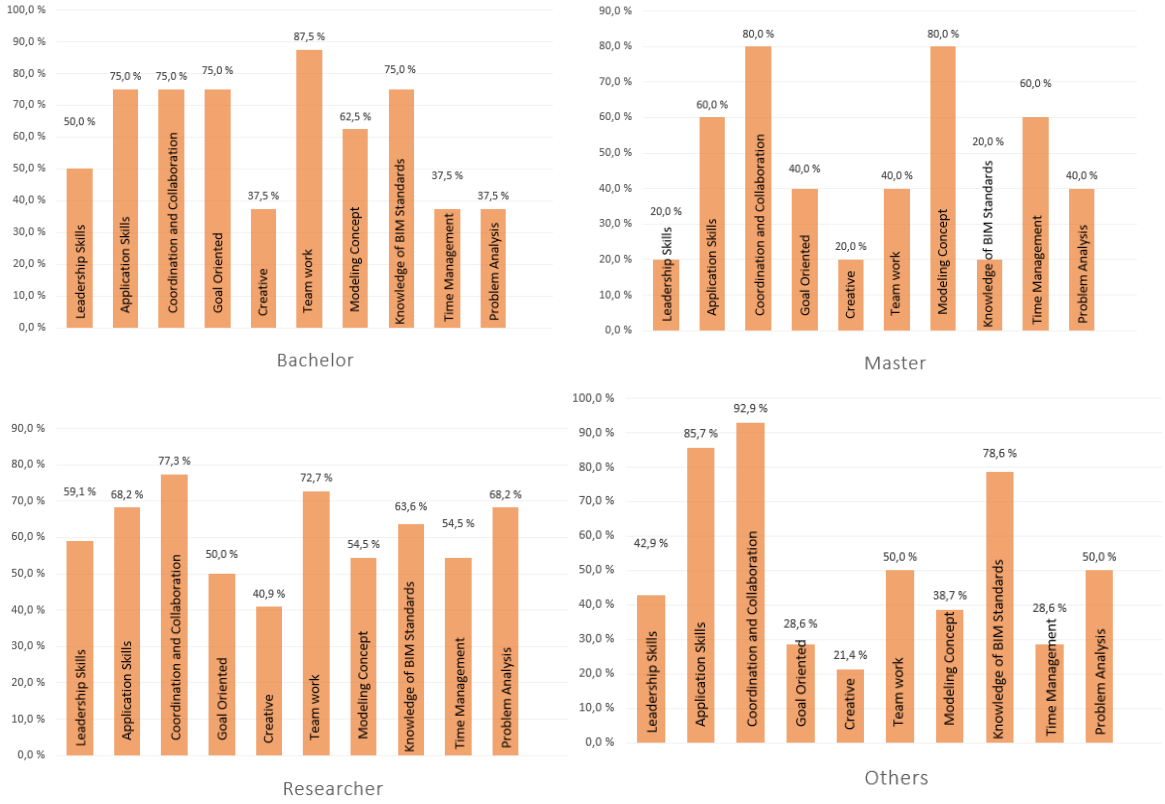


Figure 21. BIM skills possessed by respondents as per their discipline

3 DISCUSSION AND FINDINGS

Workforce which is ready to start working should be competent with the required skills that industries expect when hiring a worker. BIM is an essential process today for the construction sector that has positive impacts on increasing the quality of the projects as well as saving time and money in the projects. Due to the diverse use of BIM in construction projects, the demand for BIM professionals has been increasing. So, to provide the skilled workforce with BIM skills, there should be some measurement of BIM competence of a person. BIM competent workforce as an individual as well as a team player requires various kinds of BIM competencies, BIM knowledge, and BIM experience.

The literature review took most of the time in the research, even though searching for the research papers was easy and quick. Studying of the research papers took time as they needed to be reviewed to get output that is required for this thesis. In the literature review, researchers have provided mostly specific skills as to the subject of their research paper with the repetition of some of the skills. Most of the researchers have missed the skills related to personal traits which were also needed for the BIM working environment. The author suggested some of the skills regarding the personal characteristics. So, with the skills gathered from the literature review and the skills proposed by the author, a questionnaire survey was created for

different BIM professional positions like BIM manager, BIM coordinator, BIM designer and BIM team.

During the survey questionnaire, there was a problem regarding how to contact the BIM personnel. Some of the emails of the BIM professionals were collected from the proceedings of the World Building Congress (WBC) 2016. Some of the emails were gathered from Linkedin profiles which are mostly for the BIM professionals from Finland. A survey questionnaire was also forwarded to the participants of Aalto BIM summer school that was held in June 2016. Some of the respondents of the survey questionnaire were interested in the research topic. They were even interested in getting a copy of this research.

The results were at somewhat different from the results expected by the author. The results in the BIM professionals like BIM Manager, as the manager position is for leading a unit from the organization, the author had expected that the skills like leadership skills, communication skills, negotiation skills and decision-making skills would be scaled more than to output result that was received. Similar results were also expected for a BIM coordinator, but the output results were opposite of what the author had expected.

In the survey questionnaire analysis results mostly, the skills which were studied by the researcher got most of the result. Also, some of the skills about the personal traits which were suggested by the author also got good results with more than the average percentage. The possible reason for some of the personal traits getting less percentage might be that the respondents may just broadly have thought about the skills that are related to the use of BIM applications skills. However, collaboration and coordination are seen as the most important competencies required for BIM competence workforce compared with the personal traits.

The average of the output results was needed to be calculated for some of the questions for the survey questionnaire. The results have been computed through “MS Excel” as the survey results were directly created in Excel file format. It was easier and quicker to calculate the average in Excel file format compared with the other software and manual calculation experimented bu the author. Some of the results were confounding as some of the respondents were not reading the survey questionnaire accurately which were in the closed-ended questionnaire in *section 2*, there was mentioned that the option “1” is the most important and some of the people thought “1” as the least important. Because of this, there was a problem in calculating the average of all the skills. Further research on BIM competence can be conducted regarding more BIM skills and the BIM knowledge. Also, research on providing the BIM competency certification through an individual organization could be done.

A skill set was produced selecting the top 4 skills from the *section 2:* BIM skills and competence survey questionnaire *Table 5.* which can be used as a reference as a BIM skill sets for a BIM professionals.

Table 5. Top 4 skills selected from BIM professionals position from survey questionnaire

BIM Manager		**BIM Coordinator**	
Collaboration	84%	Knowledge of BIM standards	82%
Update knowledge of BIM development	82%	Update knowledge of BIM developments	79%
Fluency in BIM application	80%	Leadership skills	76%
Technical skills	78%	Application skills	76%

BIM Designer		**BIM Team**	
Application skills	82%	Teamwork	84%
Update knowledge about BIM development	81%	Coordination and collaboration	83%
Knowledge of BIM standards	77%	Knowledge of BIM standards	79%
Time management	77%	Problem analysis	77%

As a conclusion, there was a challenge to write a thesis on BIM competence because of an insufficient amount of knowledge on BIM literature. It took a while, but with the support from the World Building Congress, Aalto BIM summer school and support from supervisor and friends, the author manages to complete the challenge.

4 VALIDATION

The research problems mentioned at the beginning of this thesis with the clarifications are presented below:

RQ1. *What does the construction industry think about BIM Competency?*

Construction industries expect engineering graduates, to develop and gain both technical and non-technical competencies while they are studying. The construction industries also expect their future employees to have knowledge and skills in information technology, as there has been a growing demand for construction professionals with BIM knowledge and expertise. Construction industry looks for employees with BIM background as they can quickly adapt to the working environment as they already have BIM skills and experience.

RQ2. *Is BIM competency required for engineering graduates?*

The demand for the BIM competent workforce is increasing day by day in the AEC industry and is creating new opportunities in the industry for new graduates. An educational institution plays a vital role in creating a new BIM-based competent professional during their study years. A graduate with BIM competence tends to get new opportunities in the AEC industry quicker than those without BIM competencies.

RQ3. *What type of BIM competencies should the graduates have?*

An educational institution is a place where there can be a significant amount of learning the outcome of BIM and its related skills. Different kinds of skills are gained while learning in the institution rather than going for some training. The top skills needed for the graduates are shown in *Table 5*.

RQ4. What kind of BIM competencies are needed for individuals and organizations?

Individual competencies like skills, qualification, attitude and knowledge are the core competencies. The skills like leadership skills, application skills, ideas about BIM standards comes into those headings. Organizational competencies such as follow-up of national or international BIM standards, collaboration, and coordination of the project are seen beneficial.

5 CONCLUSION

BIM is an emerging technology in the AEC industry. BIM has gained significant momentum in the AEC industry in a short period. The performance in the projects is improved when adopting BIM in the planning phase. BIM helps in reducing costs, supports better time management and also enhances the relationship between the employees. Due to the rising market demand for BIM competent professionals, companies require adjusting the recruitment practice through improved and proactive collaboration with an educational institution. BIM qualified workforce is the present need of the construction industry as there is an enormous demand for individuals who have required BIM skills and knowledge for faster employment in the industry. The AEC industry is experiencing plenty of challenges from serving skilled workforce shortage and also for the updated new workforce skill set which is demanded by industry. BIM skills and their co-related skills are likely to increase the likelihood of BIM professionals. The comparative analysis of the literature review and survey questionnaire revealed several kinds of competencies required for BIM professionals.

The survey questionnaire was appreciated by most participants for initiating a research that was very much needed. This survey was for the different positions in BIM working environment, while there is an overlap in the

skills possessed between individuals in each position, the way those skill sets are used may differ.

The study was limited to creating a competence model in the first case. Further studies for collecting qualitative and quantitative feedback from experienced BIM professionals to support the competencies listed here could refine and finalize skill sets of competencies. Also, similar future research may be required for determining the best way to learn and apply the skills sets. Nonetheless, a further study may evaluate findings of the BIM competencies from the current study case using more industrial cases or by developing relevant curriculum aligned with the BIM skills discussed in this thesis to help the engineering students to learn the new BIM skill sets that are seen important today.

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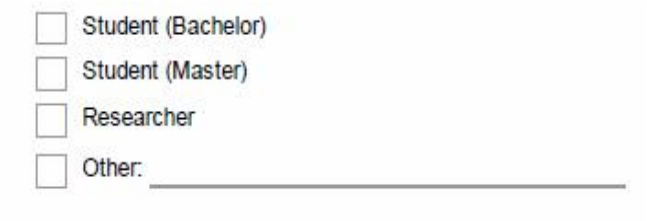
Appendix 1

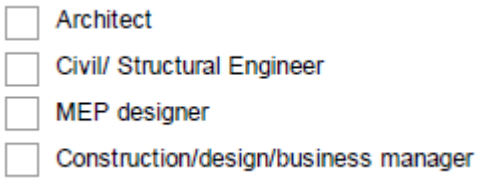
SURVEY QUESTIONNAIRE

A. BIM Questionnaire

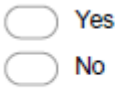
1. Which of the following most closely describe your role?
   Check all that apply



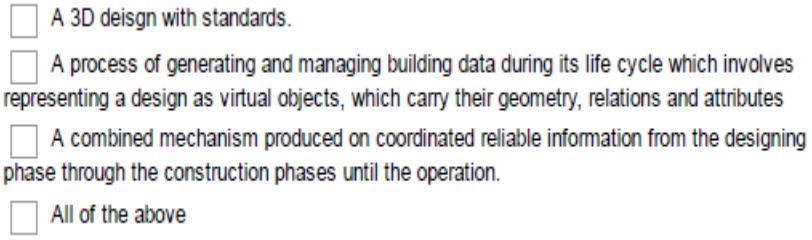
2. What is your professional background?
   Check all that apply



3. Do you have experience working with BIM?
   Mark only one oval



4. How would you describe BIM?
   Check all that apply



5. Do you think BIM competent engineer is a requirement for the industry?
   Mark only one oval

- ◯ Yes
- ◯ No
- ◯ Maybe

6. Do you think that a national level certification system for measuring BIM competency is required?
   Mark only one oval

- ◯ Yes
- ◯ No
- ◯ Maybe

7. Who should be responsible for BIM competence certification system?
   Check all that apply

- ☐ Government
- ☐ Educational organisations
- ☐ Engineering professional bodies
- ☐ BIM software vendors
- ☐ Other: _____

8. Which do you think the most important BIM competency needed? (1* - most important)
   Mark only one oval

	1	2	3
BIM skills (fluency in use of BIM applications)	◯	◯	◯
BIM knowledge (BIM know how and ongoing development around BIM)	◯	◯	◯
BIM experience (experience level in BIM applications)	◯	◯	◯

9. Please list 10 most important skills/competencies required for any BIM professional?
   *(*please use "enter" or "comma" to separate the skills)*

_____

_____

_____

_____

B. <u>BIM skills and competencies</u>

*(Please rate the following skills as per their importance from 1 – 10 *, please note that 1 = MOST IMPORTANT or MOST NEEDED)*

10. How important are the following skills for BIM Managers?
Mark only one oval per row

	1	2	3	4	5	6	7	8	9	10
Leadership	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Collaboration	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Quality and Document Management	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Technical Skills	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Communication Skills	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Goal Orientation	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Negotiation Skills	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Decision Making	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fluency in BIM applications	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Updated knowledge of BIM Developments	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

11. How important are the following skills for BIM Coordinator?
Mark only one oval per row

	1	2	3	4	5	6	7	8	9	10
Leadership Skills	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Quality and Goal Oriented	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Knowledge of BIM Standard	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Application Skills	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Communcation Skills	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Problem Analysis	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Progress Monitoring	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Awareness of Stake Holders	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Creativity	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Update Knowledge of BIM developments	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

12. Which of the skills mentioned below is the most important for BIM Designer?
Mark only one oval per row

	1	2	3	4	5	6	7	8	9	10
Application Skills										
Knowledge of BIM standards										
Modeling Concept										
Communication Skills										
Time Management										
Creativity										
Teamwork										
Problem Analysis										
Sense of Discipline										
Updated knowledge of BIM Development										

13. Which of the skills mentioned below is the most important for BIMTeam?
Mark only one oval per row

	1	2	3	4	5	6	7	8	9	10
Coordination and Collaboration										
Teamwork										
Creativity										
Project Management										
Knowledge of BIM Standards										
BIM Competence										
Vision										
Progress Monitoring										
Problem Analysis										
Sense of Discipline										

14. Which of these following skills have you at the moment if you want to be a BIM personnel?
Check all that apply

- [ ] Leadership Skills
- [ ] Application Skills
- [ ] Coordination and Collaboration
- [ ] Goal Oriented
- [ ] Creative
- [ ] Team work
- [ ] Modeling Concept
- [ ] Knowledge of BIM standards
- [ ] Time Management
- [ ] Problem Analysis